UNIVERSITÉ DE LORRAINE | BIBLIOTHÈQUES UNIVERSITAIRES

AVERTISSEMENT
DROIT D'AUTEUR

Ce document est le fruit d'un long travail approuvé par le jury de soutenance et mis à disposition de l'ensemble de la communauté universitaire élargie.

Il est soumis à la propriété intellectuelle de l'auteur. Ceci implique une obligation de citation et de référencement lors de l'utilisation de ce document. Toute contrefaçon, plagiat ou reproduction illicite encourt une poursuite pénale.

Contact bibliothèque : ddoc-theses-contact@univ-lorraine.fr
(Cette adresse ne permet pas de contacter les auteurs)

Code de la Propriété Intellectuelle. articles L 122. 4
Code de la Propriété Intellectuelle. articles L 335.2- L 335.10

UNIVERSITÉ DE LORRAINE
34 COURS LÉOPOLD — CS 25233
54052 NANCY CEDEX
WWW.UNIV-LORRAINE.FR

UNIVERSITY OF ORADEA
Doctoral School of Geography,
Sports Science and Physiotherapy

UNIVERSITÉ DE LORRAINE
École doctorale Humanités Nouvelles -
Fernand Braudel, Laboratoire LOTERR

Cotutelle thesis

presented and publicly defended on **March 6, 2026,** for the award of

doctor in Geography

by

Anca-Paula PASTOR (CIURBA)

The balneoclimatic potential of Bihor County (Romania) and its therapeutic valorization

Committee members:

President:	Prof. PhD. Pierre GINET	Université de Lorraine, France
Rapporteur:	Prof. PhD. Laurent TOUCHART	Université d'Orléans, France
Rapporteur:	Prof. PhD. Nicoleta IONAC	University of București, Roumanie
Examiner:	Prof. PhD. Dorina IANC	University of Oradea, Roumanie
Coordinator:	Prof. PhD. Ionel HAIDU	Université de Lorraine, France
Co-coordinator:	Prof. PhD. Ovidiu Răzvan GACEU	University of Oradea, Roumanie

- 2026 -

Acknowledgements

My gratitude to all those who have supported me, each in their own way, is immeasurable. I would like to express my gratitude to all those who, directly or indirectly, contributed to the success of this thesis through their collaboration and support.

As this is an opportune moment, I would like to especially thank the two thesis coordinators who combined their scientific and teaching skills and experience to support this research project. Professor **Ovidiu Răzvan Gaceu** for his role in the doctoral research process, the choice of the topic and the establishment of a fruitful co-supervision with Professor **Ionel Haidu** from the Université de Lorraine with his immense involvement, rigor and trust as co-coordinator. Their scientific expertise, humanity, encouragement, enthusiasm and availability were invaluable elements in the completion of this work.

I would like to thank the Doctoral School of Geography, Sports Science and Physiotherapy at the University of Oradea, as well as the Laboratoire Loterr at the Université de Lorraine, France for the opportunity to have access to the human and material resources necessary to complete this thesis.

Finally, my thanks go to my family, friends, and colleagues who have been by my side with their trust and support.

Dedication

I dedicate this work to my son **Markus** for his mature appreciation, encouragement, and help with my work in carrying out this research.

Contents **5**
List of figures **7**
List of tables **12**
1. Introduction **16**
2. Brief history of the research **20**
3. Research aim, objectives and methodology **23**
3.1. Aim and objectives **23**
3.2. Data and research methodology **24**
3.2.1. Data collection 24
3.2.2. Applied research methods 29
4. The natural framework of Bihor County. General characteristics **33**
4.1. Brief history of physico-geographical research **33**
4.2. Geographical location and boundaries **34**
4.3. Elements of geology **34**
4.4. Physical relief characteristics **36**
4.4.1. The Apuseni Mountains 37
4.4.2. The Western Hills 41
4.4.3. The Western Plain 45
4.5. Climatic characteristics **47**
4.5.1. Particular features of the thermal regime 51
4.5.2. Air humidity characteristics 63
4.5.3. Specific features of rainfall regime 65
4.5.4. Snow cover 74
4.5.5. Characteristics of the wind regime 75
4.5.6. Climatic risk phenomena 76
4.6. Surface and groundwater hydrology **78**
4.6.1. Groundwaters 78
4.6.2. Surface water network 81
4.7. Biogeographical and pedological characteristics **84**
4.7.1. Vegetation 85
4.7.2. Fauna 89
4.7.3. Soils 91
4.7.4. Protected natural areas 95
5. The assessment of balneoclimatic potential of Bihor County **98**
5.1. The assessment of balneary potential of Bihor County **98**

5.1.1. Current research status on balneotherapy 99
5.1.2. Legislative framework for balneary exploitation of hydromineral resources 103
5.1.3. Thermomineral, cold minerals waters and therapeutic muds resources 104
5.1.4. Physico-chemical properties of geothermal waters in Bihor County 118
5.1.5. Physico-chemical properties of some cold mineral waters from Bihor County 121
5.1 6. Determination of the microbiological load in cold mineral waters from Bihor County 126
5.1.7. Personal contributions regarding the therapeutic potential of cold mineral waters from Bihor County 127
5.1.8. The effects of mineral water crenotherapy on human health 129
5.1.9. The COVID-19 Pandemic: Effects on balneary tourism and patient profile – Personal insights 131
5.1.10. Personal contributions on the effectiveness of mineral water balneotherapy in patients with gonarthrosis 135
5.1.11. Therapeutic effects of thermomineral waters from Bihor County 142
5.2. The assessment of bioclimatic potential of Bihor County 158
5.2.1. Overview of research on bioclimatic indices relevant to balneary tourism 158
5.2.2. Bioclimatic characteristics of Bihor County 166
6. The assessment of socio-economic potential of balneary resources in Bihor County 210
6.1. The current state of socio-economic research 210
6.2. Personal contributions regarding the socio-economic potential of balneary resources in Bihor County 212
6.2.1. Forms of administration of locally relevant balneary resources 214
6.2.2. Alternative uses of geothermal water in rural areas and in emerging new tourist resorts of Bihor County 216
6.2.3. Sustainability risk associate with exploiting balneary resources in rural areas 216
6.2.4. Classification of localities according to the present condition of balneary resource exposure 217
7. Personal contributions regarding the directions of capitalizing on the balneoclimatic potential 224
7.1. Current state of research on the valorization of balneary resources in Bihor County 225
7.2. Localities and infrastructures currently in use 226
7.3. Localities with immediate potential for the utilization of balneary resources 251
Conclusions 258
Bibliographic references 264
Synthesis of author's research contribution to thesis development 295

Valorization of research activity **297**
Abstract **300**
Résumé **301**

List of figures

Figure 1. Localities with hydro-mineral resources in Bihor County. 18
Figure 2. a) Meteorological station Oradea. Figure 2.b) Meteorological station Săcueni. 26
Figure 3. Visual Analog Scale (Delgado et al., 2018). 31
Figure 4. Geological map of Bihor County. 35
Figure 5. Major relief units in Bihor County. 38
Figure 6. Geological section through the Stâna de Vale area. 40
Figure 7. The cross-sectional profile (W-E) across the Crișuri Plain shows the existence of four generations of glacis and three elevation steps. 46
Figure 8. Meteorological stations located in and nearby Bihor County. 50
Figure 9. Thermal and rainfall profile of the analysed weather stations. 51
Figure 10. Multiannual average temperature in Bihor County. Distribution of isotherms. 53
Figure 11. Non-periodic variations of annual average temperature in Bihor County between 1961 and 2021. 55
Figure 12. Deviation of annual mean temperature from the multiannual average of 9.5°C between 1961 and 2020 in Bihor County. 56
Figure 13. Deviation of annual average temperature from the multiannual mean of 10.7°C between 1961 and 2020 at the meteorological station Săcueni. 57
Figure 14. Deviation of annual average temperature from the multiannual mean of 10.1°C between 1961 and 2020 at the meteorological station Ștei. 57
Figure 15. Deviation of annual mean temperature from the multiannual mean of 4.4°C in the interval 1961 - 2020 at Stâna de Vale meteorological station. 58
Figure 16. Thermal rating of the years according to the Hellman criterion in the interval 1961 to 2020 in Bihor County. 59
Figure 17. Thermal rating of the years according to the Hellman criterion from the meteorological station Săcueni between 1961 and 2020. 60
Figure 18. Thermal rating of the years according to the Hellman criterion from the meteorological station Ștei between 1961 and 2020. 62
Figure 19. Thermal rating of the years according to the Hellman criterion from the Stâna de Vale meteorological station between 1961 and 2020. 63

Figure 20. Correlation between relative humidity and air temperature at the meteorological stations in Bihor County during the period 1961–2020. 64
Figure 21. Multiannual average rainfall in Bihor County. Isohyets' distribution. 66
Figure 22. Săcueni meteorological station. Deviation of the annual average precipitation from the multiannual average of 576.4 mm between 1961 and 2020. 68
Figure 23. Ștei meteorological station. Deviation of annual average precipitation from the multiannual average 704,8 mm between 1961 and 2020. 68
Figure 24. Stâna de Vale meteorological station. Deviation of the annual average precipitation from the multiannual mean of 1656,6 mm between 1961 and 2020. 69
Figure 25. Rainfall rating of years by Hellman criterion at meteorological stations in the interval 1961 -2020 in Bihor County 69
Figure 26. Rainfall rating of years according to the Hellman criterion at the meteorological station Săcueni between 1961 and 2020. 71
Figure 27. Rainfall rating of the years according to the Hellman criterion at the meteorological station Ștei between 1961 and 2020. 72
Figure 28. Rainfall rating of the years according to the Hellman criterion at the meteorological station Stâna de Vale between 1961 and 2020. 73
Figure 29. Bagnouls - Gaussen diagram for meteorological stations 1961 - 2020. 74
Figure 30. Multiannual monthly wind speed regime in Bihor County 1961-2020. 76
Figure 31. Groundwater in Bihor County. 79
Figure 32. Watersheds in Bihor County and the surface water network. 82
Figure 33. Biogeographical regions in the Bihor County area. 85
Figure 34. Bihor County soils. 94
Figure 35. Protected natural areas in Bihor County. 96
Figure 36. Examples of unsustainable exploitation of thermal water in protected areas: the case of nature reserves: a) at the Peța stream in the Băile 1 Mai balneoclimatic resort and b) at the mesothermal springs from Răbăgani. 97
Figure 37. Bihor localities with hydromineral resources, carbon dioxide resources and therapeutic mud resources. 102
Figure 38. Geological section through the lower Pontian thermal aquifer Săcueni: (a) detail of the geological section Săcueni (b) the horst and graben structure of the basement. 107
Figure 39. Natural mineral water well in Tămășeu (Tămășeu commune). 111
Figure 40. Natural mineral water drilling in Sântimreu (Sălard commune) in 2021 and 2022. 111
Figure 41. Sălard. First water eruption of July 2018. 112
Figure 42. Sălard. Drinking water drilling in April 2021 112

Figure 43. Sălard. The second water eruption of October 2021. (www.ebihoreanul.ro) 112
Figure 44. Location of the carbonated mineral spring captured in the Pădurea Neagră holiday village (Popești commune). 113
Figure 45. The carbonated spring captured in the Pădurea Neagră holiday village (Popești commune). 113
Figure 46. Another spring with flat mineral water from the Black Forest (Popești commune). 113
Figure 47. The natural mineral water fountains from the Băile Tinca. 115
Figure 48. The oligomineral spring with flat water "Izvorul Minunilor" in the balneoclimatic resort of Stâna de Vale, Budureasa commune. 116
Figure 49. Sapropelic mud resources from the balneoclimatic resorts of Băile 1 Mai and Băile Felix. 117
Figure 50. Dry residue at 180°C. 122
Figure 51. Carbon dioxide content. 122
Figure 52. Piper diagram of the studied natural mineral waters. 125
Figure 53. Stiff diagram of the studied natural mineral waters. 126
Figure 54. Respondents' response regarding the quality of mineral water from Tămășeu, Pădurea Neagră and Sântimreu. 128
Figure 55. The health effect perceived by the population after consuming mineral water. 129
Figure 56. Annual number of patients who benefited from balneary treatment at the Balneary Treatment and Work Capacity Recovery Society (Hotel Ceres) in Băile 1 Mai between 2010 and 2020. 132
Figure 57. Categories of beneficiary patients depending on the type of treatment tickets from the Balneary Treatment and Work Capacity Recovery Society (Hotel Ceres) in Băile 1 Mai. 133
Figure 58. Types of pathologies that had balneotherapy as a therapeutic indication at the Balneary Treatment and Work Capacity Recovery Society (Hotel Ceres) in Băile 1 Mai. 134
Figure 59. Types of arthrosis treated with balneotherapy at the Balneary Treatment and Work Capacity Recovery Society (Hotel Ceres) in Băile 1 Mai. 134
Figure 60. Pilot study content. 137
Figure 61. Assessing the impact of the mean difference of the intervention on various metrics in the experimental and control groups. 141
Figure 62. Spatial distribution of the effective equivalent temperature index in Bihor County for the intervals 1961 - 1990 and 1991 - 2020. 170
Figure 63. Bioclimatic particularity in Bihor County (a) 1991 – 2020 and (b) 1991 – 2020. 171
Figure 64. Multiannual variation of the monthly average values of the thermo-hygrometric index at the Săcueni meteorological station for the intervals 1961 – 1990 and 1991 – 2020. 173

Figure 65. Multiannual variation of the monthly mean values of the thermo-hygrometric index for the meteorological stations analyzed during the period 1961 – 1990. 174
Figure 66. Multiannual variation of monthly mean values of the thermo-hygrometric index for the meteorological stations studied between 1991 and 2020. 176
Figure 67. Multiannual monthly variation of thermo-hygrometric index values in Bihor County in the 1961 - 1990 and 1991 – 2020 intervals. 177
Figure 68. Territorial distribution of the thermo-hygrometric index in Bihor County in the intervals 1961 - 1990 and 1991 - 2020. 179
Figure 69. Multiannual variation of wind chill index values at the Săcueni meteorological station for the intervals 1961 - 1990 and 1991 – 2020. 182
Figure 70. Multiannual variation of monthly mean values of the wind chill index for meteorological stations analyzed in the period 1961 – 1990. 183
Figure 71. Multiannual monthly average values of the wind chill index for the meteorological stations analyzed in the period 1991 - 2020. 185
Figure 72. Variation of the monthly average of the wind chill index in the intervals 1961 - 1990 and 1991 - 2020. 186
Figure 73. Territorial distribution of the wind chill index in Bihor County in the intervals 1961 - 1990 and 1991 - 2020. 188
Figure 74. Monthly variation of multiannual average values of the equivalent temperature of the wind chill in Săcueni in the intervals 1960 - 1990 and 1991 - 2020. 190
Figure 75. Monthly variation of the multiannual average values of the equivalent temperature index of wind chill at the analyzed stations in the period 1961 - 1990. 192
Figure 76. Monthly variation of multiannual average values of the equivalent wind chill temperature index in the period 1991 - 2020. 194
Figure 77. Monthly variation of multiannual average values of the equivalent wind chill temperature index for the periods 1961 - 1990 and 1991 - 2020. 195
Figure 78. Territorial distribution of wind chill equivalent temperature index values in the intervals 1961 - 1990 and 1991 - 2020. 197
Figure 79. Number of exceedances of the 90th percentile for maximum values of the equivalent effective temperature index at the Săcueni meteorological station in the period 1961 - 1990 and 1991 - 2020 199
Figure 80. Number of non-exceedances of the 10th percentile for the minimum values of the equivalent effective temperature index at the Săcueni meteorological station in the period 1961 - 1990 and 1991 - 2020. 199

Figure 81. Variation in the number of non-exceedances of the minimum extreme values for the effective equivalent temperature index by the 10p percentile at the meteorological stations analyzed in the intervals 1961 - 1990 and 1991 - 2020. 201
Figure 82. Variation in the number of exceedances of the maximum extreme values of the effective equivalent temperature index by the 90p percentile for the meteorological stations analyzed in the intervals 1961 - 1900 and 1991 - 2020.....202
Figure 83. Variation in the number of non-exceedings of the minimum extreme values of the thermo-hygrometric index obtained by the 10p percentile for the meteorological stations analyzed in the intervals 1961 - 1990 and 1991 - 2020.....203
Figure 84. Variation in the number of cases of exceeding the maximum extreme values for the thermo-hygrometric index obtained by the 90p percentile at the meteorological stations analyzed in the periods 1961 - 1990 and 1991 - 2020.....204
Figure 85. Variation of cases in which the minimum extreme values of the wind chill index do not exceed the 10p percentile at the meteorological stations analyzed in the periods 1961 - 1990 and 1991 - 2020.....205
Figure 86. Variation in the number of cases in which the maximum extreme values of the wind chill index obtained by the 90p percentiles were exceeded at the meteorological stations analyzed in the intervals 1961 - 1990 and 1991 - 2020.....206
Figure 87. Variation in the number of cases in which the minimum extreme values obtained by the 10p percentile for the equivalent wind chill temperature were not exceeded at the meteorological stations analyzed in the intervals 1961 - 1990 and 1991 - 2020. 208
Figure 88. Variation in the number of cases in which the minimum extreme values of the wind chill equivalent temperature index were exceeded calculated by the 90p percentiles at the meteorological stations analyzed in the intervals 1961-1990 and 1991-2020. 208
Figure 89. Salonta Sports and Recreation Center in December 2024. 221
Figure 90. Comparative analysis of thermal water valorization in the periods 1960 - 1989 and 1990 - 2024.....223
Figure 91. Lotus Therm Resort in Băile Felix. 230
Figure 92. Auxologico Medical Recovery Hospital in Băile Felix. 231
Figure 93. Road and pedestrian infrastructure in Băile Felix (2023). 233
Figure 94. Treatment, accommodation and restaurant infrastructure at Băile Tinca. 235
Figure 95. The Laguna thermal complex in Beiuș. 236
Figure 96. The thermal bath in Aleşd. 237
Figure 97. The treatment base at the Day Center for the Elderly in Aleşd. 238
Figure 98. The thermal bath in Săcueni. 238

Figure 99. The old thermal bath in Sânnicolau de Munte 239
Figure 100. The new thermal bath in Sânnicolau de Munte. 239
Figure 101. The thermal bath in Livada de Bihor. 239
Figure 102. Thermal bath in Mădăras. 240
Figure 103. Thermal bath in Tămășeu. 241
Figure 104. Thermal bath in Chișlaz. 241
Figure 105. The playground in the Chișlaz thermal bath. 249

List of tables

Table 1. Distribution of localities with hydro-climatic resources by major landforms. 37
Table 2. Multiannual mean temperature and multiannual mean precipitation at meteorological stations between 1961 and 2020. 51
Table 3. Multiannual monthly air temperature regime at meteorological stations in Bihor County between 1961 and 2020. 54
Table 4. Extreme annual average temperatures at the weather stations studied in the 1961 to 2020 period. 55
Table 5. Temperature deviations at weather stations in Bihor County. 56
Table 6. Thermal character of the years according to the Hellman criterion in the interval 1961 to 2020 in Bihor County. 59
Table 7. Thermal character of years according to the Hellman criterion at the meteorological station Săcueni between 1961 and 2020. 59
Table 8. Thermal character of the years according to the Hellman criterion at the meteorological station Ștei between 1961 and 2020. 61
Table 9. Thermal character of the years according to the Hellman criterion at Stâna de Vale meteorological station between 1961 and 2020. 62
Table 10. Multiannual monthly average relative humidity and multiannual monthly mean temperature between 1961 and 2020. 64
Table 11. Multiannual monthly relative humidity regime at meteorological stations in Bihor County between 1961-2020. 64
Table 12. Rainfall deviation at weather stations Săcueni, Ștei, Stâna de Vale between 1961-2020. 67
Table 13. Săcueni meteorological station. Rainfall character of the years according to Hellman criterion between 1961 and 2020. 70

Table 14. Ștei meteorological station. Rainfall character of the years according to Hellman criterion between 1961 and 2020. 71
Table 15. Stâna de Vale meteorological station. Rainfall character of the years according to the Hellman criterion between 1961 and 2020. 72
Table 16. Monthly multiannual multiannual precipitation amounts at weather stations in Bihor County in the interval 1961 – 2020. 73
Table 17. Multiannual monthly wind speed regime at analyzed meteorological stations between 1961 and 2020. 75
Table 18. Physico-chemical properties of the thermal resource from several localities of Bihor County. 120
Table 19. Specific microbiological indicators of mineral waters from Tămășeu, Sântimreu and Pădurea Neagră. 127
Table 20. Applied treatment procedures. 138
Table 21. Demographic characteristics of study participants. 140
Table 22. Effects of intervention on physical and functional outcomes in patients with knee osteoarthritis. 140
Table 23. Examples of studies on the effectiveness of balneotherapy on chronic low back pain. 144
Table 24. Examples of studies on the effectiveness of balneotherapy in rheumatoid arthritis. .. 146
Table 25. Examples of studies on the effectiveness of balneotherapy on degenerative rheumatic pathologies. 149
Table 26. Examples of studies on the effectiveness of balneotherapy in fibromyalgia. 152
Table 27. Examples of studies on the effectiveness of balneotherapy in ankylosing spondylitis. 154
Table 28. Examples of studies on the effectiveness of balneotherapy on neurological conditions. 156
Table 29. The thresholds of the effective equivalent temperature index (°C), weather types and bioclimatic particularity. 167
Table 30. Multiannual monthly values of the effective equivalent temperature index at the Săcueni meteorological station in the intervals 1961-1990 and 1991-2020. 168
Table 31. Multiannual monthly values of the effective equivalent temperature index at the meteorologicalstations analyzed in the intervals 1961 - 1990 and 1991 - 2020. 168
Table 32. Threshold values of the thermo-hygrometric index (°C), types of weather and bioclimatic particularity. 171

Tablel 33. Variables and multiannual monthly average values of the thermo-hygrometric index at the Săcueni meteorological station. 172
Table 34. Monthly and annual average values of the thermo-hygrometric index at the meteorological stations analyzed in the period 1961 - 1990. 173
Table 35. Monthly and annual average values of the thermo-hygrometric index at the meteorological stations analyzed in the period 1991-2020. 175
Table 36. Multiannual monthly average values of the thermo-hygrometric index in the intervals 1961 - 1990 and 1991 - 2020. 176
Table 37. Wind chill power (W/m^2), equivalent temperature to wind chill power, weather type and bioclimatic conditions. 181
Table 38. Wind chill index values at the Săcueni meteorological station for the periods 1961 - 1990 and 1991 - 2020. 181
Table 39. Multiannual monthly average values of wind cooling power at the analyzed meteorological stations for the period 1961 – 1990. 183
Table 40. Multiannual monthly average values of the wind chill index at the meteorological stations analyzed between 1991 and 2020. 184
Table 41. Monthly average values of wind chill values at the studied meteorological stations for the intervals 1961 - 1990 and 1991 - 2020. 185
Tablel 42. Variables, multiannual monthly average values of the wind chill equivalent temperature index at Săcueni station in the period 1961 - 1990 and 1991 - 2020. 189
Table 43. Multiannual monthly values of the wind chill equivalent temperature index at the meteorological stations analyzed in the period 1961 - 1990. 191
Table 44. Multiannual monthly average values of the wind chill equivalent temperature index in the period 1991-2020. 193
Table 45. Average of multiannual monthly mean values of the wind chill equivalent temperature index for the periods 1961 - 1990 and 1991 - 2020. 194
Table 46. Number of cases in which the monthly maximum values exceed the 90p percentile and of cases in which the monthly minimum values do not exceed the 10p percentile of the effective equivalent temperature, thermo-hygrometric, wind chill and wind chill equivalent temperature indices at the Săcueni meteorological station in the period 1961 - 1990 and 1991 - 2020. 200
Table 47. The number of cases in which the monthly average values exceed the 90p percentile and the number of cases not exceeding the 10p percentile corresponding to the monthly maximum and minimum values of the effective equivalent temperature index for the intervals 1961 - 1990 and 1991 - 2020 201

Table 48. The number of cases in which monthly values exceed the 90p percentile and the number of cases not exceeding the 10p percentile corresponding to the monthly maximum and minimum values of the thermo-hygrometric index, at the meteorological stations analyzed in the intervals 1961 - 1990 and 1991 - 2020. 202
Table 49. The number of cases in which monthly values exceed the 90p percentile and the number of cases of non-exceedance by the 10p percentile corresponding to the monthly maximum and minimum extreme values of the wind chill index for the period 1961 - 2020. 204
Table 50. The number of cases in which the maximum extreme values of the wind chill equivalent temperature index exceed the 90p percentile and the number of cases of non-exceeding minimum values do not exceed the 10p percentile at the meteorological stations analyzed in the intervals 1961 - 1990 and 1991 - 2020. 207
Table 51. The new tourist resorts with balneary potential in Bihor County. 219
Table 52. Forms of administration and exploitation of the balneary potential in the pre- and post-revolutionary period of December 1989. 222
Table 53. Localities in Bihor County that capitalize on the balneary resource..... 227
Table 54. The structure of accommodation units in Băile Felix. 230
Table 55. Infrastructure of the treatment bases in Băile Felix. 232
Table 56. Baile 1 Mai. Infrastructure of the balneary treatment facilities. 234
Table 57. Therapeutic indications of thermomineral waters from balnery resorts and tourist localities of Bihor County. 243
Table 58. Therapeutic procedures performed in treatment facilities in the studied locations. ... 245
Table 59. Tourist infrastructure of balneary localities. 247
Table 60. Public catering infrastructure in locations that capitalize on the hydrothermal resource. 248
Table 61. Recreational infrastructure in locations that capitalize on the hydro-mineral resource in Bihor County. 250
Table 62. Localities that have wells with immediate potential for balneary capitalize of hydromineral resources. 253

1. Introduction

The „balneary phenomenon" is represented by the natural therapeutic factors - hydrominerals, muds, therapeutic gases and bioclimate - which are involved in the context of health and balneary tourism.

Geothermal waters in Bihor County originate from geothermal aquifers comprising four deposits: Oradea - Băile Felix - Băile 1 Mai; Salonta - Ciumeghiu - Tinca; Răbăgani - Beiuș; Săcueni - Marghita - Balc (Pricăjan, 1985). Geothermal water deposits in the Bihor County are intercepted in 75 localities (Haidu et al., 2023), plus seven mineral water sites. The use of these waters is multiple, some of these are used for balneary treatment and recreation, particularly in balneary and tourist resorts. Other uses of geothermal water in the Bihor County include in district heating, vegetable growing, skincare industry and fish farming. Another part forms the balneary reserve fund.

In balneology, thermal water is the main natural therapeutic factor, along with lakes, therapeutic muds and therapeutic gases. Balneotherapy (bathing in thermo-mineral water) is one of the oldest forms of therapy for relieving symptoms and improving daily functionality for degenerative pathologies of the musculoskeletal system (Verhagen et al., 2008; 2015). One chronic degenerative joint pathologies characterized by degeneration of articular cartilage, peripheral bone hypertrophy and changes in the synovial membrane is arthrosis (osteoarthritis) (Solomon et al., 1997). The most common type of osteoarthritis is localized in the knee, and the prevalence is directly proportional to age (Yeğin et al., 2017).

In relation to Bihor County`s landforms, the settlements with hydromineral resources (especially geothermal ones) are mainly found in the ***plain area*** (57 localities: Adoni, Băile 1 Mai, Băile Felix, Biharia, Borș, Cadea, Cefa, Cenaloș, Cherechiu, Cheresig, Cheșereu, Chiraleu, Chișlaz, Cihei, Ciocaia, Ciulești, Ciumeghiu, Curtuișeni, Diosig, Fegernic, Galoșpetreu, Ghiorac, Girișu de Criș, Husasău de Tinca, Livada de Bihor, Marghita, Mădăras, Miersig, Mihai Bravu, Niuved, Nojorid, Olosig, Oradea, Oșorhei, Otomani, Palota, Parhida, Rontău, Roșiori, Salonta, Sarcău, Săcueni, Sălacea, Sălard, Sâniob, Sânmartin, Sântandrei, Sântimreu, Șimian, Tășad, Tămășeu, Tăuteu, Tinca, Tria, Toboliu, Tulca, and Valea lui Mihai).

In the ***hills,*** hydro-mineral resources can be found in: Betfia, Hidișel, Tășad, Corbești, Cordău, Ceica, Căbești, Coșdeni, Criștioru de Sus, Cetariu and in the ***intramontaneous depressions*** at Albești, Aleșd, Beiuș, Curățele, Cusuiuș, Finiș, Răbăgani, Tileagd, Ștei, and Vașcău. The fewest are in the ***mountain area*** (Stâna de Vale, Budureasa and Pădurea Neagră) and are represented by cold natural mineral water resources.

Regarding the drainage basins, the localities with ***hydrothermal resources*** are distributed as follows: in the *Ier river drainage basin* there are 14 localities: Curtuișeni, Valea lui Mihai, Sălacea, Șimian, Galoșpetreu, Cherechiu, Otomani, Cheșereu, Adoni, Săcueni, Olosig, Ciocaia, Cadea, and Diosig.

In the *Barcău river drainage basin* there are 21 localities (Marghita, Sânnicolau de Munte, Balc, Sâniob, Chiraleu, Chișlaz, Ciulești, Tăuteu, Tria, Cenaloș, Pădurea Neagră, Sarcău, Fegernic, Sântimreu, Sălard, Roșiori, Mihai Bravu, Niuved, Parhida, Tămășeu, and Biharia).

In the *drainage basin of Crișul Repede river* there are 21 localities (Aleșd, Borș, Sântion, Cetariu, Oradea, Girișu de Criș, Sântandrei, Palota, Toboliu, Cheresig, Livada de Bihor, Nojorid, Păușa, Băile Felix, Băile 1 Mai, Sânmartin, Betfia, Cordău, Cihei, Tileagd and Hidișel).

The Crișul Negru River area includes 25 comunities (Cefa, Miersig, Mădăras, Salonta, Husasău de Tinca, Tulca, Tinca, Ciumeghiu, Ghiorac, Tășad, Corbești, Ceica, Albești, Coșdeni, Căbești, Răbăgani, Curățele, Beiuș, Budureasa, Stâna de Vale, Finiș, Cusuiuș, Ștei, Vașcău, and Criștioru de Sus).

As far as ***natural cold mineral waters*** are concerned, they are less representative for Bihor County, with only seven locations presently known - Tămășeu, Sântimreu, Pădurea Neagră, Sălard, Tinca, Stâna de Vale, and Budureasa. Three of these springs (Izvorul Minunilor, Hera and Litihinia) are on the list of recognized mineral waters in Romania (compiled by the National Agency for Natural Resources) (Figure 1).

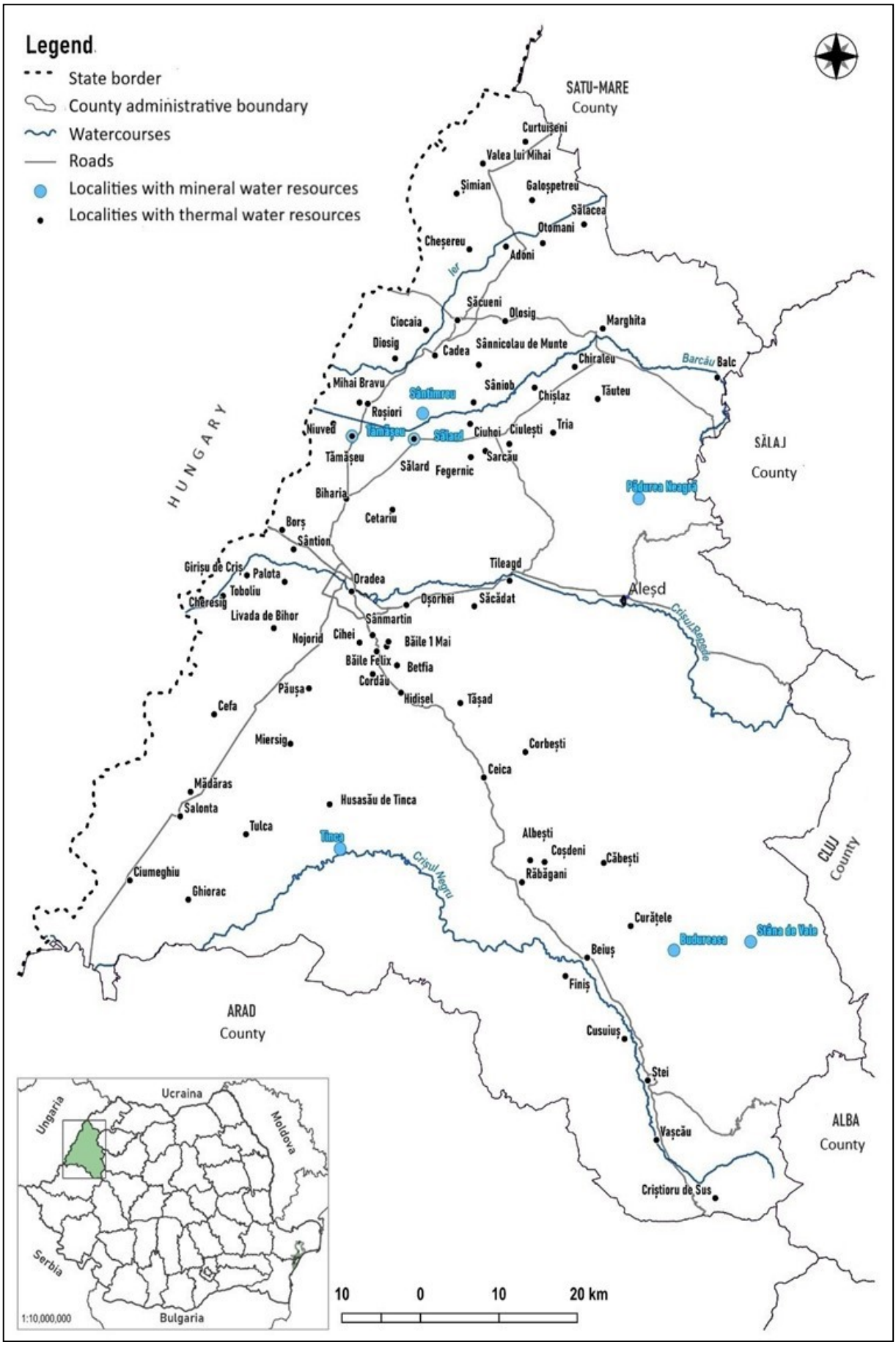


Figure 1. Localities with hydro-mineral resources in Bihor County.

The „balneary phenomenon" is based on important aspects that contribute to the sustainability of the exploitation of geothermal resources, influenced by their administrative apparatus. In the administrative-territorial units where the local administration was involved and concerned with their evolution and improvement, accommodation structures were developed in Sânnicolau de Munte, Sarcău, Mădăras and Livada de Bihor, Săcueni (three-star motels, three-star guesthouses, wooden chalets, wooden houses, and mobile homes), thus contributing to the valorization of the balneary resource. Other sites have been permanently maintained to function even today (Chișlaz and Tămășeu), but with the process of property retrocession, some sites came into the possession of individuals who requested the local authorities to demolish the thermal bath (Răbăgani). Other locations remained in the ownership of local municipalities, but failed to remain functional due to high maintenance costs, and were left in disrepair: Mihai Bravu, Balc, Valea lui Mihai, Cadea and Ciocaia (Ciurba, et al. 2023).

The outlining of the hydromineral balneary potential of Bihor County was achieved by identifying and inventorying localities with balneal therapeutic factors; centralizing the physico-chemical profile of the thermo-mineral waters in this area, based on test reports and literature; creating a database on the infrastructure of resorts and localities with hydrotherapeutic resources; conducting a pilot study to show the effectiveness of mineral water balneotherapy compared to conventional physiotherapy in degenerative rheumatic pathology of the knee (osteoarthritis); conducting a study on the therapeutic potential of some cold mineral waters from Bihor County and its relevance in raising awareness among the population about the benefits that these natural mineral waters can bring to the therapy of various diseases.

Bioclimatic potential is an important natural resource, the state of which determines the comfort and health of the body as a whole. In order to analyze the development of balneoclimatic research reflecting the transition from the empirical use of natural resources to a scientific approach, based on modern studies and technologies, a historical development in balneoclimatic research was illustrated.

2. Brief history of the research

The balneoclimatic research considers several important aspects in the study of natural therapeutic factors (mineral waters, muds, therapeutic gases, bioclimate, etc.), the introduction of data into the clinical and prophylactic therapeutic circuit, followed by their valorization through therapeutic recommendations, particularized on specific indications and contraindications. The beneficial effects of natural therapeutic factors have been known since ancient times (Silișteanu et al., 2020).

It was the Romans who established the first thermal resorts in Europe (Italy, France, Germany, Belgium and Romania), and ensured the transportation of curative mineral waters in clay amphorae. However, it was not until the 18th century that concern for the development of balneary resorts in Europe and in our country began to make itself felt. The first publications also appeared as a result of these studies, namely the book „Memorabilia Europe"[1].

In the 16th century, several books on climate and health came out (*Mirouer de l'Air* by Antoine Mizauld (1548)[2].

Many authors consider that balneology and balneary therapy were individualized only in the second half of the 19th century, although the origins are very old. Thermal baths are the creation of the Greek, Etruscan and Roman eras, forgotten in the Middle Ages, "*the period of a thousand years without any baths*"[3], and rediscovered in the 19th century, due to the growing interest in utilizing natural therapeutic resources.

With the development of balneology in the 19th century in Romania, studies on natural therapeutic factors continued in the 19th century and the emphasis was placed on the establishment or development of several balnaery resorts. In 1829, the German doctor Wertheimer described all the mineral waters in Romania[4].

Hippocrate talks in his writings about the beneficial effect of sun, water and mud on the body (Teodoreanu, 2002).

At the beginning of the 20th century, medical literature was enriched with two scientifically valuable works that lay the foundations of Romanian balneology such as *Apele minerale și stațiunile climatice din România (in translation Mineral Waters and Climatic Resorts in Romania)*

[1] Eberhard Rudolph Roth (2011), Memorabilia Europe, Reprinted, Nabu Press, 722 pages.
[2] Mizauld, A. (1548) Le Mirouer de l'air, Paris, R. Chaudiere,.
[3] Gianfaldoni, S., Tchernev, G., Wollina, U., Roccia, M. G., Fioranelli, M., Gianfaldoni, R., & Lotti, T. (2017). History of the Baths and Thermal Medicine. Open Access Macedonian Journal of Medical Sciences, 5(4), 566–568. https://doi.org/10.3889/oamjms.2017.126
[4] Wertheimer, M., Descrierea tuturor apelor minerale/ The description of all mineral waters, Bucharest, Tipografia Sf. Mitropolii, 1853.

(1900 and 1906) written by Saabner-Tuduri[5] and *Hidroterapia medicală* (*in translation Medical Hydrotherapy* - 1904) by Baiulescu[6] (Dumitrașcu et al. 2012).

In the 19th and 20th centuries, references were made to the use of hot springs in the perimeter of Oradea and the existence of hospital units in its vicinity. The methodical investigation of thermal aquifers started in 1960. In the 20th century, tourist balneary resorts with a climatic and balneoclimatic profile proliferated across the region. Numerous guides and scientific works on the „balneary phenomenon" have been published (Munteanu et al., 1979, 1984; Teleki, 1984; Aniței et al., 1986; Dulamă, 2003; Farcaș, 2005; Linc et al., 2008, 2023; Ilieș et al., 2009; Teleki et al., 2012; Teodoreanu et al., 2013; Dogaru et al., 2016, 2025; Enescu et al., 2016; Roșca et al., 2016; Uivaroșan et al., 2018, 2019; Tarcău et al., 2022) etc.

In addition to balneology, which capitalizes on hydro-mineral resources, the bioclimate of a resort contributes to the area's health-giving effect.

The beginnings of the history of bioclimatology were recorded by Hippocrates of Kos who was a keen observer of the relationship between patient, disease and weather. In the Middle Ages, weather was a linking element in the relationship between astrology and medicine (Teodoreanu, 2002). In the 17th century, cosmic and climatic elements and relationships on life were studied; Richard Mead emphasized the influence of the world and the sun on health and disease, as well as the influence of atmospheric pressure. etc. Another important publication is represented by Jacob Bontius work *De Medicina Indorum* published in 1642[7]. In 1763, the chief physician of Bihor County, Francisc Szivers, and the pharmacist Ioan Sztacha submitted a report to the higher authorities detailing the state of the baths and the diseases successfully treated here. Professor Stephanus Hathvani publishes the book *Therme Varadienses* in 1777[8], in which he presents the current resorts (Băile 1 Mai and Băile Felix) with the aim of emphasizing the therapeutic benefits of the thermal baths.

In the 19th century, in Stuttgart, Hirsch (1881 - 1886) developed a new concept of diseases caused by micro-organisms in the air[9]. In 1877 - 1881, Lombard published in Paris *Traité de climatologie medicale*[10] etc. (Teodoreanu, 2002). In the last decades of the 20th century, numerous studies in the field of bioclimatology appeared. Known journals dealing with different aspects of

[5] Saabner-Tuduri, A. (1906), Apele minerale și stațiunile climatice din România/The mineral waters and climate resorts from Romania, Bucharest, "Gutenberg" Joseph Göbl Printing Press.
[6] Baiulescu, G. (1904), Hidroterapia medicala /Medical Hydrotherapy, Minerva Publishing House, Brasov.
[7] Bontius J. (1642), De medicina Indorum, Lugduni Batavorum: Apud Franciscum Hackium, 212 S.
[8] Hathvani S. (1777), Thermae Varadienses, Viennae, Apud Rudolphum Graeffer, pp. 63, 69, 163;
[9] Hirsch, A. (1881). Handbuch der historisch-geographischen Pathologie, Vol. 1, Enke.
[10] Lombard, H.C. (1887) Traité de climatologie médicale comprenant la météorologie médicale et l'étude des influences physiologiques, pathologiques, prophylactiques et thérapeutiques du climat sur la Santé, vol. 1 of 4, Paris, Baillière.

bioclimatology are: International Journal of Bioclimatology, Journal of Applied Physiology, Presse thermale et climatique, Weather, Geophysik und Bioclimatologie, and etc (Teodoreanu, 2002).

In Romania, observations of the relationship between the environment, weather and man have been passed down orally from generation to generation. Observations on climate in parallel with chemical analyses of different mineral waters were made at the beginning of the 19th century (Teodoreanu, 2002). At the Romanian Balneary Congress in 1921, the Statutes of the Society of Medical Hydrology and Climatology were voted, and in 1923, the Law of Balneary Organization were adopted. *Les stations balnéaires et les eaux mineralés de Roumanie. Aperçu sur les stations climatiques* work that was also published in Paris in *Traité de climatologie bioclinique et médicale*[11], in 1934, published by Piery. In 1949, the Institute of Balneology and Physiotherapy was set up, with a research sector on therapeutic natural resources, including a Bioclimatology sector (Teodoreanu, 2002).

Since the middle of the 20th century, the Romanian bioclimatological research in the Institute of Balneology has focused mainly on aspects of climatotherapy and biometeorology, through the work of physicians Maria Modval, Camelia Ardeleanu-Voiculescu and physicist Ștefan Pascu, along with the physicists of the Meteorological Institute (Vania Crețeanu, Mircea Frimescu, Vladimir Costin, etc.) and that of doctor Mauriciu Deleanu, for the research of air ionization, especially in balneary resorts.

Numerous researches in the field of biometeorology and bioclimatology have been carried out on a restricted geographical area with an overview on medical bioclimatology, bioclimate of Romanian resorts, the influence of climate on human behavior, the distribution of thermal comfort, bioclimatic stress indices, etc. (Barnea et al., 1968; Ardelean et al., 1972; Teodoreanu, 1983; Teodoreanu et al., 1984; Dragotă et al., 1993; Teodoreanu, 1994, 1995; Ciulache et al., 1998; Ionac et al., 2007a, 2009).

In 2013, Levico Terme hosted *the Congress of the World Organization of Balneology and the International Society of Hydrothermal Techniques*. In 2016, the 41st *World Congress of the International Society of Medical Hydrology and Climatology* was held in Bucharest. In 2020, the Romanian Association of Balneology organized the *Congress of Physical Medicine and Balneology* that took place online.

This historical contextualization of balneoclimatology provides the foundation for the methodology section of the thesis, where the tools and techniques used to assess the "balneoclimatic phenomenon" in Bihor County are presented and analyzed.

[11] Piery, M. (1934), Traité de climatologie bioclinique et médicale, I-III, Maisson Publishing House, Paris.

3. Research aim, objectives and methodology

3.1. Aim and objectives

The aim of this thesis is to contribute to the knowledge of balneoclimatic resources, providing a complete image of them and their importance, by identifying the current utilization and the balneoclimatic potential for the sustainable development of balneary tourism and balneotherapy in Bihor County, Romania.

The main objectives of the study are:

- *Outlining the balneary potential of* Bihor County by: identifying and inventorying all localities with balneoclimatic therapeutic factors; realizing a physico-chemical profile of the thermo-mineral waters in this area; creating a database on the balneary and tourist infrastructure of the resorts and localities with balneary resources that can be permanently updated; conducting a pilot study in the balneoclimatic resort of Tinca by highlighting the beneficial impact of mineral water in degenerative rheumatologic diseases; identifying the pathologies with the highest success rate of balneotherapy;

- *Identifying the current directions of valorization of* the hydromineral resource through balneotherapy and balneary tourism, as well as an alternative application through the skincare industry and socio-economic activities, based on the richness of the existing balneoclimatic resources in Bihor County, resulting from the interaction between local geology, bioclimate and hydrogeological processes.

- *Identifying the climatic particularities of* Bihor County by following the thermal regime, rainfall, air humidity and wind regime by analyzing some climatic parameters specific to Bihor County that could contribute to the adaptation of the climate for balneary tourism and the evolution of the bioclimatic potential.

- *Outlining the bioclimatic potential of* Bihor County by calculating relevant bioclimatic indices in balneary tourism and balneotherapy, such as the equivalent effective temperature, the thermo-hygrometric index and the wind chill index with its equivalent temperature, which highlights the evolution of bioclimatic features and bioclimatic framing of localities with potential for immediate capitalization of balneary resources.

- *Identification of socio-economic potential through the analysis of the administrative factor* of balneary resources, which directly influences development strategies, financing, and sustainable promotion, ensuring sustainable tourist and balneotherapeutic valorization

3.2. Data and research methodology

The research methodology of the thesis comprised several steps that ensured a rigorous and systematic approach to the research process, supported the validity and relevance of the findings.

In Phase 1, bibliographical documentation was carried out, which helped define the structure and phases of the reasearch. Thus, numerous scientific works, consisting of specialized treatises, books, doctoral theses, scientific articles, university courses, tourist guides, etc., were reviewed.

Phase 2 involved data collection and organization of the statistical, clinical, hydrochemical, sociological, touristic, climatic and administrative databases, etc.

Phase 3 contains the agreegation, processing, analysis and interpretation of data using valid scientific methods in order to obtain relevant results.

In the fourth stage, the research results were capitalized by participating in various national and international scientific events such as symposia, conferences, congresses. Scientific articles were published in specialized journals, contributing to the advancement of the field and dissemination of results.

The theoretical and practical foundation relied on qualitative and quantitative data, as well as the methods used to guide data processing and interpretation.

3.2.1. Data collection

In order to build up a data base that is related to the reality on the ground, several sources were used, such as: bibliographical documentation, field investigations, physico-chemical test reports of geothermal waters, physico-chemical analysis of cold mineral waters, climatic data, statistical data, data obtained from objective and clinical examination (questionnaires, scales, tests), as well as legislation.

a) *Data obtained from bibliographic documentation*

This was an key source in developing the research database used in the research. The documentation included specialized studies from multiple relevant fields, such as: balneology, geography (through the branches of climatology, geography of tourism with a focus on balneary tourism), geology (through the hydrogeological component), sociology, as well as the administrative sphere, thus contributing to an interdisciplinary approach of the work.

b) Data obtained by field investigation of hydro-mineral resources

The field investigation included approaching each location and administrative entity by visiting the location, making an inventory of restaurants and food services, accommodation, treatment and leisure infrastructure. On the basis of the investigation, the *field sheet* was realized for each visited location. It included 26 items that allowed a detailed inventory of the location. In addition, 12 interviews were conducted with private administrators, mayors or representatives of the municipalities, as well as with a geothermal water exploitation specialist from Transgex who provided information on the situation of the hydromineral resource from the development to the present. The field investigation was conducted over a period of five years (2020 - 2024).

c) Data obtained from geothermal water test reports

The test reports were obtained from the managers of the hydromineral resource and from published specialized works, such as doctoral theses, articles and books (Țenu, 1981; Gilău et al., 2001; Mitrașcă, 2006; Stănășel et al., 2006; Setel et al., 2010; Sebeșan, Sebeșan, 2014; Sebeșan et al., 2015; Orășeanu, 2016; Nicula, 2021 etc.).

A number of 20 test reports were centralized, from the hydro-mineral springs in Marghita, Aleșd, Ștei, Beiuș, Valea lui Mihai, Săcueni, Livada de Bihor, Chișlaz, Mădăras, Sânnicolau de Munte, Tămășeu, Cenaloș, Sarcău, Cheșereu, Mihai Bravu, Ciocaia, Răbăgani, Ciumeghiu, Borș, and Adoni.

d) Data obtained from physico-chemical and microbiological analysis reports of cold mineral waters

These data were obtained by taking samples from three water sources (Tămășeu, Sântimreu, and Pădurea Neagră) in two sampling sessions, in April 2022 and May 2023 respectively. For the determination of physico-chemical and microbiological characteristics, sterilized 0.5 liter glass-stoppered flasks were used. Sampling for microbiological analysis was carried out according to the Romanian Standard SR EN ISO 19458/2007-Water quality. They were then processed in the laboratories of the Bihor Public Health Department where the quality of the analyses was ensured by the use of high purity reagents (Merck[12], Bucharest, Romania), the use of experimental methods approved by the standardization bodies and certified laboratory equipment for high precision chemical analysis.

e) Climate dates

Climate data were collected from seven meteorological stations (Oradea, Săcueni, Borod, Holod, Dumbrăvița de Codru, Stâna de Vale, and Ștei) in the Bihor County area, as well as from two nearby stations (Chișineu Criș in Arad County and Vlădeasa in Cluj County). These

[12] Global science and technology company, www.merckgroup.com.

meteorological stations are managed by the National Administration of Meteorology and have a long series of observations, covering the period 1961 - 2020. Some of the stations were established later, so data from that year onwards were taken into account (1979 - Stâna de Vale, 1968 - Holod, 1983 - Dumbrăvița de Codru, 1971 - Borod). Climatic data include monthly averages of temperature (°C), atmospheric precipitation (mm), wind speed (m/s), pressure (mm/Hg) and relative humidity (%). Meteorological data were also obtained from the online platform www. meteomanz.com.

Concerning the location and physico-geographical characteristics of the meteorological stations in Bihor County, we present those of two meteorological stations located in the plain area (Oradea and Săcueni), because most of the hydro-mineral resources are located in this area (Figure 2). Thus:

The meteorological station Oradea is located at an altitude of 136 m, at the south-south-west border of the municipality in the immediate vicinity of the airport, in an open rural environment with alluvial soils, covered with vegetation. It has been operating on this site since 1969 (Șerban, 2010). It is a representative meteorological station for the Crișuri Plain, northern subdivision of the Western Plain, designated for synoptic-climatological measurements, with WMO identification code 15080 (Haidu et.al, 2024).

The meteorological station Săcueni is located at an altitude of 125 m, with WMO identification code 15042, in the Ier Plain, on open land, surrounded to the north by arable land; to the northeast by arable land and scrubby trees; to the east by arable land; to the south-east land with thickets at a distance of 40 m, then the Ier valley and vineyards; to the south sloping land occupied by meadow; to the south-west and west there is arable land up to 47 m, then bushes; to the north-west there is arable land up to about 60 m (Șerban, 2010).



Figure 2.a) Meteorological station Oradea.



Figure 2.b) Meteorological station Săcueni.

f) Statistical data obtained from the patient register and the annual balance register

Were obtained from the Society for Balneary Treatment and Recovery of Work Capacity (Hotel Ceres) in Baile 1 Mai. Data on the pathologies treated, procedures used, and patient demographics were collected from the *patient register* for 2020. The *annual balance register* was analyzed over a period of 11 years (2010 - 2020). It presented the annual evolution of the number of patients who benefited from balneary treatment, as well as the categories of balneary treatment beneficiaries according to the type of treatment tickets (decontated or subsidized by the Health Insurance House, County Pension House, on their own, outpatient or occasional).

g) Data obtained from questionnaires

Questionnaires were administered to explore themes such as patients' quality of life in knee osteoarthritis and residents' perceptions of mineral water quality and health impacts.

The questionnaires on the quality and health effects of mineral water were administered to the population living in three *rural localities with cold mineral water resources* (Tămășeu, Sântimreu and the holiday village of Pădurea Neagră) and neighboring localities (12 localities). The questionnaire contained 23 items and was structured in two parts. The first part consisted of 18 items referring to mineral waters, collecting data on the quality of mineral waters and their possible effect on human health. The second part focused on the socio-demographic situation of the respondents. The questionnaires were administered between June and July 2023, using both the online method, through the *Google Forms* application, and the face-to-face method. For accessibility, the questionnaires were delivered in Romanian and Hungarian. A total of 102 valid responses were received. Another questionnaire set was distributed to knee osteoarthritis patients in Băile Tinca and Salonta, assessing pain, perceived health, and knee function.

Participants gave voluntary consent by signing an *informed consent* form, in accordance with the Oviedo Convention (1997)[13] makes it mandatory to obtain informed consent from participants in any research involving human subjects (Alexa-Stratulat et al., 2018).

h) Data from (objective and clinical) assessment of patients with osteoarthritis of the knee

To evaluate the effectiveness of balneotherapy, clinical and objective assessments were performed on two groups of patients with osteoarthritis of the knee from Băile Tinca (experimental group of 52 patients) and from the medical rehabilitation center Fizio Help Med Salonta (control group of 49 patients).

The objective assessment revealed several characteristics such as bilateral or unilateral knee involvement; presence of pain on palpation or joint mobilization; preserved or altered joint

[13] European Convention for the Protection of Human Rights and Dignity of the Human Being with regard to the Application of Biology and Medicine.

amplitude; knee involvement (unilateral or bilateral), joint mobility, muscle tone, stability during walking, and body weight were recorded.

The radiologic features were evidenced on knee radiography by narrowing of the joint space (osteophytosis, pseudocysts, etc).

Height and weight were measured with standard equipment while patients wore minimal clothing Body Mass Index (BMI) was then calculated.

Clinical assessment was performed using functional tests (stair-climbing test, gait test and sit-to-stand test) recommended by the advisory group and endorsed by the International Osteoarthritis Research Society. Three validated functional tests were used: stair-climbing, gait speed, and sit-to-stand performance.

Assessments were conducted before and after the two-week treatment.

i) Legislation

Two categories of laws were consulted. The first category includes *legislation related to the quality of drinking water and mineral waters:* Government Decision no. 1020/2005 for the approval of the technical rules for the exploitation and marketing of natural mineral waters; Council Directive 80/777/EEC of July 15, 1980 on the approximation of the laws of the Member States relating to the exploitation and marketing of natural mineral waters; Official Gazette no. 103 of 07.02.2023, List of Recognized Natural Mineral Waters in Romania ; Directive 2009/54/EC of the European Parliament and of the Council of 18 June 2009 on the exploitation and marketing of natural mineral waters; Government Decision No. 532 of 2 June 2010 on the amendment and completion of the technical rules for the exploitation and marketing of natural mineral waters, approved by Government Decision No. 1020/2005, published in the Official Gazette No. 400 of 16 June 2010.

The second category of laws refers to the *approval of the attestation as tourist resorts* of some localities with geothermal resources in Bihor County in the period 2020 - 2023; the Note of substantiation to the Government Decision no. 898 of 13 July 2022 on the approval of the attestation of an area in the area of the municipality of Oradea, established in the historic central area of the city, with an area of 444.44 ha; Note of substantiation to the Government Decision no. 910 of 13 July 2022 on the approval of Marghita as a tourist resort of local interest; the Note of substantiation to the Government Decision no. 343 of 19 March 2021 on the approval of Salonta and Săcueni as tourist resorts of local interest; the Note of substantiation to the Government Decision no. 377/2020 for the approval of Oradea (historic center - bed of the Crișul Repede river) as a tourist resort of national interest; the Note of substantiation to the Government Decision no. 887 of 22 October 2020 on the approval of Borș and Ștei as tourist resorts of local interest; Note

of substatiation to Government Decision no. 1.073 of 11 December 2020 on the approval of Beiuș and Mădăras as tourist resorts of local interest.

3.2.2. Applied research methods

Several research methods were employed, each playing a key role in identifying the balneoclimatic potential of Bihor County and assessing its therapeutic value.

The field observation was a crucial component of the study research methodology, offering detailed insights into the balneotherapy potential of the area.

Statistical methods were applied to extensive numerical datasets, processed using Microsoft Excel to calculate bioclimatic indices from nine meteorological stations across two periods: 1961–1990 and 1991–2020. This enabled a comparative analysis of the evolution of the values of the bioclimatic indices analyzed between the two time intervals. Additionally, the ANOVA linear model was employed to assess differences in monitored parameters between the two patient groups in the pilot study. Data were analyzed using the *R* method[14] *(version 3.6.3*), with packages such as *Kaplan-Meier tidyverse*, *finalfit*, *mcgv*, *survival*, *stringdist*, *janitor* and *Hmisc.*

The cartographic method a core geographic tool, was used to analyze and map spatial distribution of indicator values using Geographic Information Systems (GIS) in *ArcMap 10.8.1, SAGA 9.5.1 and QGIS 3.40.1.* The application of the cartographic method in this work involved the use of climate data interpolation methods for modeling the values of bioclimatic indicators, generating continuous raster surfaces for each indicator. This involved specific steps of data collection and organization as well as spatial data analysis. The numerical data for the indicator values were processed using *Microsoft Excel*. Their spatialization involved spatial association with the meteorological stations in GIS. Subsequently, the preparation of the GIS database of bioclimatic indicators for interpolation was an important preliminary stage of converting point (vector) data to raster data. *Kriging* interpolation methods are frequently used in climate studies (Drignei, 2009; Meng et al., 2013; Aalto et al., 2013; Sfîcă et al., 2018; Ichim et al., 2020), due to their complexity and high degree of accuracy of the results following interpolation. Thus, the *universal Kriging* method was applied by determining the most suitable function for modelling the input data using variograms, different for each indicator, depending on the frequency of input values, their correlation and their validity. The result of the interpolation is the raster data model

[14] A non-parametric statistical method that compares two groups.

for each indicator, corresponding to the two time intervals analyzed as well as their cartographic representation by visualizing the values in value classes established according to the literature.

The method of analysis provided a solid basis for interpreting the results obtained from clinical and objective assessments, observations, surveys, mapping, bioclimatic indices and legislation.

The comparative method was used to compare the balneoclimatic and tourist resources in the locations under study and highlighted the distinct characteristics of some of the resorts or localities studied. These comparative approaches were preceded by the operations of classifying the localities with balneal resources, as well as the evolution of bioclimatic indices between the two analyzed intervals.

The method of laboratory determinations was used to evaluate the physico-chemical and microbiological composition of mineral water from the Sântimreu and Tămășeu boreholes and from the spring of Pădurea Neagră, in Bihor County. This approach has allowed a characterization of the type and qualities of the mineral water analyzed, providing information for the substantiation of strategies for its valorization.

The survey method included the application of the two sets of questionnaires mentioned under "data obtained".

The anamnesis method was used to obtain a detailed history of the pathologies and personal physiologic, heredocolateral, living and working conditions, long-term use of certain medications, of the gonarthrosis patients included in the pilot study.

The experiment method was applied for the pilot study involving two groups of patients (experimental and control). Within this method we distinguish the measurement and evaluation method, the test method, the intervention method of balneary procedures.

The measurement and evaluation method helped to obtain somatometric and functional data on the parameters analyzed in order to establish specific biomotor particularities for the purpose of evaluating the effectiveness of balneary treatment with mineral water. The objective examination revealed bi- or unilateral knee impairment, the presence of pain on palpation or joint mobilization, preserved or altered joint amplitude, knee stability in orthostasis and walking, level of muscle toning, joint symmetry of the lower limbs, and the patient's weight.

The method of the tests and scales for the evaluation of the subjects included in the pilot study consisted of tests (gait test, stair-climb test, sit-to-stand test) and scales (visual analog scale, Lequesne scale, Lysholm scale). *The sit-to-stand test* measures the number of times the patient gets up from the chair in 30 seconds, with hands crossed at the opposite shoulder. It involves recording the number of lifts and sit-ups that a person can complete in 30 seconds without the use of arm support (Jones et al., 1999). *The gait test* measures the time it takes to walk up and

down a 10 m length of stairs four times (Bohannon, 1997). *The stair-climb test* assesses the time it takes to climb nine flights of stairs that are 20 cm high (Kennedy et al., 2005).

The applied scales covered parameters such as pain intensity, osteoarthritis severity, knee functionality, self-perceived depression, quality of life and quality of sleep in the patients included in the study.

V*isual Analog Scale* used to assess pain intensity on a 0 –10 scale, where 0 = no pain and 10 = umbearable pain. The patient marks a point on the axis according to the perceived pain (Figure 3) (Delgado et al., 2018).

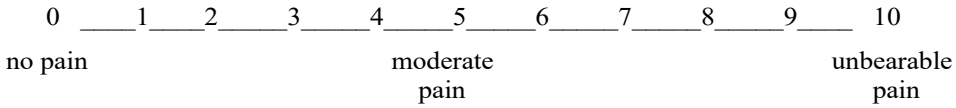


Figure 3. Visual Analog Scale (Delgado et al., 2018).

The Lequesne scale was used to assess the severity index of osteoarthritis. It contains questions related to specific symptoms and functional physical disability of patients with hip or knee osteoarthritis. Evaluates osteoarthritis severity through 11 items related to pain, gait, and daily activity. Scores range from 0 (no disability) to 24 (extreme disability) and is scored as the sum of all questions, where 0 is no disability, 1 - 4 indicates mild disability, 5 - 7 expresses moderate disability, 8 - 10 represents severe disability, 11 - 13 indicates very severe disability and 14 represents extremely severe disability (Lequesne et al., 1987).

The Lysholm scale was used to assess the functional status of the knee joint. This consists of eight questions relating to a patient's knee function related to pain, swelling, giving way, locking, locking, limping, stair climbing, squatting and support. Each question is scored on a scale from 0 to 10, with a possible total score of 100. Interpretation of the Lysholm scale results depends on the total score achieved by the patient. Assesses knee functionality across eight parameters, with a total score of up to 100. Scores ≥ 95 indicate excellent function: 65-83 points expresses acceptable knee function; < 65 points reflects poor knee function) (Lysholm, Gillquist, 1982).

The KOOS scale is an instrument that assesses short- and long-term treatment outcomes in knee injury. Comprises 42 items across five subscales: pain, symptoms, daily activities, sports/recreation, and quality of life. Scores range from 0 (extreme symptoms) to 100 (no symptoms). Each item has five possible response options scored from 0 (no problems) to 4 (extreme problems) and each of the five scores is calculated as the sum of the items included. The scores are presented on a scale from 0 to 100, with zero representing extreme knee problems and 100 indicating a healthy knee. Scores between 0 and 100 represent the total possible score obtained (Roos et al., 2003).

The intervention method included with mineral water at 37.5°C, complemented by kinesitherapy, ultrasound therapy, and capacitive/resistive electrical transfer procedures

The comprehensive methodology adopted in this study enabled a systematic investigation of Bihor County's balneoclimatic potential. The region's natural features - relief, geological structure, climate, and hydrography - play a decisive role in shaping its hydromineral and bioclimatic therapeutic resources.

4. The natural framework of Bihor County. General characteristics

The general characteristics of the natural setting are the set of elements that define the geographical environment of the area. The link between environment and health is the potential improvement in physical, mental and social well-being through daily exposure to the natural environment (Frumkin, 2001).

4.1. Brief history of physico-geographical research

Physical-geographical research in Bihor County has evolved from simple geographical descriptions to complex studies.

Among the major reference works dedicated to Romania that include aspects of Bihor County's physical geography are mentioned: *The Geographic Monography of the People's Republic of Romania, vol. 1, Physical Geography* (1960) and the treatise *of Geography of Romania,* published in five volumes, of which volumes 1, 3 and 4 are particularly relevant to this thesis. Another sintezis is appeared in 2008 (*Climate of Romania*). Hydro-technical studies with national coverage have also contributed to the understanding of the region. For example, Blidaru et al. (1962) analyzed major hydro-improvement works across Romania, while the Hydrological Monograph of the Crișuri River Basin (1968) provided a detailed assessment of river regimes based on hydrometric data, enabling a comprehensive characterization of the hydrological system in the Crișuri Basin.Another category of works that deal with the Romanian area and in which one can find useful information about Bihor County is represented by *university courses* and *doctoral theses.* Some of these have been published by various publishers. Before 1989, doctoral dissertations completed and publicly defended, followed or not by publication, were rare. But after the establishment of doctoral schools of geography, scientific productivity increased.

Further contributions come from to *tourist guides, monographs, atlases, books* and scientific articles with reference to Bihor County include Cohut (1986), Măhăra and Linc (1993), Măhăra (1994, 1996), Măhăra et al. (1999), Gilău et al. (2001), Gaceu and Linc (2005), Măhăra et al. (2002, 2005), Gaceu et al. (2009), Setel et al. (2010), Ilieș et al. (2011), Paál (2013), Herman and Tatar (2015), Teodoreanu (2015), Borodi and Nemet (2016), Vlaicu et al. (2016), Mihăilă et al. (2016), Sărac (2016), Miclăuș et al. (2017), Tătar et al. (2018), Sfică et al. (2018), Stupariu and Morar (2018), Pereș and Koteles (2012, 2014), Galiș (2014), Șerban et al. (2022) etc.

4.2. Geographical location and boundaries

Situated in the northwestern part of Romania, Bihor County coversan area of 7,544 square kimometers lying between the parallels of 46° 24' and 47° 35' north latitude and the meridians of 21° 27' and 22° 43' east longitude. To the *west,* it borders the Hungarian counties of Hajdu-Bihar and Békeș, in the *northeastern* part, it shares a boundary with Satu Mare County. *The eastern* boundary separates it from the counties of Sălaj, Cluj, Alba, and in the *south,* it borders the County of Arad. Within these boundaries, Bihor County features a stepped relief structure, ranging from elevations of over 1,800 meters - peaking at 1,848 meters at Cucurbăta Mare Peak - descending through the Crișana Hills (approximately 600 to 200 meters in elevation), and gradually transitioning into the western plains at around 90 meters above sea level.

4.3. Elements of geology

Geologically, Bihor County comprises three major structural units: the Northern Apuseni Mountains, the external Neogene basins of the Apuseni Mountains, and the Pannonian Depression (Berindei and Pop, 1972).

The Northern Apuseni include part of the Bihor Mountains, Codru-Moma, Vlădeasa, Pădurea Craiului and Plopiș Mountains. In terms of age, rocks from the Proterozoic to the Quaternary (Figure 4) are found here, arranged in various structural and tectonic configurations. Two main domains are present: the Bihor - Pădurea Craiului autochthonous unit and the Codru Nappe system. On top of these are found the pre-alpine, alpine, post-tectonic sedimentary cover and the Laramide magmatites. As a whole, in this geological sector there is a great variety of rocks (from volcanic rocks of the granodiorite and crystalline schist types to limestones, sandstones, sandstones, marls, clays, sands) which form a petrographic mosaic. The petrographic and structural diversity determines, in its turn, a great variety of relief (Berindei and Pop, 1972; Bleahu and Bordea, 1981; Geografia României-*Geography of Romania*, vol, III, 1987; Bradu et al., 2010).

Neogene orogenetic movements triggered intense faulting and uneven uplift or subsidence of crustal blocks, resulting in a "checkerboard" structural pattern. This tectonic configuration led to pronounced fragmentation of the mountain unit, forming a series of intramontane basins (grabens) such as Beiuș, Borod, and Sânnicolau. These depressions now align with the corridors of the Crișul Negru, Crișul Repede, and Barcău rivers, which became distinct following the Badenian transgression.

The presence of bedrock formations - especially limestones and magmatic intrusions- modelled as hummocks that introduce local geographic differentiation should also be mentioned.

Overall, in the western Apuseni Mountains there is an alignment of hills extenddeep into themountain interior, forming the golf-depressions that separate the main mountain units (Geography of Romania, 1987). Here, the geological formations are represented by Neogenic deposits, predominantly coarse, with frequent lateral facies changes, so that at the periphery of the Apuseni Mountains ***the present western hills*** covered by Mio-Pliocene formations covered by piedmont structures which were later removed by the action of the hydrographic network were individualized as dry land. Quaternary-age terrace gravels occur on the terraces (Berindei et al., 1972; Bradu et al., 2010).

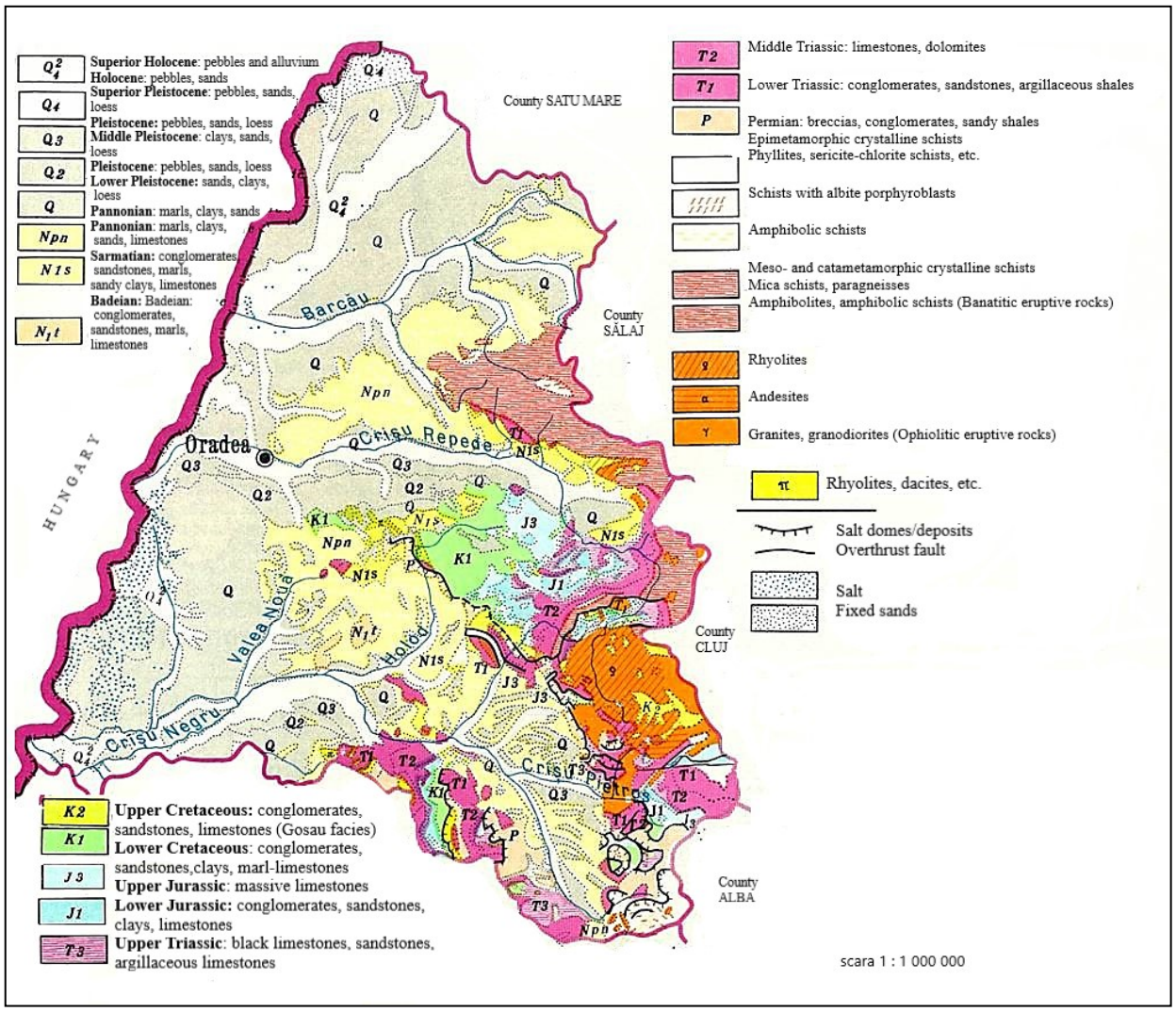


Figure 4. Geological map of Bihor County.

(source: the Geographical Encyclopedia of Romania, 1982)

The Pannonian Depression represent a structural unit in western Bihor County that tentacularly penetrates the western Apuseni Mountains, through the golf depressions. Its old crystalline bedrock is strongly fragmented by faults and compartmentalized in uneven blocks located at varying depths (several hundred meters at Tinca, aproximately 1,500 meters at Inand

and more than 5,000 meters at Biharia); In this region, the checkerboard structure is well-developed, but relatively little visible in relief (Bradu et al., 2010).

On top of the crystalline basement, there is a sedimentary blanket varied in age: Paleogene facies deposits north of Barcău; Cretaceous, Miocene and Pliocene formations between Barcău and Salonta; Miocene and Pliocene formations south of Salonta. In the Miocene, the sedimentary conditions became almost uniform, with layers of marls, gray clays and sands being deposited, while for the Pliocene, a lithologic monotony is observed, due to the predominance of clays, marls and sands.

Quaternary deposits cover the entire surface of the depression. The Pleistocene period is represented by proluvial deposits formimg the broad depositional cones located at the outlets of mountain rivers. In the Upper Pleistocene, red clays accumulated, alternating in places, with loess and loess-like deposits. During the Holocene, the present river system was formed, which led to the formation of terrace deposits consisting of gravels, coarse sands covered with sandy dusts and dusty clays. Also, the sands of the Carei, Valea lui Mihai and the marsh deposits of the Ier valley were formed.

4.4. Physical relief characteristics

The topohraphy of Bihor County is structured into three main altitudinal zones: the Crișuri Plain, the Crișene Hills and the Apuseni Mountains (Figure 5).

The mountainous unit, shaped like an arc bordered by peripheral basins, is located in the southeastern part of the county and covers about 24% of its surface. To the west of the mountainous area, and also between its subdivisions, lies *the hilly area* which acts as a transitional unit between the Apuseni Mountains and the Crișuri Plain. It reaches its greatest extent on the mountainous flanks of the Barcău, Crișul Repede and Crișul Negru River depressional corridors. This hilly belt varies in widths from 5 to 30 kilometers, with elevations decreasing from around 600 or 500 meters to 200 meters. Then, up to the western border with Hungary, there is the *plain unit,* which includes the Crișuri Plain and the southern part of the Someș Plain (Bradu et al., 2010).

Most localities with hydro-climatic resources in Bihor County are situated in plains and hills, excepting the Stâna de Vale resort and the village of Finiș located in the mountainous area and partially the villages of Budureasa and Voivozi (through the holiday village of Pădurea Neagră). Additionally, nine localities are located in intramontane depressions or valley corridors (Table 1).

Table 1. Distribution of localities with hydro-climatic resources by major landforms.

The Western Plain (57 locations)	***The Western Hills*** (11 locations)	***Intramontaneous depressions / valley corridors*** (10 locations)	***The Apuseni Mountains*** (3 locations)
Adoni, Băile 1 Mai, Băile Felix, Biharia, Borș, Cadea, Cefa, Cenaloș, Cherechiu, Cheresig, Cheșereu, Chiraleu, Chișlaz, Cihei, Ciocaia, Ciulești, Ciumeghiu, Curtuișeni, Diosig, Ghiorac, Fegernic, Galoșpetreu, Girișu de Criș, Husasău de Tinca, Livada de Bihor, Marghita, Mădăras, Miersig, Mihai Bravu, Niuved, Nojorid, Olosig, Oradea, Oșorhei, Otomani, Palota, Parhida, Păușa, Rontău, Roșiori, Salonta, Sarcău, Săcueni, Sălacea, Sălard, Sâniob, Sânmartin, Sântandrei, Sântimreu, Șimian, Tămășeu, Tăuteu, Tinca, Toboliu, Tria, Tulca, Valea lui Mihai.	Balc, Betfia, Căbești, Ceica, Cetariu, Cordău, Corbești, Coșdeni, Criștioru de Sus, Hidișel, Sânnicolau de Munte.	Albești, Aleșd, Beiuș, Curățele, Cusuiuș, Finiș, Răbăgani, Ștei, Tileagd, Vașcău.	Budureasa (Hera), Stâna de Vale, Voivozi (holiday village Pădurea Neagră).

4.4.1. The Apuseni Mountains

The Apuseni Mountains stand out within the Romanian Carpathian system through several features. There are three high peaks (over 1,800 meters) in the Bihor, Vlădeasa and Gilău massifs, while the rest of the mountain units are significantly lower in altitude (below 1,300 meters). These features results in clear differences in landscape as well as habitat potential (the mountains are also populated on interfluves). The lithological diversity of the Apuseni Mountains establish their status as a petrographic synthesis of the entire Carpathian arc. Tectonic fragmentation is pronounced due to the horsts and grabens structure. On the relatively flat or gently rolling, polyclinically modelled interfluves, numerous scattered "ridge" type settlement are found between 1,000 and 1,400 meters in altitude (the Geography of Romania, 1987).

In the mountainous region of Bihor County, the Apuseni Mountains are represented by the *Bihor and Vlădeasa Mountains,* which form an orographic node. From this node, *the Crișuri Mountains* (Codru-Moma and Pădurea Craiului) and the *Plopiș Mountains* - which are horsts divided by graben-type depressions (such as Beiuș; Oradea - Vad – Borod and Barcău) branch westward (Bradu et al., 2010).

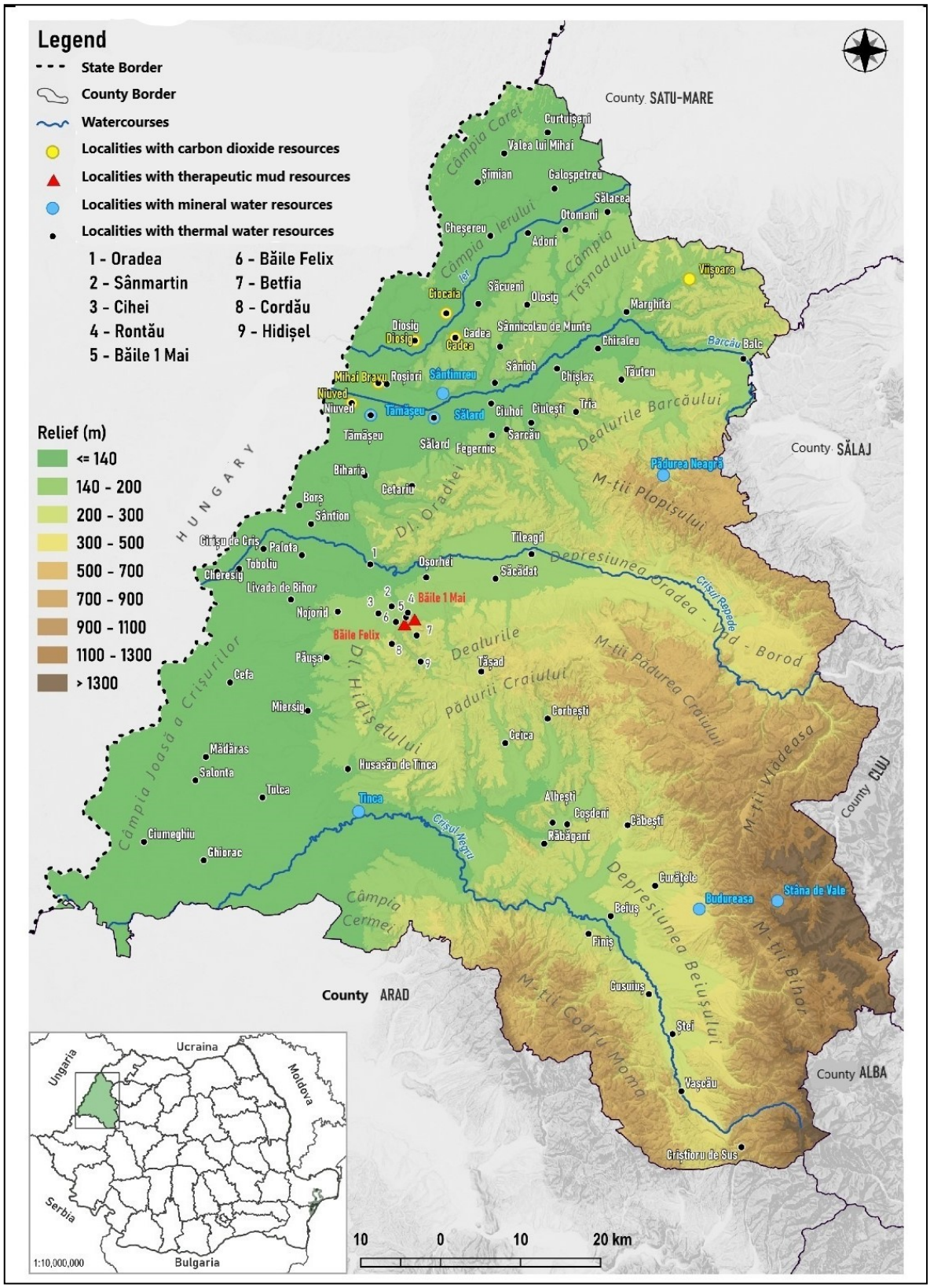


Figure 5. Major relief units in Bihor County.

The Bihor Mountains, the Vlădeasa Mountains and **the *Plopișului Mountains*** are of interest for the study area. They form the highest compartment of the Apuseni Mountains and have a predominantly longitudinal layout. In Bihor County lies the western part of this mountain range,

which forms the highest altitudinal areas, with elevations ranging between 1,200 and 1,800 meters - reaching 1,849 meters at Cucurbăta Mare Peak (in the Bihor Mountains) and 1,836 meters in the Vlădeasa Mountains (in Cluj County). The boundary between the two mountain units is marked by the Crișul Pietros River valley and its tributary, the Boga Valley.

These mountains are primarly composed of crystalline schists and Mesozoic limestones, with the addition of Laramide magmatites (granodiorites, diorites, and andesites) in Vlădeasa unit. They form both an orographic node from which the main mountain branches of the Apuseni mountains radiate, and a hydrographic node, as the major rivers of the Apuseni have their sources here. Depending on geological structure, rocks age and morphology, transversally divided into three compartments: Southern Bihor (located outside Bihor County), *Northern Bihor and the Vlădeasa Mountains* (Bleahu et al., 1981; Bradu et al., 2010).

Due to the extensive development of leveling surfaces and evolved karst formations, the northern part of th Bihor Mountains is also known as the *Bătrâna Mountains.* In northern Bihor, as well as in the Vlădeasa Mountains, well-defined *leveling surfaces* can be observed in the upper zones, marked by wide interfluves and small elevation differences related to local lithological variations. Additionally, the complex petrographic composition and geologic structure have sometimes played a key role in shaping the detailed relief, with limestones formation covering large areas and giving rise to exceptional *karst topography*. Well-defined karst areas in the Bihor Mountains are represented, in particular, by the endorheic Padiș Basin, the headwater sector of the Someș Cald River and the Sighiștel Valley. Northern Bihor ranks first in the country in terms of the development of karst landforms (Berindei et al., 1972; Bleahu et al., 1981; Pop, 2006).

Vlădeasa Mountains. They represents the northernmost compartment of the Bihor Mountains, extending up to the Crișul Repede valley. Within Bihor County, only a narrow sector lies within its territory, represented by a portion of the interfluve between Cornu Muntelui - Cârligați Ridge and the Crișul Repede, located west of the watershed between Drăgan Valley and Iad Valley. In the Remeți graben (Iad Valley), a karst landscape featuring numerous caves has developed on limestone and dolomite, and the slopes of the Iad Valley deliniate a sequence of gorges sectores, separated by broader basins that are occupied by human settlements (Bradu et al., 2010).

At the contact zone between northern Bihor and Vlădeasa, at an altitude of aproximately 1,100 meters, a small tectono-erosive depression has formed along the upper course of the Iad Valley, the ***Stâna de Vale Depression***. It is relatively small in size (2 km in length and 1.5 km in width) and is enclosed by surrounding peaks that rise 200 to 400 meters above it. The geographical position, relief morphology, altitude and slope orientation (about 40% are shaded), along with the sheltering bioclimate, enabled the development of *the balneoclimatic resort of Stâna de Vale*

almost 140 years ago [15] (Orășeanu, 2016; Vlaicu et al., 2016). By far, the best-known hydrographic feature of the Stâna de Vale resort is *Izvorul Minunilor*, a still mineral water spring (Figure 6).

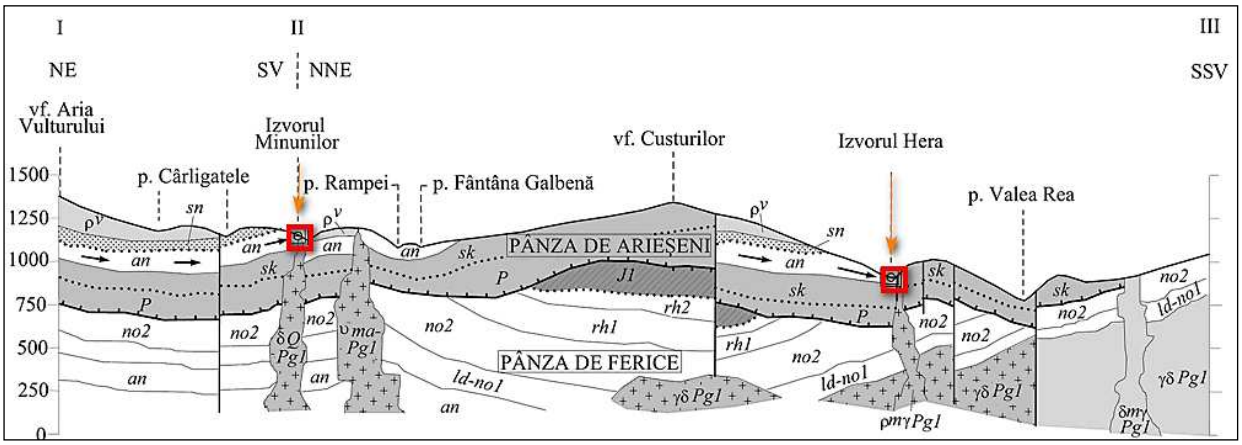


Figure 6. Geological section through the Stâna de Vale area.
(after Bordea, 1999, processed by Orășeanu, 2016)

Southwest of Stâna de Vale, also within Budureasa commune, is *the Cuciului (Hera) spring*, which emerges from Urgonian limestones (Lower Cretaceous) at 907 m above sea level. For a period, the mineral water from this spring was collected and marketed under the name Hera. There are also two other springs (Pescăriei and Rampei), which were tapped for the needs of the European Drinks industrial platform (production of soft drinks and alcoholic beverages at Rieni and Sudrigiu).

The Plopiș Mountains represent the northwestern "peninsula" of the Apuseni *Mountains*, extending approximately 35 km in lenght and 12 to 15 km in width. They are easily delineated, appearing as a horst structure, surrounded by lower depressional areas, bordered by fault lines to the north and south (corresponding to the valley corridors of the Barcău and Crișul Repede rivers). The bedrock of this mountain unit is formed by the Bihor autochthonous, covered by sedimentary strata dominated by clay shales, dolomitic conglomerates and limestones.

The Plopiș Mountains are generally surrounded by piedmont hills, within small depressional basins have formed. In the piedmont hills at the edge of the Plopis Mountains, Mio-Pliocene sedimentary deposits predominante, consisting primarly of conglomerates, marls, sandstones and sandy clays. The main interfluve between the Crișul Repede and Barcăului basins is broad and preserves the traces of ancient leveling surfaces, the most proeminent being the one at 600 to 700 m,which gives the landscape a plateau-like appearence (hence the alternative name

[15] http://www.istorielocala.ro/index.php/biblioteca-judeteana-gheorghe-sincai-bihor/item/735-st%C3%A2na-de-vale-perla-muntilor-apuseni.html

the Șes Mountains). Some peaks rise above this area and exceed 700 m in altitude (Merișorul 882 m, Ponorul 851.8 m, Osoiu 777 m, and Poiana Florilor 706 m). From the main ridge, a series of secondary interfluves branch off to the northeast, separating the tributaries of the Barcău River and gradually decreasing in altitude to 350 to 400 m. The valleys are relatively deep (200 to 300 m) and narrow, with steep slopes exceeding 25° (The Geography of Romania, 1987; Josan et al., 2004; Pop, 2006).

In the Plopiș Mountains, within the Popeşti commune, outside Voivozi village, on the right bank of the Bistra river, the *holiday village Pădurea Neagră* was developed[16] after 1990, on the grounds of the children's campsite. At the upstream edge of the village, there is a *spring with* ferruginous, carbonated *mineral water,* which was also used locally in the past.

4.4.2. The Western Hills

They form an almost continuous hilly rim at the western base of the Western Carpathians. They have a shallow-submerged Carpathian bedrock that influenced the mode of sedimentation differently.

In terms of landform types, the region features a series of *piedmont hills* (such as the Pădurea Craiului hills, the hills west of the Codru-Moma Mountains, the Bihor hills), *erosion surfaces* (in the Oradea Hills and the Tășad Hills), *glacis formations* (in the Cigher Depression), *crystalline and* isolated *eruptive hummocks*, of small dimensions, frequent in the Beiuș Depression (Pietrani Hills, Borz Hills, Osoi Hills, Urviș Hills, Forău Hills, etc.), which have favored the appearance of epigenetic ravine sectors separated by depressional basins (Dezna, Nușfalău). More rarely, limestone spurs occur on a crystalline support, as seen between Vadu Crișului and Șuncuiuș where the Crișul Repede river has carved a series of quays (Petrea et al., 1994).

As a whole, the Western Hills penetrate deep into the mountain range to the east, following a series of valleys formed by the Someș, Crasna, Barcău, Crișul Repede, Crișul Negru, Crișul Alb, Mureș, Bega, and Timiș rivers. Due to the way they have evolved (through Badenian sinking and fragmentation, followed by the accumulation of thick sedimentary layers and then their partial erosion), the Western Hills are in the form of clearly expressed hills and bridges. In terms of elevation, they range between 200 and 400 m, occasionally reaching up to 600 m (Pop, 2005).

Within the boundaries of Bihor County, the **Crișana Hills** form part of the Western Hills, developed along the river valleys of Barcău, Crișul Repede and Crișul Negru. Their latitudinal extent, but especially their position in relation to the mountainous area, combined with the action

[16] Not to be confused with the locality of Pădurea Neagră which, administratively, belongs to the city of Aleșd.

of the hydrographic network, complicates the individualization of the topographical sub-units. However, a distinction is made between two categories: *peripheral* (outer) *hills*, located at the western extremity of the mountains, and *internal hills, which* borders the gulf-like depressions which, in part, also have an intra-mountainous function (Mihăilescu, 1966; Geografia României, 1992).

The morphology of these hills is characterized by long, wide ridges, that slightly slope toward the surrounding plains or toward the axes of depressions, with altitudes ranging between 200 and 500 m. The valleys comprise broad plains accompanied by multiple terrace levels, which rise asymmetrically and often display a fan shaped arrangement. Slope processes (gullies and landslides) occur on steeper slopes.

The hills of Crișana are distributed across several depressions or valley corridors. According to Pop (2005), they can be grouped into two main categories: those located in the *gulf-depressions or valley corridors* along the Barcău, Crișul Repede, Crișul Negru rivers (Barcău Corridor, Crișul Repede Depression and Crișul Negru Depression) where they form the *internal hilly step* at the contact with the mountain; and the external (peripheral) hills, located at the western edge of the mountainous "peninsulas" and are represented by: the Oradea Hills (west of the Plopiș Mountains) and the Pădurea Craiului /Lăzăreni Hills (west of the Pădurea Craiului Mountains).

In the following section, these subunits will be presented according to their latitudinal unfolding, irrespective of their internal or external position. From north to south they occur in the following sequence: Barcău Corridor, Oradea Hills, Crișul Repede Depression, Padurea Craiului Hills, Crișului Negru Depression.

Barcău Corridor. It is the result of the deepening of the homonymous river in Pannonian formations, between the Marca gorge and the contact with the Crișuri Plain (on the alignment of the localities of Roșiori, Sălard, Biharia). It presents features common to the other depressional corridors in the western Apuseni Mountains: asymmetry, crystalline shaped gorge sectors, existence of local subsidence areas. The Marca gorge, modeled in a crystalline spur of the Plopiș Mountains, divides the Barcău valley into two sectors: one upstream (represented by the Nușfalău Depression) and the other downstream, with the aspect of a bay wide open towards the Crișuri Plain. The Barcău floodplain is well developed, has a low slope which enable persistent excessive humidity. Even if the Barcău River is dammed, there is a risk of flooding, a fact frequently proven in the 2000s.

At Chiribiș, due to a local subsidence, the floodplain is very wide, with the meanders successively abandoned by the Barcău River. The left slope is structured in a system of 3-4 terraces.The lower terraces bridges are hundreds of meters wide and accommodate the majority of the human settlements (Bențe, 1999; Josan et al., 2004; Pop, 2005; Bîdiliță, 2009).

The area is particularly known for its lignite, crude oil and associated gas resources, but also for oil explorations which have also led to identification of significant ***thermo-mineral water*** resources within the territories of the communes of Balc, Derna, Sălard, and Tăuteu.

Hills of Oradea. Formed entirely of clays, gravels and sands, Oradea Hills are located at the western extremity of the Plopiș Mountains. They are delimited to the north by the Barcău Corridor, and form the right slope of the Crișul Repede Valley to the south (within the Oradea – Bratca depressional corridor). Their altitude range between 150 and 350 m. The landform fragmentation has high values (2.5 - 3 km/km^2) and the slopes are steep, especially in the upper section often exceeding 20°. Shaped in Pontian formations, the slopes are prone to landslides (Josan et al., 2004; Pop, 2005). No boreholes indicating thermo-mineral water resources have been identified in this sector.

Crișul Repede Depression. This is a gulf-type depression located in the western part of the country, sculpted into Neogene formations within the graben structure, situated between the Pădurea Craiului and Plopiș Mountains. The lithology consist of conglomerates, sandy marls, Badenian limestones overlain by Pannonian sandy and sandy-clay deposits, as well as Quaternary and recent alluvium deposits. (Badea, 2008).

Within this depressional corridor, the geological prospecting has identified ***thermo-mineral reservoirs*** in Oșorhei and Aleșd areas, hosted in permeable porous rocks and fissured rocks, such as limestone, dolomite, sandstone type (Petrea et al., 2009).

Pădurea Craiului Hills. These hills are found in the western part of the Pădurea Craiului Mountains and are divergently disposed towards the Crișul Negru Corridor, the Miersig Plain and the Oradea - Borod Corridor. They are mainly composed by Pannonian deposits (clays and sands) where slope processes are very active, leading to landslides and deep erosion. In their north-western extremity (Tășad Hills sub-unit), boreholes have revealed the existence of ***thermal springs*** (in the village of Cordău).

Crișul Negru Depression or Corridor. This sector most clearly exemplifies the characteristics of gulf-type depression and is composed of two compartments: an *internal* one, represented by the Beiuș Depression, and an *external* one, corresponding to the Tinca - Holod Depression. These two units are separated by Măgura Forăului.

The Tinca - Holod external Depression appears as a wide bay (10 - 12 km in width) where a wide, often swampy floodplain and a system of symmetrically developed terraces have formed. The low drainage slope of the Crișul Negru and Holod rivers causes frequent flooding and excess water surfaces. *In this sector,* ***cold mineral waters*** *have been both identified and therapeutically exploited within the Tinca balneoclimatic resort, located on the right bank of the Crişul Negru, on the second terrace bridge, at an altitude of 131 meters*.

The Beiuș Depression, of tectonic origin**,** is the internal compartment of the Crișul Negru Corridor and has been the subject of a panoply of geographical, geological, hydrogeological, historical studies. This area is referred to by various names, among which *Țara Beiușului (Beiuș Country)* is by far the most widely used. However, in geographical terms, the Beiuș Depression represents strictly the depressional sector of Beiuș Country (Berindei et al., 1977; the Geography of Romania, 1992; Pop, 2005; Filimon, 2012; Orășeanu and Malacu, 2016).

This depression is shaped by the Crișul Negru River and its tributaries (Roșia, Nimăiești, Crișul Pietros, Crișul Băiței) which have created a branched system of valleys with terraces and meadows formed in the Neogene deposits of the graben between the Bihor - Pădurea Craiului and Codru-Moma Mountains. As a whole, the topography is terraced and arranged like an half-open amphitheater facing northwest, while also presents an asymmetry characteristic due to the development of the depression on the right side of the Crișul Negru river (Berindei et al., 1977; Bradu et al., 2010; Filimon, 2012).

The depression is bordered by the mountain range of Bihor - Vlădeasa, Pădurea Craiului and Codru-Moma, which connects to the center of the depression through a series of *internal piedmont hills* with different morphologic displays. These include: the Curmătura Crițiorului Hills, the Bihor Hills, the Momei and Codrului Hills, and Pădurea Craiului Hills, at the contact with the Western Plain. All these hills feature a broadly rounded ridges relief with altitudes ranging between 250 - 350 meters, derived from accumulation foothills (Geografia României, 1992).
Among these, the ***Bihor Hills*** have the widest spatial extension and accompany the western edge of the Bihor - Vlădeasa Mountains. They have been fragmented by the main valley that drain them into several sub-units such as: the Beiușele, Budureasa, Gorunilor and Lazuri Hills. To these are added the Curmăturii Crițiorului Hills, located in the extreme south of the county, between the Bihor and Codru-Moma Mountains, arranged in the form of a wide saddle that connects the Beiuș Depression with the intramontane Brad- Hălmagiu depressional sector (Bradu et al., 2010).

The heart of the Beiuș Depression is represented by the *terraces* and the main rivers *beds.* The Crișul Negru presents a system of seven terrace levels, asymmetrically developed, between which the middle terraces (fourth and fifth terraces) have a large spatial extension (Berindei et al., 1977).

In the area of the Beiuș Depression, there is a dense network of boreholes that reveal the existence of ***thermal waters*** *both in the center of the depression and in the marginal hills (Beiuș, Ștei, Vașcău, Cusuiuș, Căbești, Curățele, Finiș, Albești, Coșdeni, Răbăgani, and Criștioru de Sus).* These thermal waters are exploited for balneary purposes in the city of Ștei and in the city of Beiuș; they are mainly used for residential heating and recreational activities

4.4.3. The Western Plain

The studies of Ștefan Manciulea in the first half of the 20th century (1923, 1938) consecrated this area in the geographical literature. A long line of geographers, among them Măhăra (1977), wrote a doctoral thesis focused on the Crișuri Plain. A comprehensive approach can be found in the following studies: Geografia României, 1992; Posea, 1997; Pop, 2005; Badea et al., 2011.

In its eastern part, this major plain unit of Romania is closely connected to the Western Hills, which it fragments in the form of gulf-depression along the main valleys. The relief of the plains is characterized by a relative uniformity, determined by the widespread presence of Quaternary formations in the high plains, as well as present alluvial deposits in the low plains, which are situated at low altitudes ranging between 77 to about 200 m. Particularly in the low plains, phenomena such as rivers meandering and high groundwater level are present, which have required extensive hydroamelioration works (land improvement).

From a genetic point of view, the Western Plain (an extremity of the Great Tisza Plain) is an accumulation plain, formed by the deposition of sediments in a marine basin during Miocene, later transformed in a lacustrine basin in the Pliocene, composed of clays, marls, sands, gravels. Geologists generically refer to these deposits as *Pannonian* (from the Pannonian Depression). At the surface, this plain is covered with Quaternary deposits. The major subdivisions are the Someș Plain, the Crișuri Plain and the Banat Plain.

***The Crișuri Plain*.** It is the central part of the Western Plain, centered on the valleys of the Barcău River and the three Criș Rivers. Its foundation consists of Carpathian type formations, characterized by horsts and grabens formations separated by major fault lines, including the Pannonian fault (with longitudinal disposition east of Carei and west of Oradea and Timișoara), which separates the Apuseni Mountains from the lowlands.The Carpathian faults are disposed latitudinally and the main rivers of western Romania are aligned along them.

The Crișuri Plain has the greatest latitudinal extent among the subunits of the Western Plain (maximum 160 km in width), but longitudinally it features significant narrowings (about 15 km in width) well evidenced by the advance of the Western Hills toward the plain.

Among the subdivisions of the Western Plain, the Crișuri Plain has the most eastward ramifications, penetrating far into the hills along the main rivers. Heavily alluviated, its base level correspond to the subsidence area of Sárrét in the Tisza Plain (Hungary). At the boundary with the hills, the most typical glacis plain are found (Posea, 1997).

As a result of paleogeographic evolution, from both a morphometric and morphographic point of view, the topography of the Western Plain is arranged in steps, with a distinction between

high and low *plains.* The relief features, along with genesis characteristics, have led to the subdivision of the Crișuri Plain into high and transitional plains, developed on the border with the hills, and alluvial lowlands.The altitude of the Crișuri Plain ranges between 90 and 220 m (Măhăra, 1977; Posea, 1997; Pop, 2005) (Figure 7).

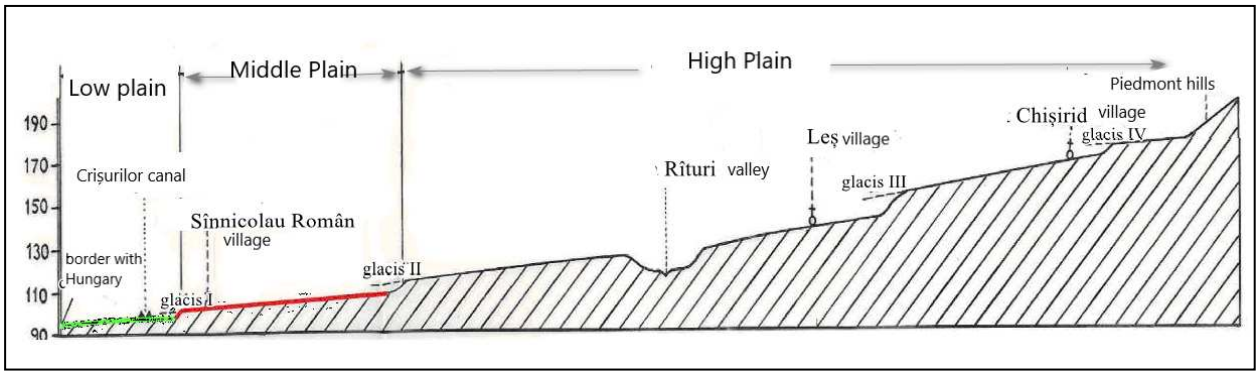


Figure 7. The cross-sectional profile (W-E) across the Crișuri Plain shows the existence of four generations of glacis and three elevation steps.

(source: Măhăra, 1977)

The high plains or sub-hilly plains are located on the border with the hills (except for the Carei - Valea lui Mihai / Nirului Plain), between the Barcău and Teuz rivers, respectively the Pir, Biharia, Miersig plains. They present altitudes between 220 and 120 m and correspond to Pleistocene glacis and fluvial terraces (Bradu et al., 2010).

Posea (1977) considers the high plains originate from the erosion material from the western hills, accumulated at their base, where river terraces descend into the low plains or widen laterally into subcollinear glacis. The high plain is transversally fragmented by the Barcău, Crișul Repede and Crișul Negru rivers, which individualize the following compartments: *The Barcău Plain,* consisting of a complex glacis extending between the Barcău, Derna and Bistra floodplains; *the Biharia Plain* continues the Barcău glacis west of the Fâneața Mare Valley, extending westward from the Oradea hills to the Crișul Repede floodplain; the *Miersig Plain,* the most extensive, is located between the Tășad Hills and the Colector Canal on one side and the Crișul Repede and Crișul Negru floodplains on the other.In the west, it presents an intermediate step called the *Gepiu* Plain (Posea, 1977) or the *Veljuri Plain* (Măhăra, 1977).

The low plains have a much wider spatial extent. They run between the Colector Canal and the Hungarian border at an altitude ranging between 89 to 100 m, extending tentacularly into the glaciated plain along the main rivers. The lowest elevation is at the outlet of the Crișul Negru and Crisul Alb rivers from the country (89 m at Ant). Orographically, these plains rise about 1 - 5 m above the talweg, but their surface is often at or below the level of the riverbeds. Thus, the rivers

used to flow between levees or dykes, which favored frequent overflows. The landscape features numerous abandoned meanders and channels, lakes, marshes and swamps with isolated river segments without source or springs. Genetically, they are subsiding plains formed through fluvial sedimentation processes and prolonged toward the hills by wide floodplains. They are also called divagation plains or alluvial plains (Posea, 1997; Bradu et al., 2010).

Poor drainage and excess water required extensive ***hydro-improvement*** works that have significantly altered the present appearance of the western lowlands. The main rivers (Barcău and the three Criș rivers) were dammed, some dykes were raised, embankments were strengthened, meanders were corrected and courses were straightened. Numerous canals were dug (the Colector Canal/Canal Crișuri, the Mill Canal, the Cermei - Tăuț Canal, etc.), numerous marshy areas were drained, and where water excess persisted, fishponds were created (at Cefa, Mădăras, Cermei, etc.) (Blidaru et al., 1962).

Within the sub-units of the Crișuri Plain, there are 22 localities that benefit from ***hydro-therapeutic factors.*** These include the balneoclimatic resorts Băile Felix, Băile 1 Mai, Oradea, the local tourist resort Marghita and the village of Sarcău, where the thermal therapeutic factor is used in balneotherapy at a higher level.

Oradea**,** the flagship city on the Crișul Repede River, is located at the junction between the Low Plain and the Hills of Oradea**,** using thermal water for recreational purposes and residential heating. In 2020, the central part of the city along the Crișul Repede river received the status of *national tourist resort* and since 2022 it also holds the status of *national balneoclimatic resort.*

Băile Felix and ***Băile 1 Mai*** are located at the contact between the Miersig Plateau and the Pădurea Craiului Piedmont Hills, sub-unit of the Tășad Hills.

In the village of ***Sarcău*** (Sârbi commune), the Adorianis balneary-thermal complex has been developed over the last 20 years, located at the contact between the Biharia Plain and the Oradea Hills.

Marghita is a newly established local tourist resort with natural therapeutic factors, namely thermal waters. The city-resort extends into the Barcău Corridor on its lower terraces and into the High Plain of Marghita (the Viișoara Hills, according to some authors).

4.5. Climatic characteristics

The climate characteristics in Bihor County are conditioned by climatogenic factors such as geographical position, solar radiation, changes imposed by the peculiarities of the underlying surface and the atmospheric circulation of air masses.

Radiative factors determine how solar radiation interacts with the Earth's atmosphere and surface. These factors include the absorption, reflection, transmission and emission of radiation, which affect the temperature and climate of a given region (Teodoreanu et al., 2013).

Solar radiation is the most important climatogenetic factor. It depends on altitude, atmospheric transparency and cloud cover and it influences the major, defining features of the climate. The global solar radiation is considered to be the sum of direct and diffuse radiation, influenced by the atmospheric conditions, related processes and the altitude. The annual pattern is characterized by a maximum in June and a minimum in December. Diurnal *direct solar radiation*, reaches its highest values at midday (12 noon), although these values vary under cloudy conditions. *Diffuse solar radiation* is influenced by the atmospheric mass travelled, atmospheric opacity and cloud cover. Its intensity also depends on the color and nature of the earth's surface (in winter, snow cover reflects sunlight, increasing diffuse radiation intensity) (Gaceu, 2005).

Dynamic factors play an important role in individualising weather types and climate. Centers of atmospheric action – such as Azores Anticyclone, Icelandic Cyclone, East European Anticyclone, Mediterranean Low - and less frequent baric centers like Greenland Anticyclone, Scandinavian Anticyclone, North African Anticyclone and Arabian Cyclone, contribute to important weather variations (Gaceu, 2005). Thus, the dominant air masses are polar maritime, transported by the westerly circulation. They are humid, thermally moderate and most frequent in late spring and summer. Polar-continental air masses follow, being cold and dry in winter and warm and dry in summer. Arctic-maritime air masses, originating from the North Atlantic, bring freezing and relatively wet weather in winter and frost in spring and fall.

Physico-geographical factors or the active underlying surface are represented by geological structure, topography, hydrography, vegetation and soils. They influence the regional climate by affecting solar radiation absorption and reflection, uneven heating and cooling, changes in wind speed and direction.

Bihor County has a heterogeneous underlying surface, where topography plays an important role through variation in elevation (hypsometric steps), degree of terrain fragmentation and slope exposure, thus determining the differences in major climatic elements.

Within the process of interaction between radiative, dynamic climatic factors and local geographic factors, a notable role is played by the forced ascent of western air masses a the slopes of the Apuseni Mountains, which causes ***important nuances*** in the value and regime of climatic elements (Bradu et al., 2010).

To summarize them, Bihor County lies within *Romania's temperate continental transitional climate zone*. However, factors such as the air masses circulation, its position in the

western part of the country with a wide opening to the western plains, its varied relief (particularly the orographic influence of the Apuseni Mountains) and the characteristics of the active surface contribute to a *moderation* of typical continental climate. On the whole, moderate characteristics mean winters that are not too cold, summers that are confortably warm, with humidity and precipitation within normal parameters (Pop, 2005).

In the light of this characterization, it is noted that the moderate thermal and hydric character of winter is fading, especially in lowland and hilly areas, but also that summers are characterized by longer periods with high temperatures and low precipitation.

For the climatic characterization of Bihor County, an extended dataset covering 60 years, from 1961 to 2020, was analyzed using data from seven meteorological stations situated across the county's major relief steps. Thus, the meteorological stations of *Oradea* and *Săcueni* are positioned in the lowland area, those of *Holod, Ștei* and *Borod* are situated in intramontane depressions, and the stations of *Dumbrăvița de Codru* and *Stâna de Vale* belong to the mountainous zone. Additionally, data from two nearby stations - *Vlădeasa* and *Chișineu Criș* – were included, even though they lie outside Bihor County administrative borders, to better illustrate altitudinal climatic variation (Figure 8).

It should be noted that the data series is not uniform in length, as some stations were established later: Borod in 1971, Stâna de Vale in 1979, Dumbrăvița de Codru in 1983. The analyzed climate data includes monthly values for temperature (°C), rainfall (mm), wind speed (m/s), atmospheric pressure (mm/Hg) and relative humidity (%), for the 1961 – 2020 period.

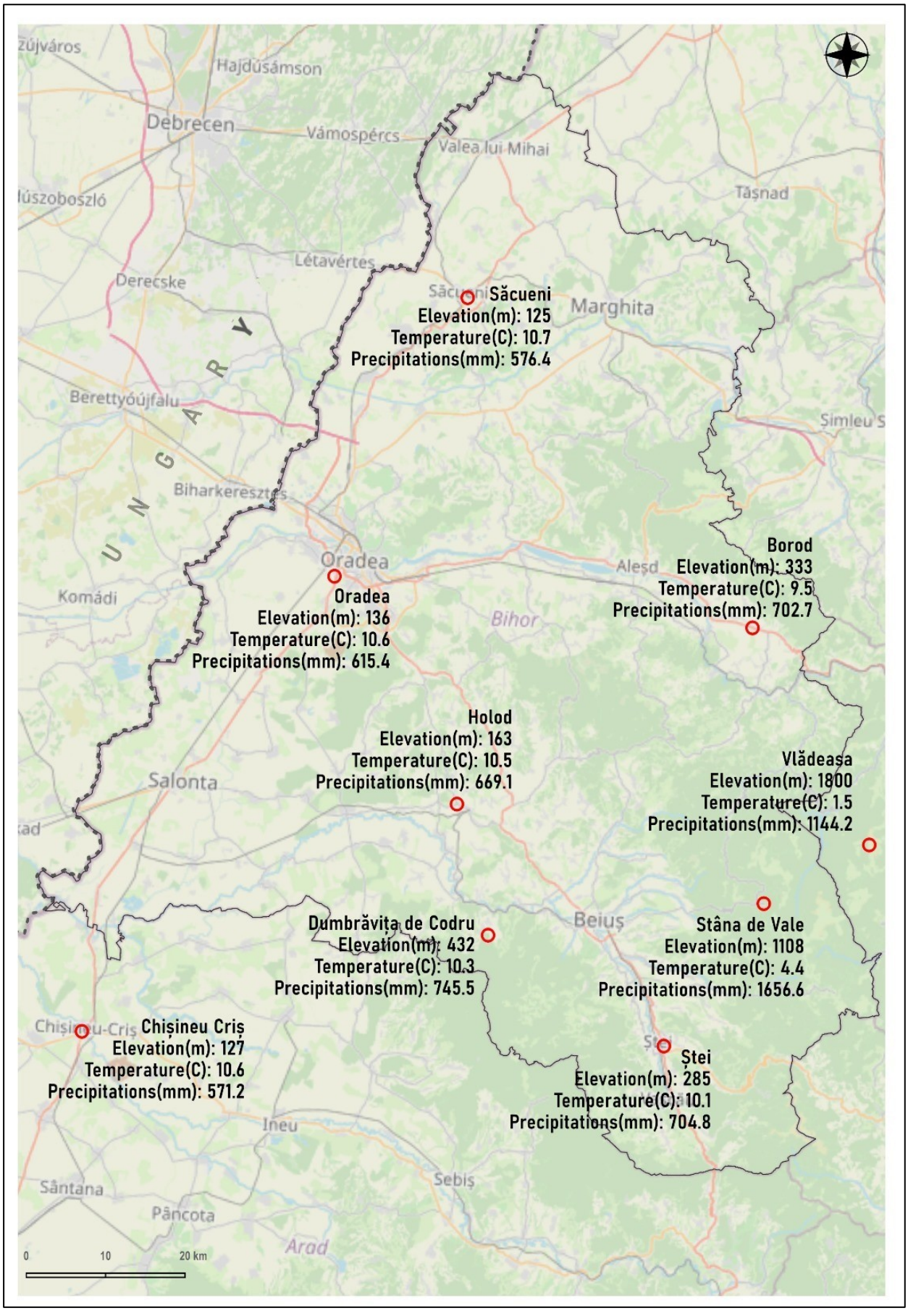


Figure 8. Meteorological stations located in and nearby Bihor County.

4.5.1. Particular features of the thermal regime

The spatial distribution of multiannual average temperature values, in Bihor County, for 1961- 2020 period shows certain variation based to the placement of weather stations across the major landforms and the latitudinal extent of the county (Figure 9). Vertically, the multiannual average temperature decreases along a vertical temperature gradient of 0.52°C/100 m. The differentiation of temperature values is emphasized by the *thermal profile* derived from the average annual temperatures recorded at the seven meteorological stations in Bihor County, along with the data from the nearby meteorological stations at Chișineu Criș and Vlădeasa (Table 2).

Table 2. Multiannual mean temperature and multiannual mean precipitation at meteorological stations between 1961 and 2020.

Meteorological station / Indicator	Săcueni	Oradea	Holod	Ștei	Borod	Dumbrăvița de Codru	Stâna de Vale
Altitude (m)	**125**	**136**	**163**	**275**	**333**	**432**	**1108**
Multiannual mean temperature (C)°	10.7	10.6	10.5	10.1	9.5	10.3	4.4
Multiannual mean precipitation (mm)	576.4	615.4	669.1	704.8	702.7	745.5	1656.6

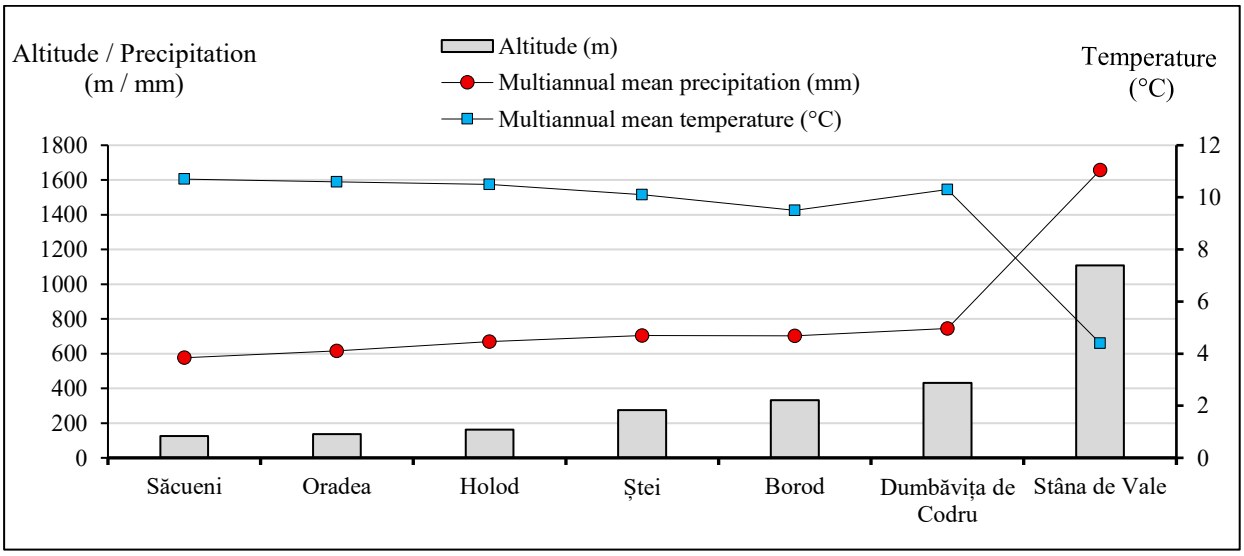


Figure 9. Thermal and rainfall profile of the analysed weather stations.

As a general rule, air temperature decreases with increasing altitude. In the Crișuri Plain, (at the meteorological stations Săcueni, Oradea, and Chișineu Criș) ***the multiannual average temperature*** exceeds 10.5°C, with very slight variations due to latitude. From there, temperatures decrease slightly with increasing altitude in the intramontane depressions (stations at Ștei, Holod, and Borod), ranging between 9.5 and 10.5°C. In the lower altitude mountain ranges (Plopiș, Pădurea Craiului, and Codru-Moma), the annual average temperature would typically be lower. However, at Dumbrăvița de Codru – the only meteorological station in this are - local conditions result in unusually high temperatures, especially during winter, when thermal anomalies are most

evident (Paucă, 1988; Măhăra et al., 1993). Thus, at Dumbrăvița de Codru meteorological station, the multiannual average temperature was higher (10.3°C). In the higher mountains, such as Bihor and Vlădeasa ranges, the multiannual average temperature is much lower: 4.4°C at Stâna de Vale and 1.5°C at Vlădeasa (1800 meters elevation) (Figure 10).

The evolution of the rise and fall of air temperature during the year is analysed using ***multiannual monthly average*** values. The interdependence between genetic climatic factors and the characteristics of the active surface is reflected in the month-to-month variation in annual temperature.

The temperature variations during the ***extreme months*** (January and July) follow the same pattern. January records *the lowest average monthly temperatures* (Table 3), largely due to frequent cold air outbreaks brought by the East European Anticyclone (Șerban, 2010).

In *January*, the Crișuri Plain is characterized by isotherms ranging from -1°C to 2°C (at the Oradea and Săcueni stations). In the low hills, sheltered by surrounding mountain range, the isotherm reaches around 0°C (at the Ștei and Holod stations), and in Bihor and Vlădeasa mountain massifs – at Stâna de Vale and Vlădeasa stations - isotherms of 5 - 7°C are found (Figure 10). The frequent advection of warm air from the west of the country leads to higher January average temperatures in the Crișuri Plain compared to other regions of the country (the Geography of Romania, 1983). According to Măhăra (1977), winters in the Crișuri Plain are moderate, without strong frosts, due to the influence of westerly air circulation and the region's more sheltered position from polar-continental air masses originating from the east and northeast.

Frequent *thermal inversions* during winter occur in the Codru-Moma Mountains (Dumbrăvița de Codru station). Paucă (1988) decribed these inversions as being circulatory in nature, associated with the topography of the terrain and which, in fact, affect all the low altitude massifs in western Romania (Măhăra, Linc, 1993). However, thermal inversions also occur in the lowland areas, especially in the Salonta low plain (Gaceu, 2009; Șerban, 2010).

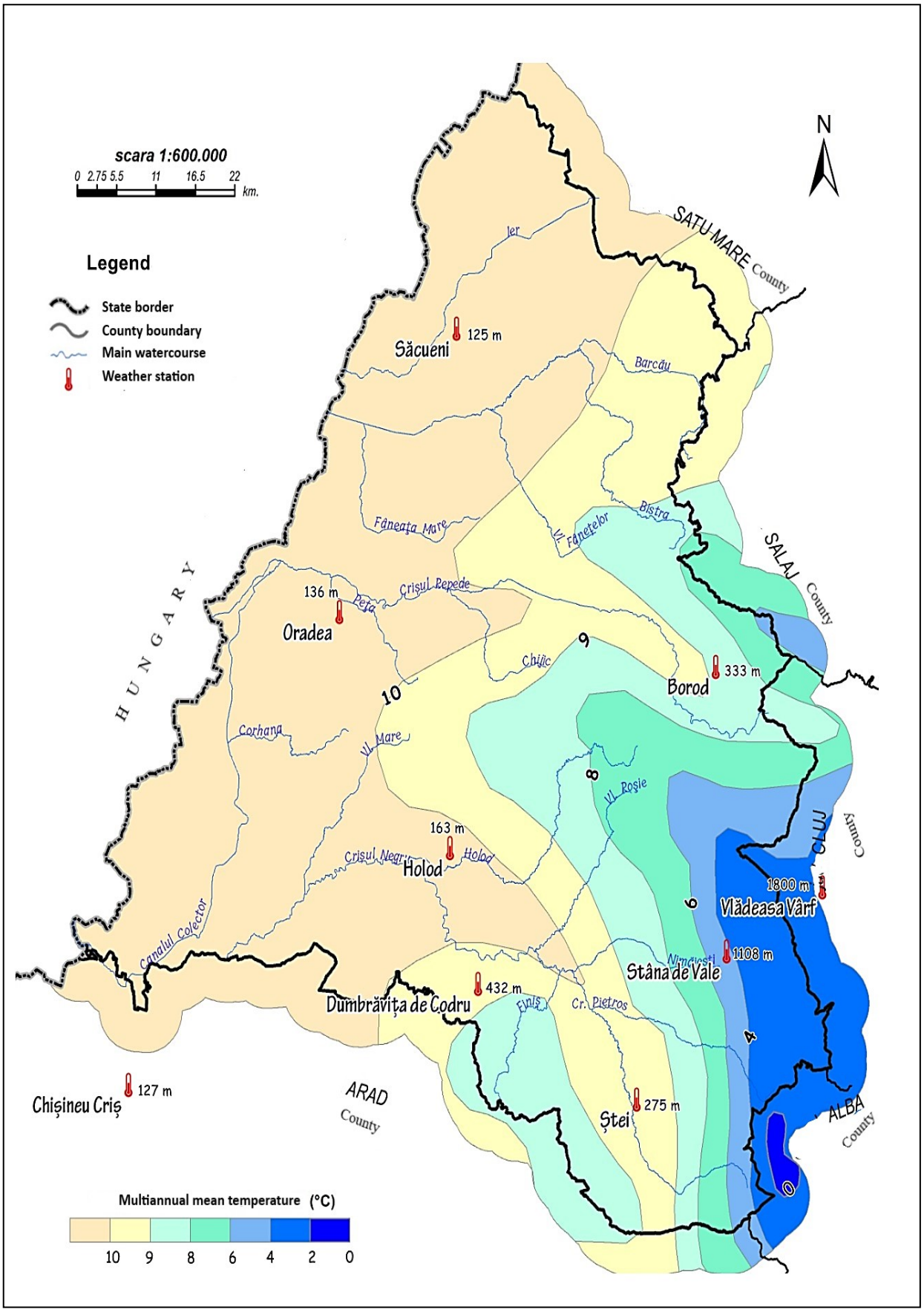


Figure 10. Multiannual average temperature in Bihor County. Distribution of isotherms.

(processing after Climate of Romania, 2008, National Meteorological Administration)

In *July*, the average temperatures are not excessively high, around 21°C in the plains and depressional areas, decreasing slightly in the low hills (19 - 20° C). In the Bihor - Vlădeasa Mountains it is between 10 - 14° C. Again, the Dumbrăvița de Codru station stands out, where the July average is similar to the lowland stations (21.3° C) (Table 3).

In the remaining months, the temperature curves follow a normal upward trend from January to July and then downward until December.

Table 3. Multiannual monthly air temperature regime at meteorological stations in Bihor County between 1961 and 2020.

Months / Weather station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Săcueni	-1.1	0.5	4.7	9.8	14.8	18.1	19.7	19.3	14.7	9.7	4.8	0.5	9.6
Oradea	1.0	4.8	10.7	15.4	19	20.9	21.3	16	11.1	6.2	0.9	-0.3	10.6
Holod	-0.6	1.4	5.8	11	16	19.3	21.0	20.6	15.8	10.7	5.4	1.0	10.6
Ștei	-1.3	0.7	5.4	11.2	16.3	19.5	21.3	20.8	16.3	10.9	5.5	0.7	10.6
Borod	-1.3	0.9	5.7	11.5	16.5	19.8	21.3	20.8	16.3	11	5.6	0.6	10.7
Dumbrăvița de Codru	-5.1	-4.2	-1.2	3.3	8.9	12.5	13.9	13.4	9.1	4.9	0.5	-3.5	4.4
Stâna de Vale	-0.8	1.1	5.2	10.5	15.2	18.3	19.9	19.6	15.3	10.5	5.8	1.0	10.1
Average stations	-1.3	0.7	5.2	10.4	15.2	18.3	19.8	18.6	14.1	9.1	4.1	0.0	**9.5**

The annual thermal amplitude is one of the most representative indicators of the degree of continentality in an area and varies significantly depending on the particularities of the active surface. In Bihor County, the annual thermal amplitude is 26.4°C (resulted from the difference between 21.3°C at Oradea and Săcueni and -5.1°C at Stâna de Vale). This value is lower than those recorded in the south, south-east and eastern parts of the country, which emphasizes *the moderate character of the temperate climate in western* Romania, as a result of oceanic climatic influences (Geografia României, 1983; Șerban, 2010).

Temporally, monitoring the regime of average annual temperatures at the weather stations in Bihor County, an oscillating evolution is noted with averages ranging from 3.1°C (in 1985 at Stâna de Vale) to 14.0°C (in 2009 at Oradea). Compared to the multiannual average values, over the years, the air temperature showed non-periodic variations depending on the frequency and intensity of different air masses adevections.

In Bihor County, the multiannual average temperature calculated for the interval 1961 - 2020 is 9.5°C, aligning with the 9-11°C interval cited in the specialized literature (Geografia României, 1983). Until the year 2000, only 8 out of 39 years exceeded the multiannual average temperature of 9.5° C, but from the year 2000 onwards, there have been 16 years in which this threshold was surpassed (Figure 11).

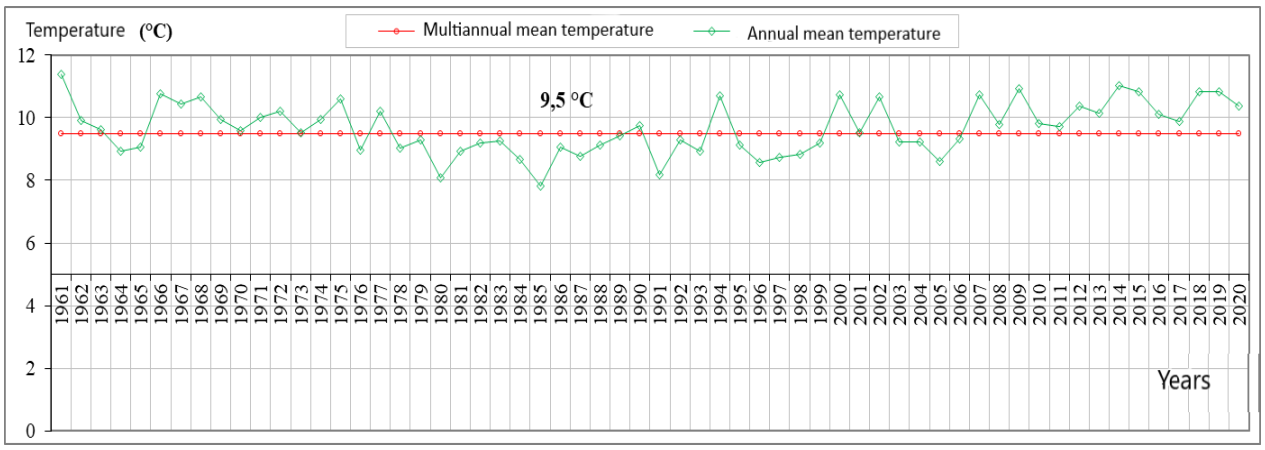


Figure 11. Non-periodic variations of annual average temperature in Bihor County between 1961 and 2021.

When examining the lowest mean annual temperatures, the years 1980 and 1985 stand out for the mountain elevation, at the Stâna de Vale weather station recording 3.3°C and 3.1°C, respectively. For the hilly elevation, we identified the years 1980 (with 8.6°C at Ștei) and 1985 (with 6.6°C at Borod). For the plain elevation, the years 1964 and 1976 impose themselves (with 8.3∘C and 8.2°C at Oradea) (Table 4).

Table 4. Extreme annual average temperatures at the weather stations studied in the 1961 to 2020 period.

Weather station	**Chișineu Criș**	**Săcueni**	**Oradea**	**Holod**	**Ștei**	**Borod**	**Dumbrăvița de Codru**	**Stâna de Vale**	**Vlădeasa**
Relief unit	Plain			Hill			Mountain		
Altitude (m)	127	125	136	163	275	333	432	1108	1800
Lowest average temperature (year)	9,0 (1985)	8,9 (1980)	8,2 (1976)	6,6 (1987)	8,6 (1980)	6,6 (1985)	8,5 (1983)	3,1 (1985)	-0,4 (1980)
Highest average temperature (year)	12,6 (2018, 2019)	12,7 (2019	14 (2009)	13,1 (2002	12,1 (2019)	11,5 (2007)	12,5 (2019)	6,0 (2014)	3,4 (2014)

In Bihor County, the positive deviations from the multiannual average temperature for the 1961-2020 period are between 0 and 1.6°C, while negative deviations have a greater amplitude, ranging between 0 and -1.8°C (Figure 12).

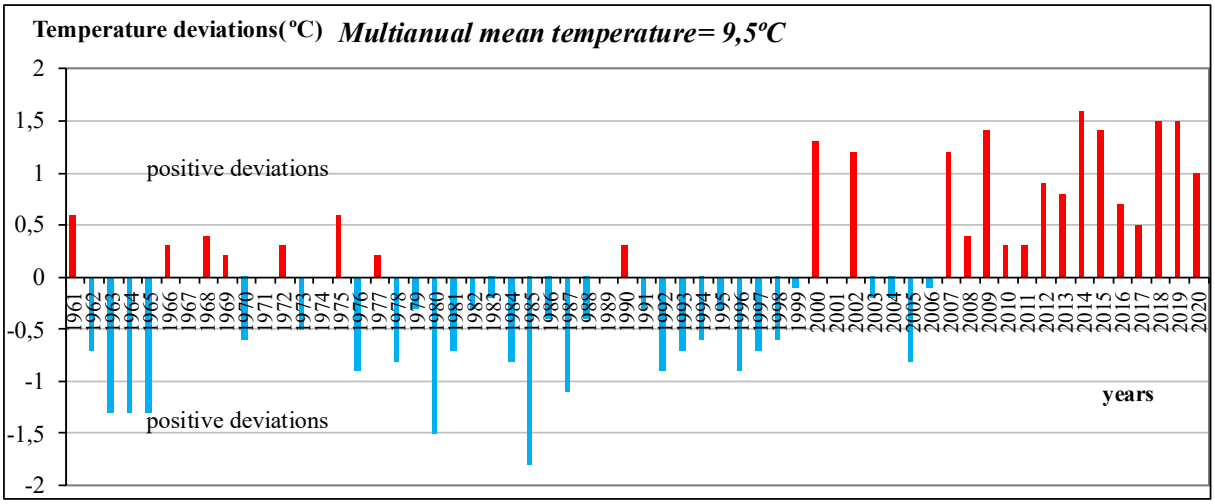


Figure 12. Deviation of annual mean temperature from the multiannual average of 9.5°C between 1961 and 2020 at meteorological station in Bihor County.

At the ***meteorological station level*** (Table 5), thermal deviations were exemplified for three stations, located in administrative-territorial units where hydro-mineral resources are found. These meteorological stations are located on different landforms, i.e. the Săcueni station is situated in the plain, the Ștei station in the hills and the Stâna de Vale station in the mountains.

Table 5. Temperature deviations at weather stations in Bihor County.

Temperature deviations							
Year	**Săcueni**	**Ștei**	**Stâna de Vale**	**Year**	**Săcueni**	**Ștei**	**Stâna de Vale**
1961	0,30	0,50		1991	-0,8	-0,8	-0,8
1962	-0,60	-0,40		1992	0,3	0,1	-0,2
1963	-0,60	-0,40		1993	-0,5	-0,4	-0,5
1964	-1,30	-1,00		1994	1,3	1,1	0,8
1965	-1,20	-1,10		1995	-0,2	-0,2	-0,5
1966	0,40	0,50		1996	-1.0	-0,6	-0,6
1967	0,20	0,10		1997	-0,8	-0,8	-0,9
1968	0,30	0,10		1998	-0,3	-0,3	-0,6
1969	-0,60	-0,40		1999	0,3	0,2	0,1
1970	-0,50	-0,50		2000	1,4	1,3	0,1
1971	-0,40	-0,40		2001	0,1	0,3	0,1
1972	-0,10	-0,10		2002	1.0	1,2	1.0
1973	-0,70	-0,80		2003	-0,2	-0,1	-0,4
1974	0,00	-0,10		2004	-0,1	-0,1	-0,4
1975	0,10	0,00		2005	-0,6	-0,7	-0,9
1976	-1,10	-1,20		2006	0,2	-0,1	-0,3
1977	-0,40	-0,30		2007	1,5	1,1	0,9
1978	-1,60	-1,40		2008	1,2	1,2	0,6
1979	-0,20	-0,20	0,20	2009	1.0	1,1	0,4
1980	-1,80	-1,50	-1,10	2010	0,2	0,6	0,3
1981	-0,60	-0,60	-0,60	2011	0,2	0,2	-0,1
1982	-0,80	-0,50	-0,60	2012	1.0	0,9	0,5
1983	-0,10	-0,30	-0,30	2013	1.0	1.0	0,6
1984	-0,70	-0,60	-0,80	2014	1,9	1,8	1,6
1985	-1,60	-1,40	-1,30	2015	1,5	1,4	0,9
1986	-0,50	-0,50	-0,70	2016	0,7	0,7	0,3
1987	-0,80	-0,70	-1,00	2017	0,8	0,8	0,6
1988	-0,30	-0,40	-0,50	2018	1,7	1,7	1,2
1989	0,20	-0,20	-0,20	2019	2.0	2.0	1,5
1990	0,50	0,20	0,10	2020	1,1	1,1	1.0

Thus, at the ***Săcueni meteorological station***, over 31 years (which is 51.66% of the cases), the thermal anomalies (deviations) compared to the station's long-term average of 10.7°C were negative, ranging between −0.1°C (in 1972, 1982, and 2004) and −1.8°C (in 1980). It is noteworthy that the majority of years with negative deviations fall between 1976 and 2008 (19 years, 13 of which were consecutive). The positive deviations compared to the long-term average range from 0.1°C (in 1975 and 2001) to 2.0°C (in 2019) (Figure 13).

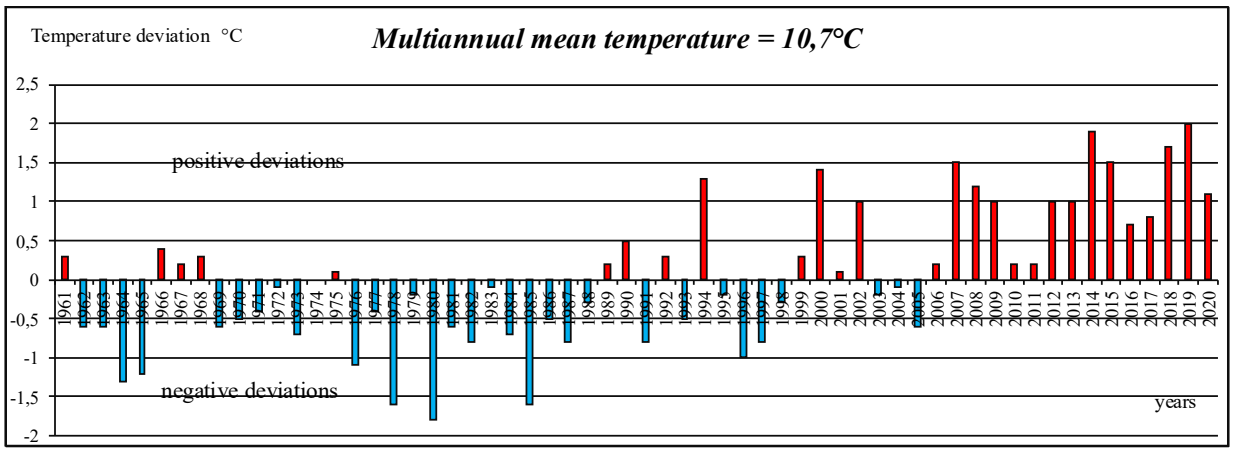


Figure 13. Deviation of annual average temperature from the multiannual mean of 10.7°C between 1961 and 2020 at the meteorological station Săcueni.

At the ***Ştei meteorological station***, over 25 years (41.67% of the cases), the thermal anomalies (deviations) compared to the station's long-term average of 10.1°C were positive, ranging between 0.1°C (in 1967, 1968, and 1992) and 2.0∘C (in 2019).

The negative deviations followed a similar pattern to those at the Săcueni station. In 35 years (58.33% of the cases), the thermal anomalies were negative, ranging from −0.1°C (in 1972, 1974, 2003, 2004, and 2006) to −1.5°C (in 1980). A notable point here is also the consecutive run of 14 years (1976 – 1989) with negative deviations (Figure 14).

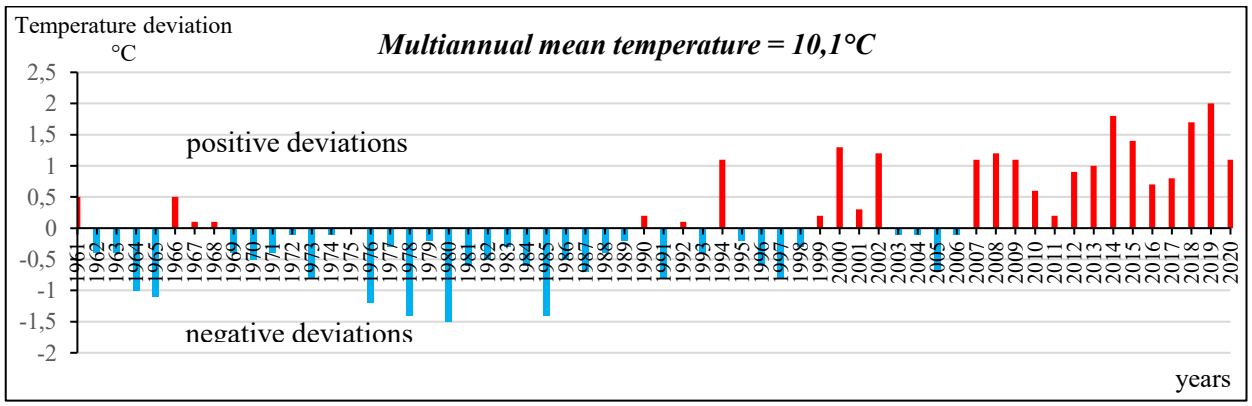


Figure 14. Deviation of annual average temperature from the multiannual mean of 10.1°C between 1961 and 2020 at the meteorological station Ştei.

At the ***Stâna de Vale meteorological station***, the observation series is shorter (42 years) because the station was only established in 1979. The altitude subtly influences the annual thermal regime, as 22 years (52.38% of the cases) recorded negative thermal anomalies (deviations) compared to the long-term average of 4.4°C. However, the range of these deviations is no greater than that of the Ştei and Săcueni stations, which are located at much lower altitudes, oscillating between −0.1°C (in 2011) and −1.3°C (in 1985). The range for the positive deviations spans between 1.6°C (in 2014) and 0.1°C (in 1990, 1999, 2000, and 2001) (Figure 15).

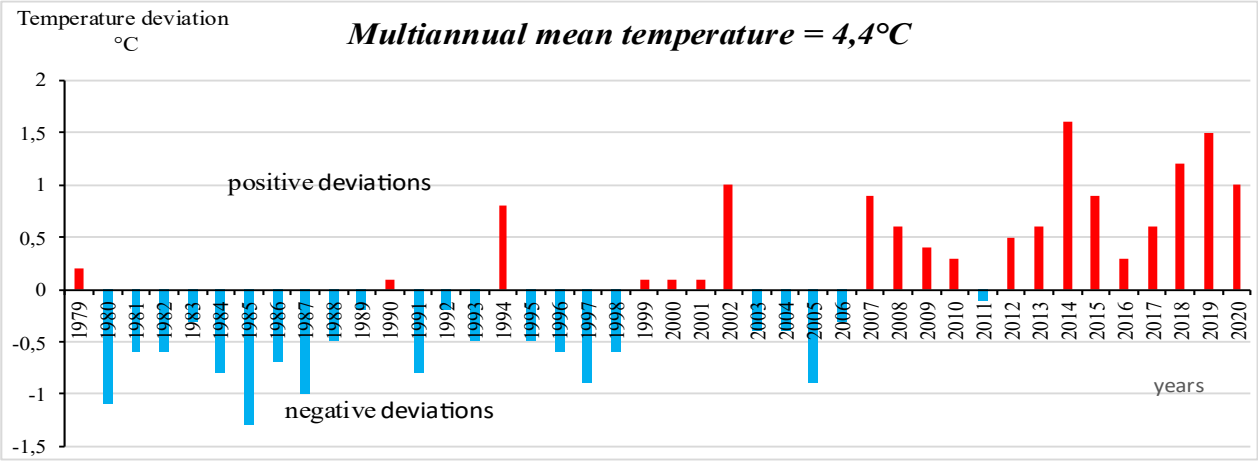


Figure 15. Deviation of annual mean temperature from the multiannual mean of 4.4°C in the interval 1961 - 2020 at Stâna de Vale meteorological station.

Applying certain thermal thresholds for deviations (Gaceu, 2001), *the Hellman criterion* was used to classify the years in Bihor County, and at three stations representative across major relief units (Săcueni, Ştei and Stâna de Vale).

Thus, according to the *Hellman criterion,* in Bihor County: **22%** of the years are classified as cool years, with temperature deviations ranging between -0.6...-1.0˚ C; The majority of years (**45%)** fall into the category of thermally normal years, showing deviations from the multi-year average in the range of 0.5... - 0.5˚C; **10%** of years fall into warm years category (thermal deviations range between 1.0 and 0.6˚C); **10%** of the years are considered cold years (with deviations between -1.0 and -2.0˚); **13%** of years are classified as very warm years (deviations range between 1.1˚C and 2.0˚C); **10%** of years are considered very cold years (deviations ranging between -1.0...-2.5˚C) (Table 6).

From the thermal point of view, for the analyzed area there are no very warm or excessively warm years, but neither very cold or excessively cold years (Figure 16).

Table 6. Thermal character of the years according to the Hellman criterion in the interval 1961 to 2020 in Bihor County.

Hellman's thermal classification	Extremely hot	Very hot	Hot	Warm	Normal	Cool	Cold	Very cold	Extremely cold
Annual average deviations (°C)	**> 5.0**	***5.0... 2.1***	***2.0... 1.1***	***1.0... 0.6***	***0.5... -0.5***	**-0.6...-1.0**	***-1.1...-2***	***-2.1...-3***	***< -3.0***
			2000	1961	1966	1962	1963		
			2002	1975	1967	1970	1964		
			2007	2012	1968	1976	1965		
			2009	2013	1969	1978	1980		
			2014	2016	1971	1981	1985		
			2015	2020	1972	1984	1987		
			2018		1973	1992			
			2019		1974	1993			
					1977	1994			
					1979	1996			
					1982	1997			
					1983	1998			
					1986	2005			
					1988				
					1989				
					1990				
					1991				
					1995				
					1999				
					2001				
					2003				
					2004				
					2006				
					2008				
					2010				
					2011				
					2017				
%	-	-	**13**	**10**	**45**	**22**	**10**	-	-

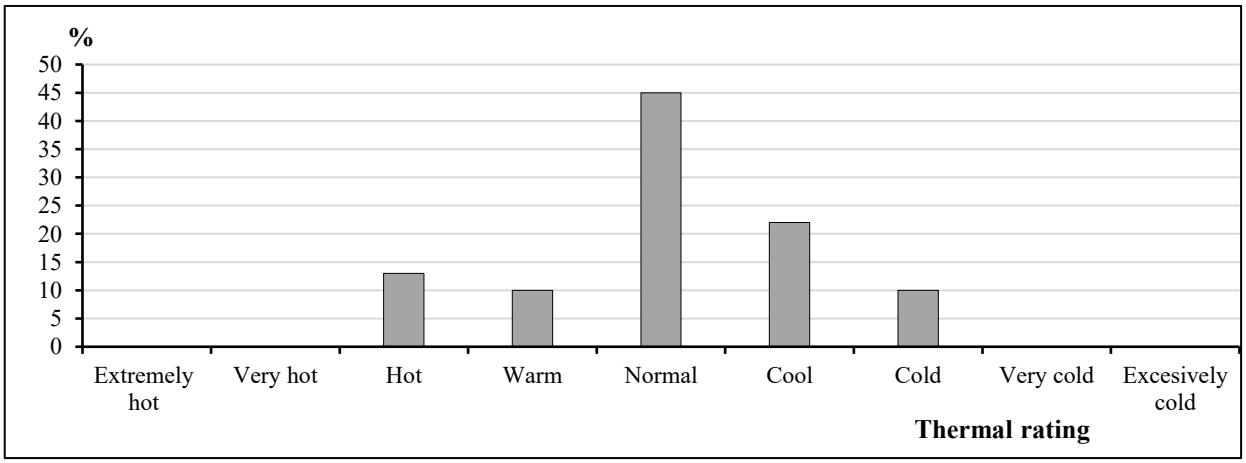


Figure 16. Thermal rating of the years according to the Hellman criterion in the interval 1961 to 2020 in Bihor County.

Following the Hellman criterion applied to the meteorological station Săcueni, the deviations from the station's multi-year average fall between the "warm" and "cold" ratings (Table 7).

Table 7. Thermal character of years according to the Hellman criterion at the meteorological station Săcueni between 1961 and 2020.

Hellman's classification	Extremely hot	Very hot	Hot	Warm	Normal	Cool	Cold	Very cold	Extremely cold
Annual mean deviations (°C)	**> 5.0**	***5.0... 2.1***	***2.0... 1.1***	***1.0... 0.6***	***0.5... -0.5***	**-0.6...-1.0**	***-1.1...-2***	***-2.1...-3***	***< -3.0***
			2008 2020	2000 2002 2009 2012 2013	1961 1966 1967 1968 1970 1971 1972 1974 1975 1977 1979 1983 1986 1988 1989 1990 1992 1993 1995 1998 1999 2001 2003 2004 2006 2010 2011	1962 1963 1969 1973 1981 1982 1984 1987 1991 1996 1997 2005	1964 1965 1976 1978 1980 1985 1986		
sum of years	-	-	**2**	**5**	**34**	**12**	**7**	-	-
%			**3,33**	**8,33**	**56,66**	**20,0**	**11,66**		

The largest share of years (56.66%) falls into the category of thermally normal years, with deviations from the long-term average ranging between −0.5°C and +0.5°C.This category is followed, in percentage terms, by cool years (20%) and cold years (11.66%). Warm years account for 3.33%, and hot years for 8.33%. For the Săcueni station, in the 1960–2020 period, there is no noticeable occurrence of either very hot or extremely hot years, nor of very cold or extremely cold years (Figure 17).

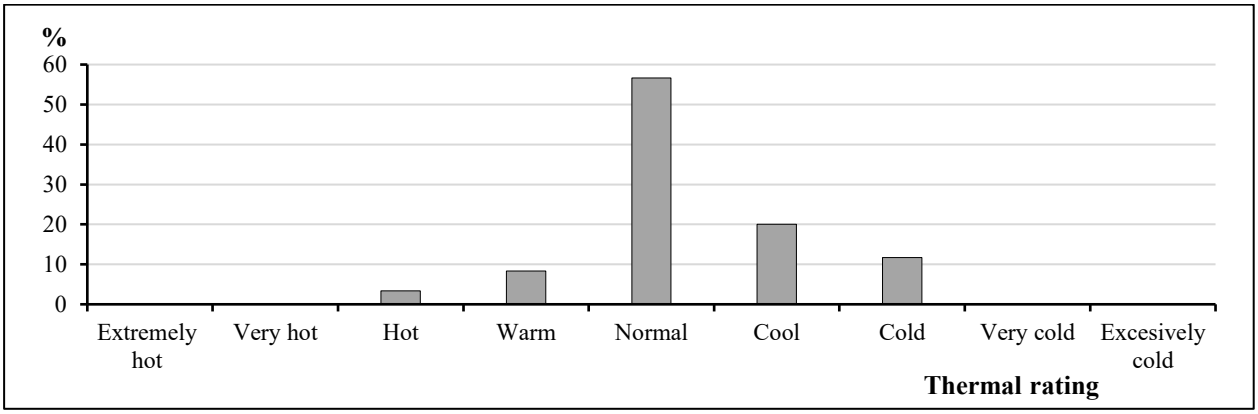


Figure 17. Thermal rating of the years according to the Hellman criterion from the meteorological station Săcueni between 1961 and 2020.

Applying the Hellmann criterion at the Ştei meteorological station, the deviations from the station's long-term average still categorize the years between 'warm' and 'cold' qualifications.

Percentage-wise, the category of thermally normal years represents 56.66% (Table 8). This is followed by the category of **warm years** with 16.66% and the **cool years** with 11.66%. **Hot years** account for 6.66% of the cases, and **cold years** for 8.33% (Figure 18). Furthermore, for the Ștei station in the 1960-2020 interval, there is no noticeable presence of any very hot or excessively hot years, nor any very cold or excessively cold years.

Table 8. Thermal character of the years according to the Hellman criterion at the meteorological station Ștei between 1961 and 2020.

Hellman classification	**Extremely hot**	**Very hot**	**Hot**	**Warm**	**Normal**	**Cool**	**Cold**	**Very cold**	**Extremely cold**
Annual mean deviations (°C)	**> 5.0**	***5.0... 2.1***	***2.0... 1.1***	***1.0... 0.6***	***0.5... -0.5***	**-0.6...-1.0**	***-1.1...-2.0***	***-2.1...-3***	***< -3.0***
			1994 2000 2002 2007 2008 2009 2014 2015 2017 2020	2010 2013 2016 2017	1961 1962 1963 1966 1967 1968 1969 1970 1971 1972 1974 1975 1977 1979 1982 1983 1986 1988 1989 1990 1992 1994 1995 1998 1999 2001 2003 2004 2006 2011	1964 1973 1981 1984 1987 1991 1997	1965 1976 1978 1980 1985		
sum of years	-	-	10	4	34	7	-	-	-
%	-	-	**16,66**	**6,66**	**56,66**	**11,66**	**8,33**	-	-

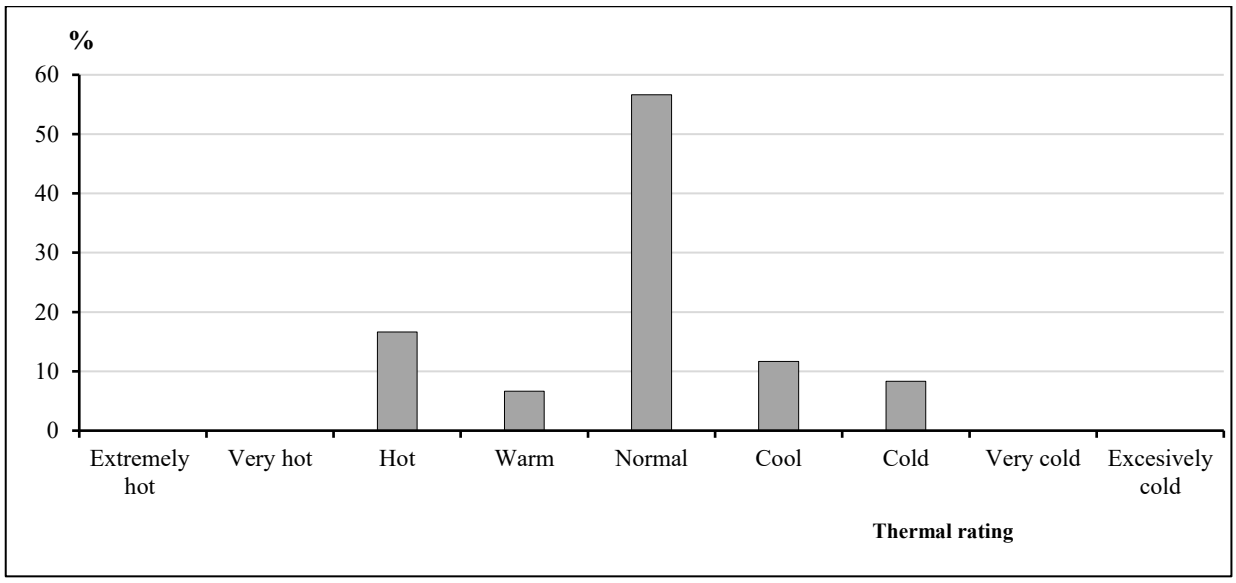


Figure 18. Thermal rating of the years according to the Hellman criterion from the meteorological station Ștei between 1961 and 2020.

At the Stâna de Vale meteorological station, the Hellmann criterion also highlights the predominance of ***thermally normal years***, which account for 45.23% of the cases (Table 9).

Table 9. Thermal character of the years according to the Hellman criterion at Stâna de Vale meteorological station between 1961 and 2020.

Hellman classification	Extremely hot	Very hot	Hot	Warm	Normal	Cool	Cold	Very cold	Extremely cold
Annual average deviations (°C)	**> 5.0**	***5.0... 2.1***	***2.0... 1.1***	***1.0... 0.6***	***0.5... -0.5***	**-0.6...-1.0**	***-1.1...-2***	***-2.1...-3***	***< -3.0***
			2014 2018 2019	1994 2002 2007 2008 2013 2015 2017 2020	1979 1983 1988 1989 1990 1992 1993 1995 1999 2000 2001 2003 2004 2006 2009 2010 2011 2012 2016	1981 1982 1984 1986 1987 1991 1996 1997 1998 2005	1980 1985		
sum of years	-	-	**3**	**8**	**19**	**10**	**2**	-	-
%	-	-	**7,14**	**19,04**	**45,23**	**23,80**	**4,76**	-	-

Following that, the category of hot years accounts for 19.04% and the category of cool years for 23.8%. Warm years represent 7.14% of the cases, and cold years 4.76% (Figure 19). Also for the Stâna de Vale station, in the 1960-2020 interval, there is no noticeable presence of any very hot or excessively hot years, nor any very cold or excessively cold years.

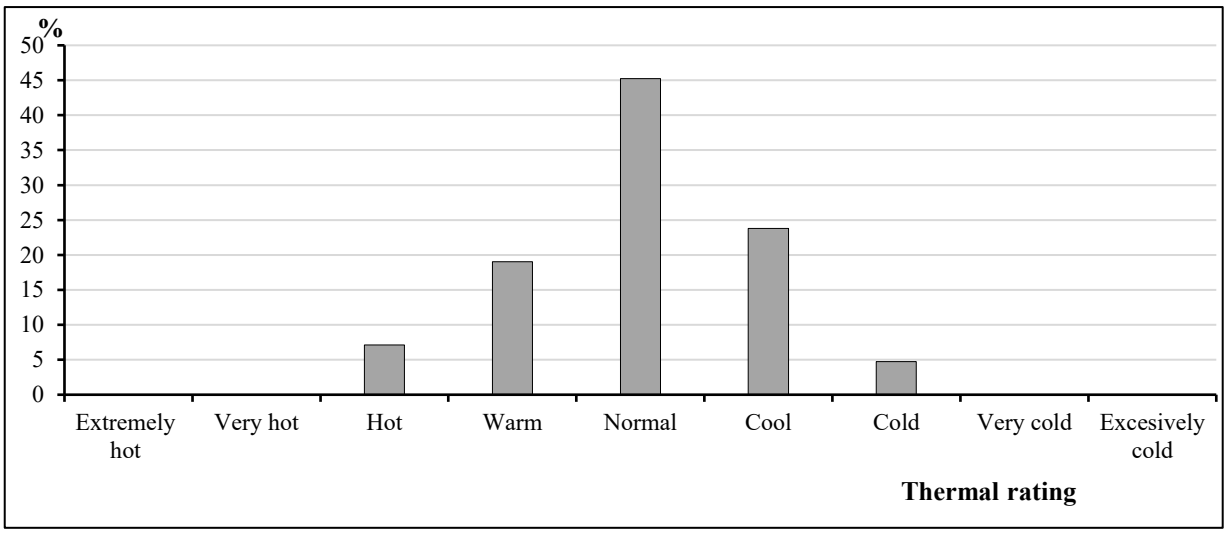


Figure 19. Thermal rating of the years according to the Hellman criterion from the Stâna de Vale meteorological station between 1961 and 2020.

These non-periodic variations are not driven by local factors, but are determined by general causes. The phenomenon occurs on a national scale and is primarily generated by the circulation of air masses with oceanic influences, further moderated by the presence of the mountainous area.

The trend of mean annual temperatures and the standardized temperature anomalies recorded at lowland meteorological stations in Bihor County indicate a gradual warming trend. However, according to Șerban (2010), the rate of temperature increase remains relatively low.

4.5.2. Air humidity characteristics

The moisture content of the air generally emphasizes the character of atmospheric circulation. On the territory of Bihor County, the largest amount of water vapor comes from the advection of moist Atlantic air masses, in addition to local sources represented by watercourses, lake accumulations, soil and plant evapotranspiration and snow cover.

Air humidity is usually characterized by three parameters: water vapour pressure, saturation deficit and relative humidity. Among these, the relative humidity will be analyzed, as it represents the degree of air saturation with water vapor, expressed in percentages. This parameter most accurately reflects the dryness or moisture degree of the air, being an important indicator in characterizing the climatic regime of a region (Șerban, 2010).

The annual moisture regime is inversely corelated with the thermal regime, but is also influenced by local landform characteristics. Therefore, during summer months, when average temperatures are high, relative humidity is lower, while in winter months with lower average temperatures, relative humidity increases (Table 10, Figure 20).

Table 10. Multiannual monthly average relative humidity and multiannual monthly mean temperature between 1961 and 2020.

Parameter \ Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Monthly relative humidity (%)	86	81	75	72	74	74	73	74	78	81	84	87	**78**
Average monthly temperature ($^{(0)}C$)	-1.3	0.7	5.2	10.4	15.2	18.3	19.8	18.6	14.1	9.1	4.1	0.0	**9.5**

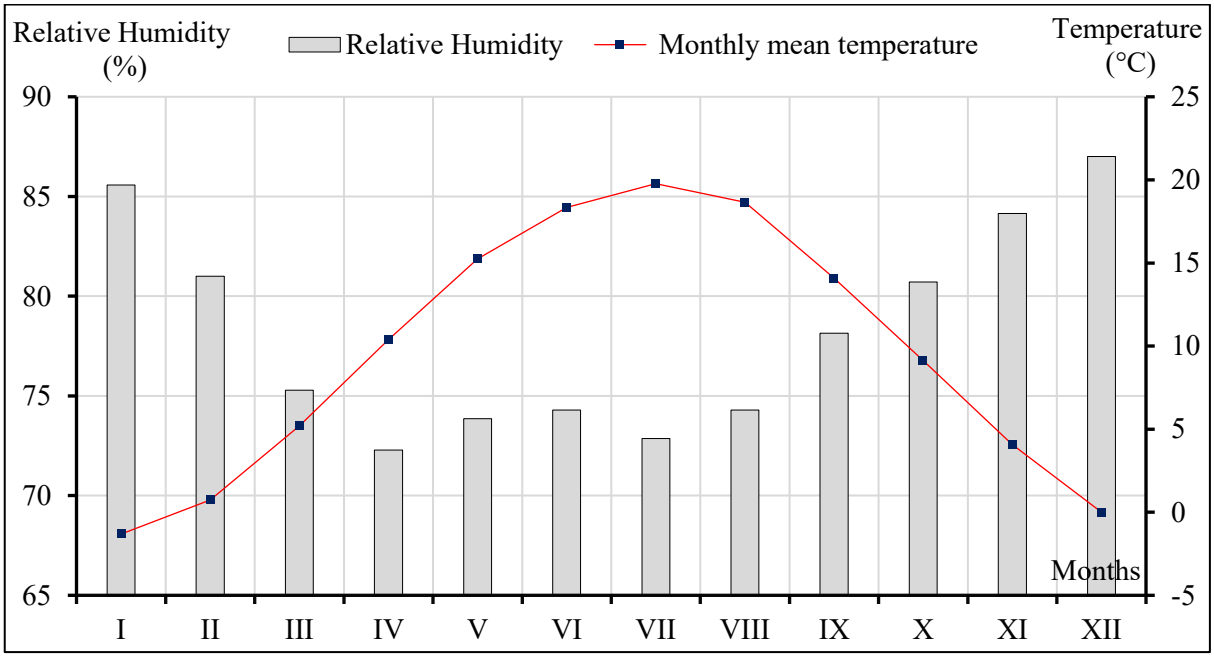


Figure 20. Correlation between relative humidity and air temperature at the meteorological stations in Bihor County during the period 1961–2020.

Throughout the year, average relative air values *peak* in the winter months (82 - 87%) and drop to a *minimum* in April, July and August (74 - 75%).

Table 11. Multiannual monthly relative humidity regime at meteorological stations in Bihor County between 1961-2020.

Weather station \ Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Săcueni	85	81	73	67	68	69	68	70	73	77	82	86	75
Chișineu Criș	89	85	77	72	72	72	70	72	76	80	86	90	78
Oradea	87	83	75	69	70	71	68	69	74	79	84	88	76
Holod	89	84	78	74	76	77	75	76	80	83	86	90	81
Ștei	84	80	74	71	74	75	74	74	78	80	81	85	78
Borod	85	81	75	72	75	76	75	76	80	81	84	86	79
Dumbrăvița de Codru	78	70	65	68	69	66	64	68	72	76	82	82	72
Stâna de Vale	91	88	87	85	85	86	86	87	90	89	90	92	88
Vlădeasa 1800	86	88	88	86	86	87	86	84	86	82	85	87	86

At the meteorological station level, the highest relative humidity values are recorded in the high mountain area, at the Stâna de Vale station (92%). At the Vlădeasa 1800 station located above the cloud ceiling, the air relative humidity does not exceed 89%. In contrast, the lowest air humidity values are observed at the Dumbrăvița de Codru station (65%), situated in the low mountain area. This anomaly is attributed to the accumulation of local conditions which influences the annual regime of all climatic parameters. In the lowland sectors, the lowest monthly average relative humidity is recorded at the stations Săcueni (67%) and Oradea (69%) (Table 11).

4.5.3. Specific features of rainfall regime

The rainfall regime depends on a number of pluvio-genetic factors, such as thermal and dynamic convection, as well as on local physico-geographical conditions. As a general rule, precipitation increases in quantity with elevation.

For the period under consideration (1961-2020), the ***multiannual average precipitation*** at the meteorological stations was ***810.1 mm*** (576 mm at Săcueni, 615 mm at Oradea, 669 mm at Holod, 704 mm at Borod, 745 mm at Dumbrăvița de Codru, 1,656 mm at Stâna de Vale) (Figure 21). At stations located near the county, namely Chișineu Criș it is 571 mm, and at Vlădeasa 1800 it is 1,144 mm.

The geographical position of Bihor County and the complex local topography determine differences in the *territorial distribution of precipitation*. The processes that lead to an increase or decrease in the amount of precipitation are influenced by the relief altitude, the orientation of orographic barriers and the humidity of the air masses. Following the rainfall profile of the stations in Bihor County (correlation altitude - precipitation amount) (Figure 21), the correlation between the increase in the amount of precipitation and altitude is evident, except for the station Vlădeasa 1,800 which is above the condensation level.

In the plains of Bihor County, the ***average annual*** precipitation ***amounts*** were between 570 - 620 mm (at Săcueni and Oradea), in the hills between 670 - 700 mm (at Borod, Ștei, Holod), and in the high mountains between 1,100 – 1,660 mm (at Stâna de Vale and Vlădeasa). Stâna de Vale had the highest annual precipitation in 1,981 (2,113 mm), being considered a precipitation pole in the country. In the middle mountains (at the meteorological station Dumbrăvița de Codru) the precipitation was about 750 mm.

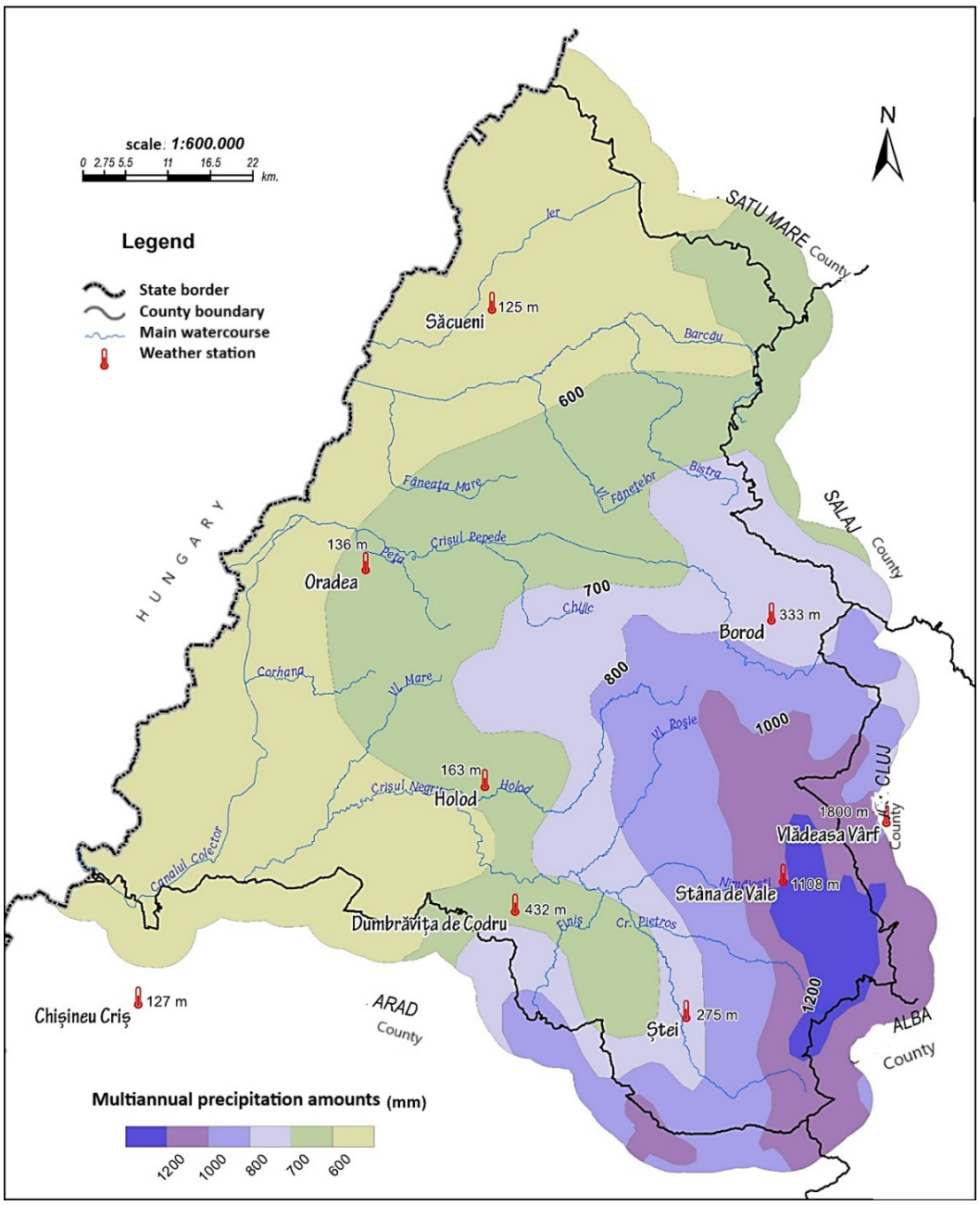


Figure 21. Multiannual average rainfall in Bihor County. Isohyets' distribution.

(based on The Climate of Romania, 2008, National Meteorological Agency)

The non-periodic variability of *annual rainfall* is dependent on the general atmospheric circulation. Tracking the time evolution of annual rainfall values over time shows that they vary considerably from year to year.

The highest annual rainfall exceeded 1000 mm and fell in 1974, 1985, 1995, 1995, 1998, 1999, 2001, 2003, 2004, 2005, 2006, 2007, 2016, 2018. The maximum annual precipitation was 2113 mm (in 1981 at the Stâna de Vale station). The lowest precipitation amounts were recorded at Dumbrăvița de Codru meteorological station with 358.6 mm in 2011 and at Săcueni meteorological station with 363.1

mm in 1986. Similay, low precipitation amounts, ranging between 360 and 500 mm, were registered in the years 1971, 1972, 1973, 1975, 2000, 2009, 2012, and 2015.

The highest and lowest precipitation amounts are accidental and can only occur in certain synoptic situations. The annual precipitation oscillations can be shown by deviations means.

The largest negative deviations with a *deficit of precipitation* compared to the multiannual average, highlight the dry years and were recorded in 1961 with -318 mm (only three meteorological stations were operating in Bihor County), then in 1971 (-209 mm), 1973 (-202 mm), 1990 (-190 mm), 2000 (-256 mm), 2011 (-194 mm).

The positive deviations with *precipitation surplus* above the multiannual average characterize *wet years* and were recorded in 1980 (+291.9 mm), 1995 (+14127.8 mm), 1998 (+147.3 mm), 1999 (+130 mm), 2001 (+275.69 mm), 2004 (+198.4 mm), 2005 (+128.0 mm).

At the ***meteorological station level***, we exemplify the rainfall deviations at three stations, located in administrative-territorial units where several hydromineral resources are found. These meteorological stations are situated on the major relief levels, namely Săcueni station in the plain area, Ștei station in the hilly area, and Stâna de Vale station in the mountainous area (Table 12).

Table 12. Rainfall deviation at weather stations Săcueni, Ștei, Stâna de Vale between 1961-2020.

Rainfall							
Year	**Săcueni**	**Ștei**	**Stâna de Vale**	**Year**	**Săcueni**	**Ștei**	**Stâna de Vale**
1961	-31.6	-31.3		1991	-4.8	2.2	-15.0
1962	11.4	-4.1		1992	-22.2	-20.6	-17.6
1963	12.1	-8.8		1993	-16.2	-6.2	-4.7
1964	15.7	20.2		1994	-29.4	-14.9	-17.8
1965	22.7	16.8		1995	1.3	18.6	34.1
1966	33.4	13.2		1996	38.5	6.9	2.7
1967	-7.1	-10.9		1997	6.9	-4.4	10.9
1968	-8.3	9.9		1998	26.5	10.0	10.2
1969	-1.8	9.3		1999	16.2	22.0	-7.2
1970	15.5	32.1		2000	-32.1	-36.8	-18.8
1971	-20.7	-20.9		2001	27.9	48.1	25.8
1972	-21.0	-13.6		2002	-2.3	-13.2	6.0
1973	-34.6	-11.8		2003	-11.9	-1.2	-24.9
1974	39.7	26.5		2004	42.9	28.9	13.4
1975	-27.0	-21.3		2005	14.7	31.0	13.8
1976	3.2	-20.3		2006	2.8	15.9	14.2
1977	3.0	12.5		2007	8.5	1.6	10.0
1978	18.1	11.8		2008	26.7	-10.2	14.2
1979	17.8	-0.4	10.1	2009	-17.7	-19.2	10.0
1980	34.5	21.0	43.1	2010	36.3	8.5	-19.5
1981	6.1	-2.4	27.6	2011	-36.9	-19.1	8.0
1982	-10.2	-26.2	0.7	2012	-31.4	4.7	-9.2
1983	-20.8	-24.5	-24.1	2013	-12.2	8.4	0.8
1984	4.8	-8.5	3.7	2014	-7.6	-6.6	-10.2
1985	-1.5	-18.1	-1.9	2015	-14.9	-6.9	-2.3
1986	-37.0	-15.4	-13.8	2016	20.8	20.5	-6.5
1987	0.2	-15.8	-23.5	2017	-6.7	20.8	-11.5
1988	-7.2	-8.8	-2.3	2018	-7.6	14.8	3.2
1989	-3.8	-1.1	-7.7	2019	-7.6	-5.5	7.6
1990	-25.2	-21.8	-21.8	2020	10.7	14.5	-9.6

Thus, at the ***Săcueni meteorological station***, in 32 years (53.3% of the cases), the rainfall deviations from the station's multiannual average of 576.4, were negative (with rainfall deficit), ranging from -37 mm (in 1986) to -1.8 mm (in 1969). Note that between 2011 and 2019 there was a

succession of rainfall deficit years. The positive rainfall deviations (with excess rainfall) are part of a range between 0.2 mm (in 1987) and 42.9 mm (in 2004) (Figure 22).

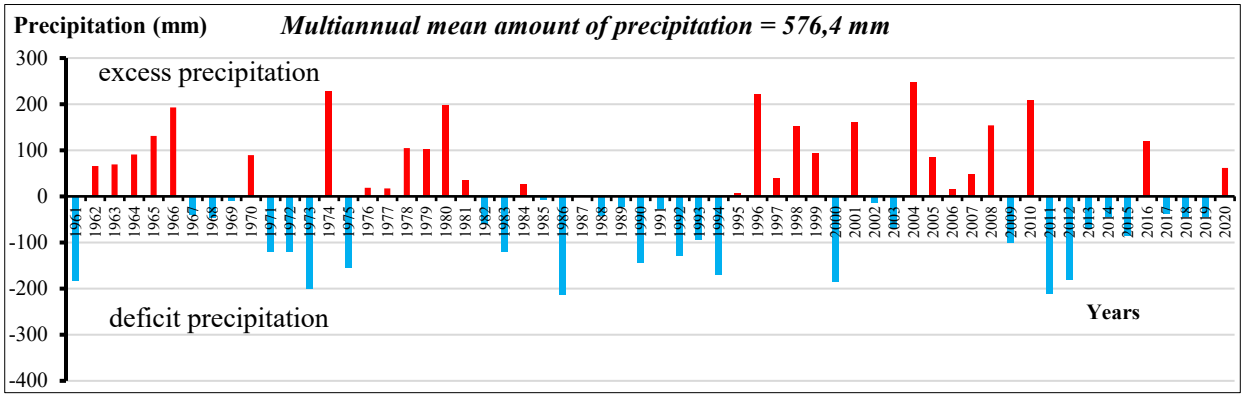


Figure 22. Săcueni meteorological station. Deviation of the annual average precipitation from the multiannual average of 576.4 mm between 1961 and 2020.

At the ***Ștei meteorological station,*** in 26 years (43.3% of the cases), the rainfall deviations from the station's multiannual average of 704.8mm, were positive (with excess precipitation), ranging from 1.6mm (in 2007) to 48.1mm (in 2001). The negative (rainfall deficit) deviations are part of a range between -0.4mm (in 1979) and -36.8mm (in 2000) (Figure 23).

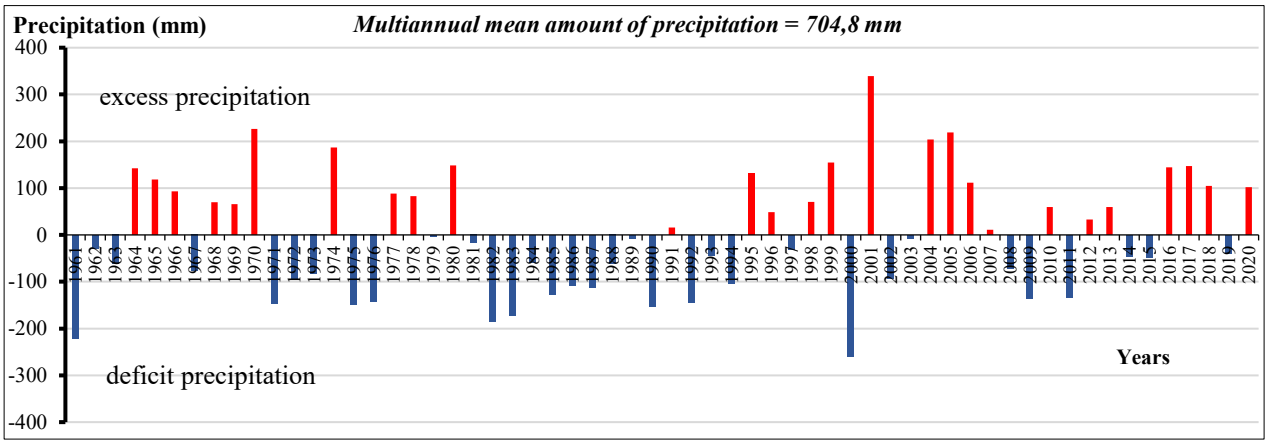


Figure 23. Ștei meteorological station. Deviation of annual average precipitation from the multiannual average 704,8 mm between 1961 and 2020.

At the ***Stâna de Vale meteorological station,*** in 21 years (50% of the cases), the rainfall deviations from the station's multiannual average of 1556.6 mm, were negative (rainfall deficit), ranging from -24.9 mm (in 2003) to -1.9 mm (in 1985). The positive (excess rainfall) deviations ranged from 0.7 mm (in 1982) to 43.1 mm in 1980 (Figure 24).

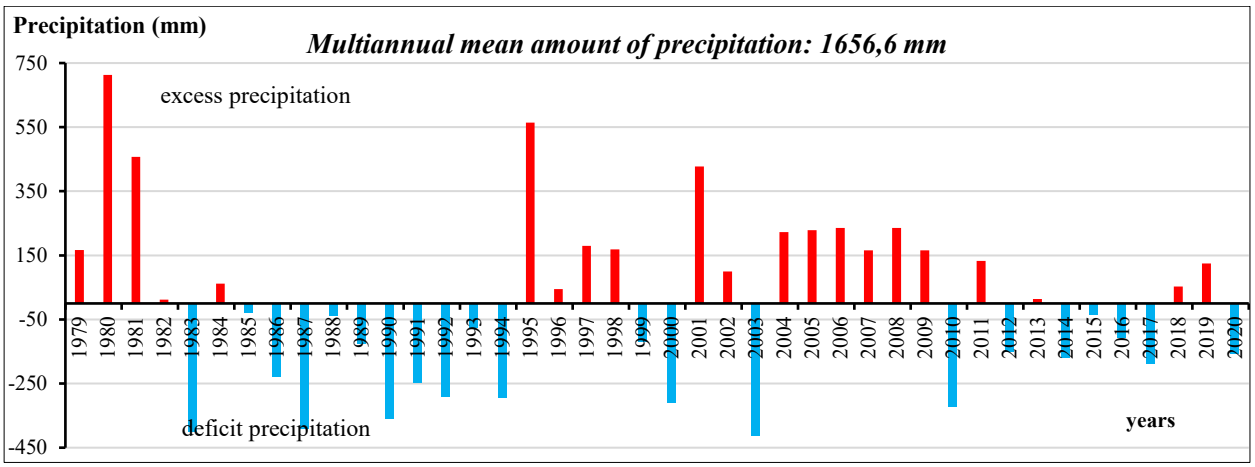


Figure 24. Stâna de Vale meteorological station. Deviation of the annual average precipitation from the multiannual mean of 1656,6 mm between 1961 and 2020.

Using certain thresholds of rainfall deviations (Gaceu, 2001), *the Hellman criterion* was applied for Bihor County, but also for the three stations representative for the major relief units of the county: Săcueni, Ștei and Stâna de Vale.

The classifications that describe the years from a pluviometric perspective cover the entire range, from excessively rainy years (1961, 1980, 2001) to excessively dry years (1971, 2000). The ***"normal"*** rainfall rating accounts for 22% of the years in the data set. This is followed by the category of moderately dry years accounting for 13% of the total and very rainy and moderately rainy years each accounting for 8% of the total (Figure 25).

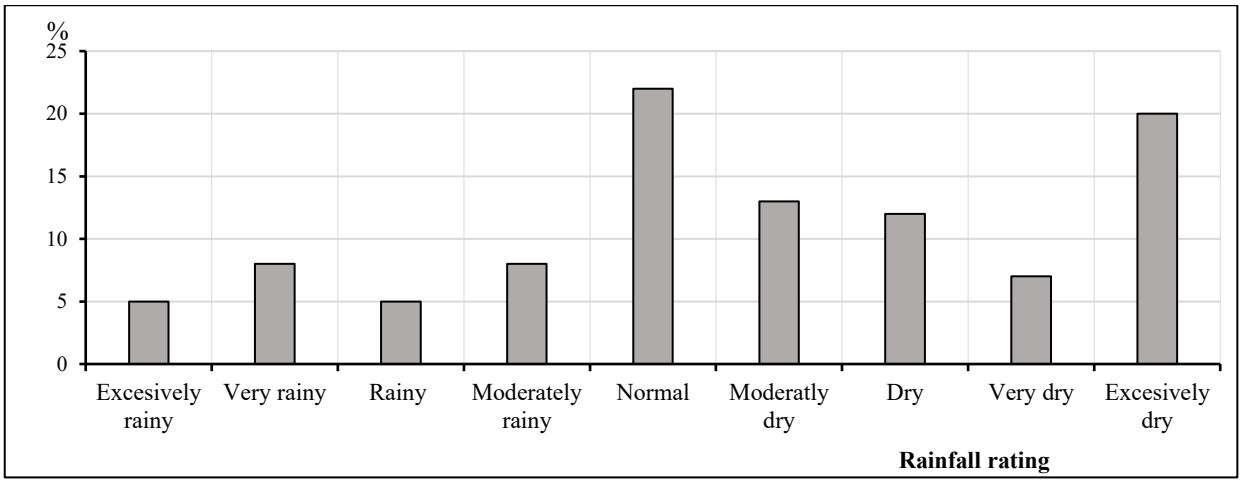


Figure 25. Rainfall rating of years by Hellman criterion at meteorological stations in the interval 1961 - 2020 in Bihor County.

Applying the standardized precipitation anomaly method for the Western Plain north of the Mureș River (in Bihor County, the stations Săcueni, Oradea, and others that are no longer operational), Șerban (2010) mentions the years 1961, 2000 as extremely dry. According to the

standardized rainfall analysis method applied to the plains of Bihor County, the rainiest years were 1974, 1980, 1981, 1998, 1999. The author also draws attention to the fact that hazardous climatic phenomena caused by *excess rainfall* can occur at precipitation amounts above 650 - 800 mm.

Following *the Hellman criterion* applied to the ***Săcueni meteorological station***, the rainfall deviations from the station's multi-year average values include the whole range of rainfall ratings from "extremely wet" to "extremely dry" (Table 13).

Table 13. Săcueni meteorological station. Rainfall character of the years according to Hellman criterion between 1961 and 2020.

Hellman rainfall classification	**Extremely wet**	**Very wet**	**Wet**	**Moderatel y wet**	**Normal**	**Moderately dry**	**Dry**	**Very dry**	**Extremely dry**
Annual mean deviation (%)	***> 20***	***15.1...20.0***	***10.1... 15.0***	***5.1...10***	***-5.0...+5.0***	***-10.0...-5.1***	***-15.0....-10.1***	***-20.0...-15.1***	***< -20***
Year	1966 1974 1980 1996 1998 2001 2004 2008 2010	1965 1970 1978 1979 1999	1962 1963 1964 2005 2020	1981 1997 2007	1969 1976 1977 1984 1985 1987 1989 1991 1995 2002 2006	1967 1968 1982 1988 2014 2017 2018 2019	2003 2013 2015	1993 2009	1961 1971 1972 1973 1975 1983 1986 1990 1992 1994 2000 2011 2012 2016
%	**15**	**9**	**9**	**5**	**18**	**13**	**5**	**3**	**23**

Therefore, most of the years (23%) fall into the category of **extremely dry years**, with deviations from the multiannual average of < -20 %. Years with normal rainfall, in the range -5.0... +5.0%, account for 18% of the cases. Excessively rainy years account for 15%, rainy and very rainy years for 9% each, and moderately rainy and dry years represent 5% each (Figure 26).

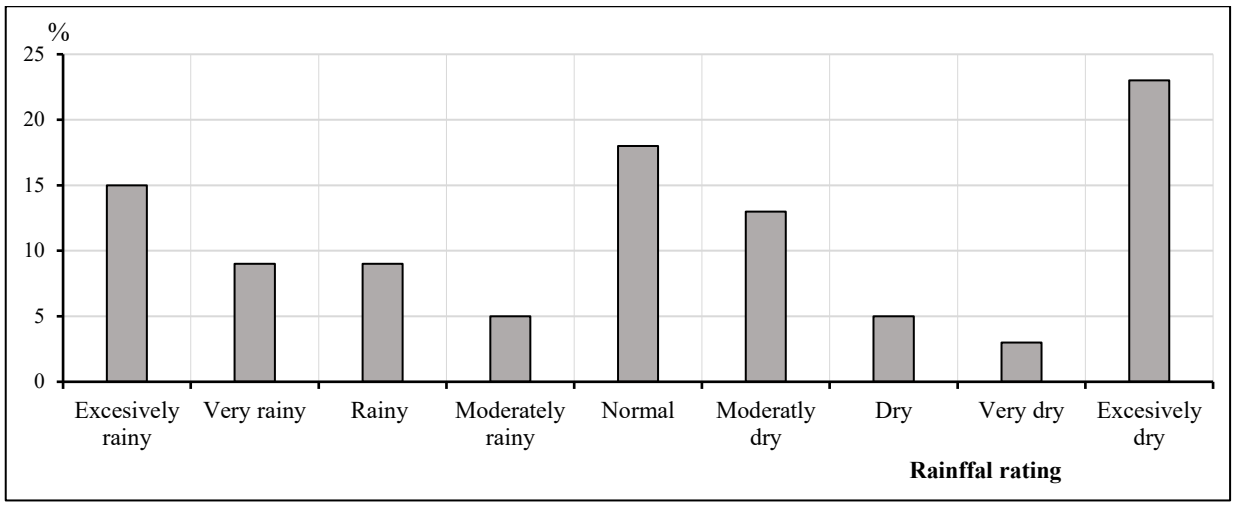


Figure 26. Rainfall rating of years according to the Hellman criterion at the meteorological station Săcueni between 1961 and 2020.

According to the *Hellman criterion* applied for the meteorological station Ștei, the rainfall deviations from the station's multiannual average include the entire range of rainfall ratings from "extremely wet" to "extremely dry" (Table 14).

Table 14. Ștei meteorological station. Rainfall character of the years according to Hellman criterion between 1961 and 2020.

Hellman rainfall classification	**Extremely wet**	**Very wet**	**Wet**	**Moderately wet**	**Normal**	**Moderately dry**	**Dry**	**Very dry**	**Extremely dry**
Annual mean deviation (%)	***> 20***	***15.1...20.0***	***10.1... 15.0***	***5.1...10***	***-5.0...+5.0***	***-10.0...-5.1***	***-15.0...-10.1***	***-20.0...-15.1***	***< -20***
Year	1964 1970 1974 1980 1999 2001 2004 2005 2016 2017	1965 1995 2006	1966 1977 2018 2020	1968 1969 1978 1996 1998 2010 2013	1962 1979 1981 1989 1991 1997 2003 2007 2012	1963 1984 1988 1993 2014 2015 2019	1967 1972 1973 1994 2002 2008	1985 1986 1987 2009 2011	1961 1971 1975 1976 1982 1983 1990 1992 2000
%	**17**	**5**	**7**	**11**	**15**	**12**	**10**	**8**	**15**

Most of the years (17%) fall into the category of **extremely wet years**, with deviations from the multiannual average being >-20%. Years with normal rainfall, whose values range between -5.0 and +5.0%, account for 15% of the number of cases, with the same percentage of the number of cases (15%) in the extremely dry years category. Moderately dry years account for 12%, moderately wet years for 11%, very dry years for 8% and wet years for 7% (Figure 27).

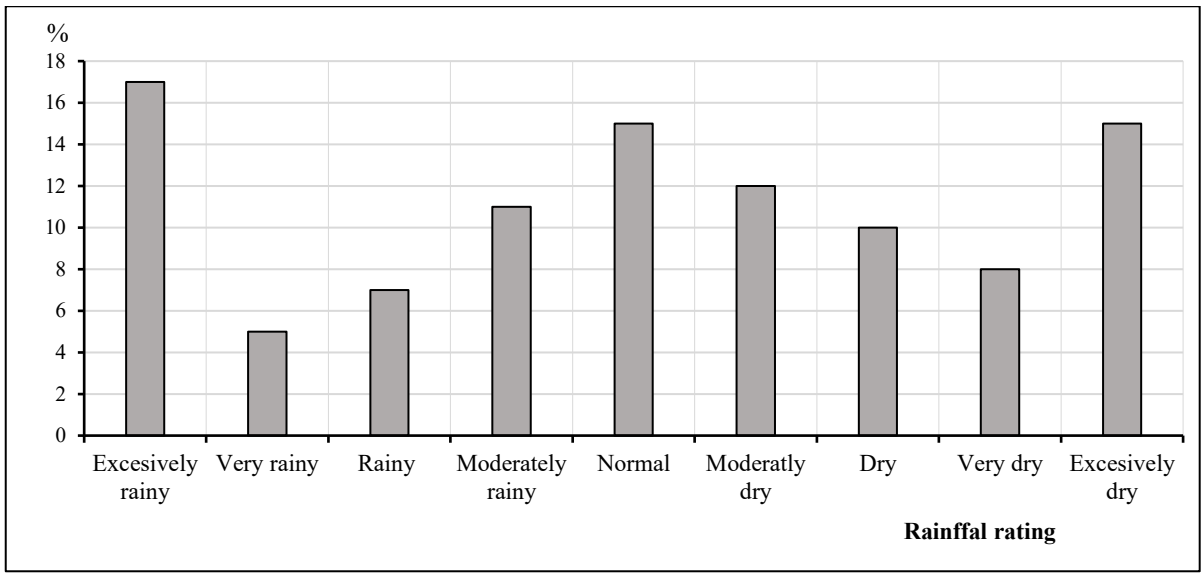


Figure 27. Rainfall rating of the years according to the Hellman criterion at the meteorological station Ștei between 1961 and 2020.

According to the *Hellman criterion* applied to the meteorological station Stâna de Vale, again the rainfall deviations from the station's multi-year average include the whole range of rainfall ratings from "extremely wet" to "extremely dry" (Table 15).

Table 15. Stâna de Vale meteorological station. Rainfall character of the years according to the Hellman criterion between 1961 and 2020.

Hellman rainfall classification	**Extremely wet**	**Very wet**	**Wet**	**Moderately wet**	**Normal**	**Moderately dry**	**Dry**	**Very dry**	**Extremely dry**
Average annual deviation (%)	***> 20***	***15.1...20.0***	***10.1... 15.0***	***5.1...10***	***-5.0...+5.0***	***-10.0...-5.1***	***-15.0....-10.1***	***-20.0...-15.1***	***< -20***
Year	1964 1970 1974 1980 1999 2001 2004 2005 2016 2017	1965 1995 2006	1966 1977 2018 2020	1968 1969 1978 1996 1998 2010 2013	1962 1979 1981 1989 1991 1997 2003 2007 2012	1963 1984 1988 1993 2014 2015 2019	1967 1972 1973 1994 2002 2008	1985 1986 1987 2009 2011	1961 1971 1975 1976 1982 1983 1990 1992 2000
%	**9**	**0**	**17**	**12**	**21**	**12**	**7**	**12**	**10**

At Stâna de Vale, most of the years (21%) belong to the category of **normal rainfall years** in the range of -5.0 and +5.0%, followed by rainy years with 17% and moderately dry and very dry years with 12% each (Figure 28).

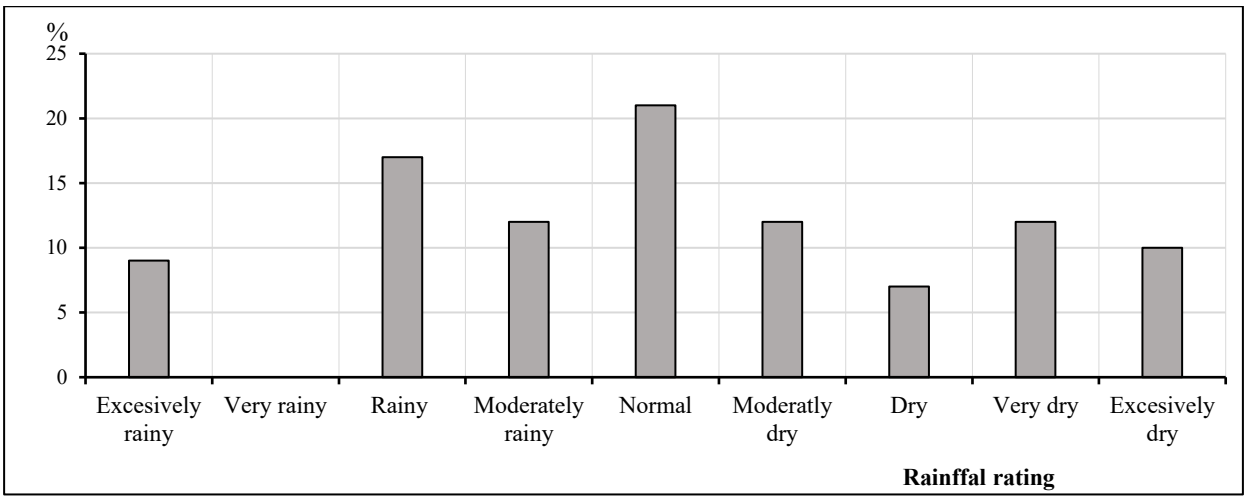


Figure 28. Rainfall rating of the years according to the Hellman criterion at the meteorological station Stâna de Vale between 1961 and 2020.

Analyzing ***the average monthly precipitation amounts***, we can conclude that they have a non-uniform distribution throughout the year, due to the variety of local physico-geographical conditions correlated with the general circulation of air masses.

The average monthly precipitation amounts increase in the lowlands from February to June, and in the mountains from March to July. In Bihor County as a whole, a *rainfall maximum* occurred in the summer, in June (105.4 mm) and a winter *rainfall minimum* in February (45.7 mm). At the meteorological station level, the minimum rainfall was recorded at Săcueni (32.5 mm in February) and at Chișineu Criș (31 mm), and the maximum at Stâna de Vale (165.7 mm in July) (Table 16).

The large amount of precipitation in June and July is caused by the oceanic cyclones advancing along the northern periphery of the Azores Anticyclone, which bring cold and moist air masses, while convective processes – both thermal and dynamic - further destabilized the atmosphere, enhancing rainfall (Gaceu, 2005).

Table 16. Monthly multiannual multiannual precipitation amounts at weather stations in Bihor County in the interval 1961 – 2020.

Weather station / Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Sum
Săcueni	32.5	32	34.2	41.6	58.4	79.8	65.8	54.4	46.3	40.7	44.5	46.2	576
Oradea	35.6	33.2	36.9	46.2	62.5	83.8	72.2	57.2	48.4	43.0	46.2	50.9	616
Holod	40.1	38.1	40.0	53.4	68.2	90.8	74.7	63	55.3	46.4	47.1	52.0	669
Ștei	38.3	37	43.7	57.7	77.6	94.7	84.4	67.8	57.2	47.1	46.4	52.8	705
Borod	35.5	33.1	39.1	54.2	80.2	98.3	87.5	74.9	59.9	48.1	44.4	47.5	703
Dumbrăvița de Codru	46	43.6	48.1	61.0	79.5	96.2	76.0	60.5	68.2	51.8	55.3	59.2	745
Stâna de Vale	119.3	108.9	130.0	143.0	157.3	165.1	165.7	156.7	140.5	122.5	118.8	132.9	1661
Average	50.0	47.0	53.0	65.0	83.0	101.0	89.0	76.0	68.0	57.0	58.0	63.0	**5657 67.6**

At meteorological station level (with the exception of the stations located in the Bihor and Vlădeasa high mountains where altitude has a decisive influence on the amount of precipitation), a great spatial variability was observed regardless of both the major relief units (plain, low hills, low mountains) and the season. During summer, the precipitation varied between 54.4 mm at Săcueni and 98.3 mm at Borod, and in winter it ranged between 32 mm at Săcueni and 59.2 mm at Dumbrăvița de Codru.

By analyzing the *Bagnouls - Gaussen diagram,* based on the correlation between the multiannual average monthly temperature and the multiannual average monthly precipitation, for Bihor County, the dryness of April - October and the wetness of November - March are highlighted, as well as the outline of a secondary maximum of precipitation in December (Figure 29). This maximum is related to the intensification of the Icelandic Depression which reaches its maximum development in December (Șerban, 2010).

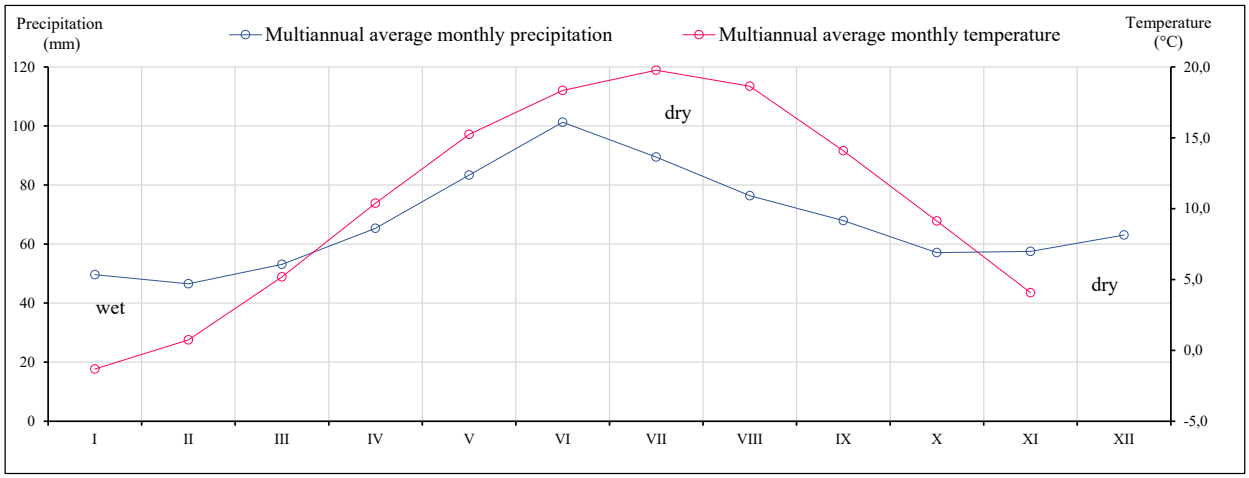


Figure 29. Bagnouls - Gaussen diagram for meteorological stations 1961 - 2020.

Applying the standardized precipitation anomaly method for each month of the year, Șerban (2010) noticed that climatic phenomena caused by *the precipitation deficit* in the Western Plain north of Mures, can occur in any month of the year and have a higher intensity in December, April, June and August. Likewise, extreme climatic events due to *rainfall surplus* can occur in any month of the year, but are most intense in October, February and March at monthly precipitation amounts above 50 - 160 mm.

4.5.4. Snow cover

Snow cover forms when ground temperature remains below 0°C. In the Crișuri Plain and the Western Hills, snow cover tends to appear only in patches, with an average of 21 to 32 *snowy days per year.* Due to the increase in air temperature, there is a tendency for a decline in the number

of snowy days - by approximately 10 days - and an increasing frequency of extreme events, such as *late spring or early fall snowfalls*, which now tend to occur later than the historical average. However, this situation of a lag and an increase in the frequency of extreme events is also noticeable in the mountain area.

The number of *days with snow cover* varies between 40 and 41 days in Oradea and between 150 and 180 days in the mountains, where the slope exposure is a key factor – snow persists longer on the north-facing slopes. Average snow cover thickness is between 20 and 30 cm in the plain and over 51 cm in the mountainous area (Bradu et al., 2010).

4.5.5. Characteristics of the wind regime

The horizontal air mass movements (winds) are determined by the general circulation of the atmosphere, influenced by the action of the main baric centers, while the vertical unfolding of the relief and the latidudinal or longitudinal orientation of the mountain ranges, imprint regional wind characteristics, by altering its speed, frequency and thermal properties. The Carpathian mountain range act as a barrier to air masses and atmospheric fronts, modifying both their direction thermodynamic characteristics throughout the year (Clima R. P. Romîne, 1962).

In the Western Plain, in the lower troposphere, the most frequent annual wind direction are north (9 - 16%) and south (8 - 16%) (Berindei et al., 1972; Șerban, 2010), but this pattern can be different from season to season. A similar pattern is observed in the Western Hills, due to their low altitudes. However, in the high mountain massifs (Bihor - Vlădeasa), the air circulation is more aligned with the general atmospheric movement typical of temperate latitudes, with westerly winds dominating (frequency of about 40%) (Gaceu, 2005).

Regarding average wind speed by direction, in the lowlands, southerly winds speed ranges between 3.3 and 6.9 m/s, being lower for the other directions (Șerban, 2010).

The overall average wind speed in Bihor County is 2.5 m/s. During the year, the highest multiannual average wind speeds are between 2.9 m/s occur in February and 3.0 m/s in March (Table 17), attributed to high temperature-pressure contrasts. The lowest average wind speeds are recorded in August (2.0 m/s).

Table 17. Multiannual monthly wind speed regime at analyzed meteorological stations between 1961 and 2020.

Months / Meteorological station	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual average
Săcueni	2.4	2.7	3.0	2.7	2.4	2.0	1.8	1.5	1.8	2.0	2.5	2.5	2.3
Oradea	3.1	3.4	3.6	3.4	3.1	2.8	2.6	2.4	2.6	2.7	3.1	3.1	3.0
Holod	1.9	2.2	2.7	2.6	2.4	2.2	2.1	1.9	1.9	2.0	2.0	1.9	2.1
Ștei	2.2	2.2	2.2	2.2	2.0	1.9	1.9	1.8	1.9	2.1	2.3	2.1	2.1
Borod	1.3	1.6	2.0	2.0	1.6	1.5	1.4	1.3	1.4	1.5	1.5	1.5	1.5
Dumbrăvița de Codru	1.8	1.8	1.8	1.6	1.4	1.3	1.3	1.6	1.6	1.8	1.7	1.6	1.6
Stâna de Vale	0.5	0.6	0.7	0.7	0.6	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6

At the meteorological station in *Oradea,* between December and May, high average wind speeds (3.1...3.6 m/s) were recorded, favored by the open topography of the Crișuri Plain, where air masses are allowed to circulate freely, and at *Stâna de Vale* the lowest speeds (below 1.0 m/s) (Figure 30). Here the station is known for the high frequency of cases of atmospheric calm (more than 75% of the cases) and low wind speeds (0.8 m/s) (Gaceu, 2005), due to the Stâna de Vale depression location, surrounded by mountain peaks with 200-400 m higher. At the Vlădeasa meteorological station, the highest average wind speeds also occurred during winter and spring and ranged between 6.2...8.7 m/s.

The low summer wind speeds can be explained by the persistence of the anticyclonic regime.

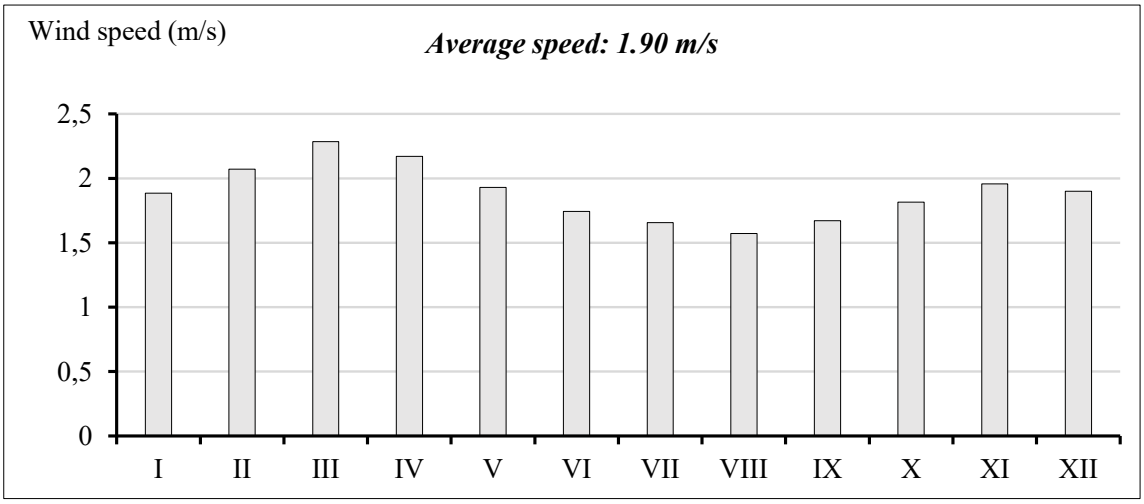


Figure 30. Multiannual monthly wind speed regime in Bihor County 1961-2020.

At the contact area between the plains and the hills there is a *breeze-type circulation*, which can also be seen along the valley corridors (the Geography of Romania, 1992). But this occurs mainly in the mountainous area in the form of mountain breezes.

4.5.6. Climatic risk phenomena

For Bihor County, this category of phenomena has been studied in detail by Cristea (2004) for the Crișuri basin, Gaceu (2005) for the Bihor and Vlădeasa mountains and Șerban (2010) for the Crișuri Plain.

Drought and dryness were more frequent in the lowland and hilly areas, where drought conditions were present annually. On average, there were four dry spells per year, each lasting approximately 16 days, amounting to nearly two months without rainfall. In addition to these

droughts, dry days occur about three months per year. In the Western Plains and Hills there is a cumulative precipitation deficit for about five months of the year.

According to Șerban (2010), the analysis of linear trends in standardized precipitation anomaly values and the Péguy-type climatograms shows that winters and springs have become increasingly dry in recent years. Moreover, the standardized precipitation index suggests that the occurrence of intense long-lasting droughts is linked primarly to general atmospheric circulation, rather than local factors.

Heavy rainfall events vary depending on altitude, the relief's orientation relative to moist advections from the west and local conditions. The months in which heavy rainstorms occur are from May to September, peaking in June and July. The highest mean maximum intensities of these rainstorms occurred in depressional areas, often generating large water volumes. In the mountainous areas, rainfall exceeded 10 mm per minute, a value also recorded at the Oradea meteorological station (for the plains, the average is 5-6 mm/min).

In the Western Plains, the standardized precipitation anomaly analysis revealed that the early and mid-autumn and mid-summer months have become wetter in recent years. Increased amounts of precipitation contribute to accelerated slope erosion processes and elevates the risk of flooding. The territory of the Crișuri Plain shows medium to high vulnerability to excess precipitation, especially when exceptional precipitation in the mountainous area leads to river overflows.

June is considered the month with the highest risk of ***thunderstorms*** and recorded the maximum number of ***thunderstorm*** (on average, between 35 and 39 thunderstorm days per year in the Western Plain) and ***hail*** cases in the Crișuri Plain and in the mountainous area Bihor - Vlădeasa.

The maximum number of ***thunderstorms*** was recorded in July in the lowland areas (the interval with medium risk of occurrence was August - September and March - April), the Plain of Crișuri being included in the medium and high vulnerability class (between 1 and 4 days with thunderstorms). In the mountainous areas, thunderstorms occurred frequently in the summer months, due to thermo-dynamic convection and the development of Cumulonimbus clouds (Gaceu, 2005; Șerban, 2010).

Between 1991 and 2018, Bihor County experienced two extreme meteorological phenomena, such as ***tornadoes*** that caused material damage: Corbești (Ceica commune) on 03.07.1991[17]. The only study on this extreme phenomenon was carried out by Cristea (2004). This

[17]http://www.rowater.ro/dacrisuri/Documente%20Repository/Directive%20Europene/PLAN%20MANAGEMENT%20DAC/Spatiul%20Hidrografic%20Crisuri/cap11_Aspecte%20cantitative%20si%20schimbari%20climatice_Crisuri%202009s.pdf

event was due to a convective supercell that took place between 15 and 16. At Corbești it had the appearance of a tornado (funnel-shaped vortex), and at Oradea, Sîntandrei, Palota, Tărian, Girișu de Criș there were massive hail falls (sizes between 5 and 8 cm); at Șuncuiuș - Borod on 12.05.05.2007[18] the occurrence and its effects were reported and described only in the mass media; at Nimăiești (Beiuș) on 8.07.2018[19] the whirlwind funnel did not reach the ground surface.

Fog was lowest monthly in the depressions (where fog usually occurs in winter), and the duration of fog persistence was highest in the upper mountain ranges in December.

Ice deposition is represented by frost and **freezing.** Of these, hard frost occurred more frequently, the monthly average number ranged from 0.1 to 2.4 days in low regions and from 15 to 18 days at high altitudes. The maximum duration of ice deposition growth varies between 20 and 60 hours at low altitudes and increases greatly on mountain peaks (e.g. in 1986 at the Vlădeasa meteorological station it reached 460 hours).

4.6. Surface and groundwater hydrology

In Bihor County, the hydrographical characteristics are determined by the surface hydrographical network, groundwater and lake units. The hydrographic network belongs to the catchment area of the Crișuri Basin formed by the rivers Ier, Barcău, Crișul Repede, Crișul Negru and their tributaries which drain the northern, western and southern slopes of the Apuseni Mountains and part of the Western Plain (Ujvari, 1972).

4.6.1. Groundwaters

Groundwater varies widely depending on local conditions (lithology, geological structure, climatic regime, flow characteristics, hydro-remediation works, etc.) Based on the depth, groundwater can be categorized into two types: phreatic waters (near the surface of the ground, without hydrostatic pressure) and deep water (located at greater depths and under hydrostatic pressure) (Figure 31).

[18]https://www.antena3.ro/actualitate/efectele-tornadei-care-a-lovit-bihorul-32382.html; https://www.libertatea.ro/stiri/judetul-bihor-lovit-de-o-tornada-19116

[19]http://stiri.tvr.ro/tornada-in-bihor-la-poalele-muntilor-apuseni-imagini-surprinse-de-un-martor_833285.html#view; https://www.ebihoreanul.ro/stiri/tornada-filmata-in-bihor-la-nimaiesti-142747.html

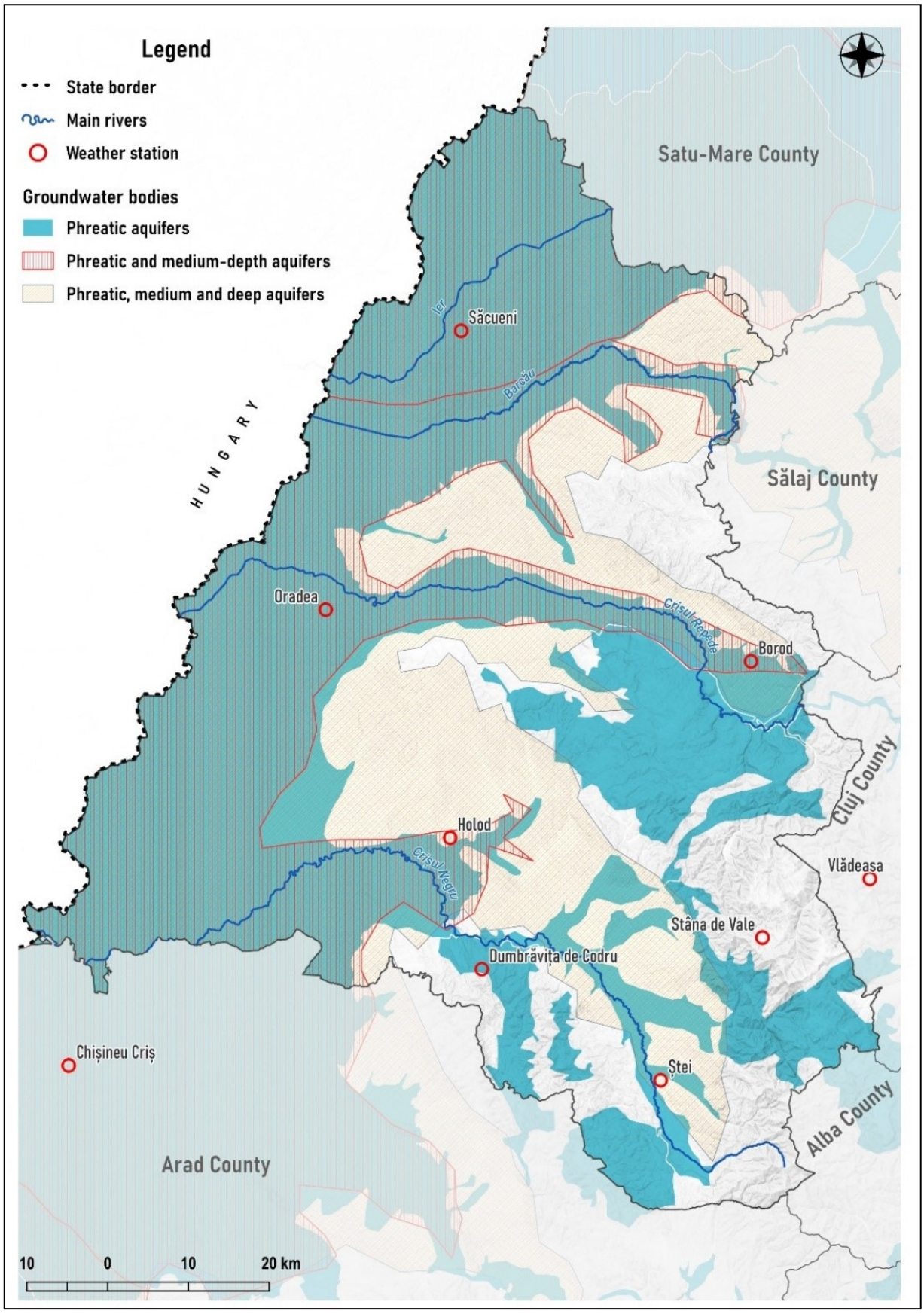


Figure 31. Groundwater in Bihor County.

(source: https://data.europa.eu/en)

In Bihor County, **groundwater aquifers** are primarly found in lowland areas, particularly in the plains, terraces and on the interfluves of the high plains, as well as in the Beiuș Depression and the mountainous area.

The groundwater aquifer of the Crișuri Plain is confined in the Holocene alluvial deposits of alluvial floodplain, low terraces and alluvial cones. The aquifer is composed of several strata separated by pelitic intercalations, but it has a unitary hydraulic character. The flow direction is from east to west, with the exception of the border area between the localities of Valea lui Mihai and Diosig, where the groundwater flow direction is from west to east, being drained to the surface by the Ier Valley. The piezometric level is located at depths ranges from less than 1 m to 2 m in the plains, and reaching depths of up to 15 m on terraces and interfluves. Above the porous permeable horizons, lie hardly permeable or semi-permeable rocks (clays, sandy clays, siltstones, clayey siltstones), so that the piezometric level of the phreatic aquifer has a slightly upward character (www.icpa.ro).

According to their chemical composition, the phreatic of the plain presents two types of water: biocarbonate-chloride-sodium waters spread in the east and center part of the plain and bicarbonate-sulphate-sodium-calcium waters in the west. Shallow waters are not suitable for drinking (Măhăra, 1977).

In the Hills of Crișana, the presence of piedmont deposits and the stepped topography on the periphery of the Apuseni Mountains, determine the existence of groundwater reserves at variable depths ranging from 10 - 15 m depth in the east and 5 - 10 m towards the plains. The water reserves are significantly higher than in the other hilly units of the country due to their position in relation to the Carpathian chain and the stronger influence of oceanic air masses (www.geomorphologyonline.com).

In the Carpathian area, the steep slopes of the relief facilitate intense drainage of water accumulation in the alteration crusts at the base where they emerge as springs.

On the whole, nine groundwater bodies are monitored on the territory of Bihor County, but also in the neighboring counties (Crișuri Basin), distributed as follows: four are in the lowland area: ROCR 01 (Oradea - Western Plain), ROCR 06 Valea lui Mihai (Western Plain), ROCR 07 Crișuri (Western Plain), ROCR 08 (Arad - Oradea - Satu Mare); one is in the Beiuș Depression: ROCR 09 (Beiuș Depression); four are in the mountainous area: ROCR 02 Zece Hotare (Pădurea Craiului Mountains), ROCR 03 Dumbrăvița de Codru-Moneasa (Codru Moma Mountains), ROCR 05 Vașcău (Codru-Moma Mountains); ROSO04 (Bihor - Vlădeasa Mountains) (extending into Someș, Crișuri and Mureș Basins).

Deep groundwaters are confined in aquifer strata under hydrostatic pressure and with an artesian or upward character. In the hills and plains of the Cișuri, deep waters are varied in

structure, hydrochemical composition and temperature. They are related to the Neogene and Quaternary formations of the plains and hills and are absent in the mountainous areas. They have low mineralization and are used for drinking water supply (in Salonta, Beiuș, Diosig, etc.). A particular case is given by the presence of deep waters linked to the fault system affecting the bedrock of the Western Plain. These are confined in the Mesozoic formations at depths of more than 2000 m and emerge at the surface through artesian springs or boreholes. These waters are *mineralized* such as carbonated waters at Tinca, bicarbonated at Tămășeu and Sântimreu, and *thermal waters,* as is the case in Oradea, Băile Felix, Beiuș, Băile 1 Mai, Borș, Tămășeu, Săcueni, Marghita, Chișlaz, Mădăras, Aleșd, Răbăgani, etc. (Berindei and Pop, 1972).

In fact, on the territory of Bihor County, especially in the plain and hilly areas, but also in the intramontane depressions, thermo-mineral waters have been evidenced either by thermal springs (since Roman times - the case of Felix Baths), or by boreholes in numerous locations.

In the Apuseni Mountains, tectonic dislocations have enabled the infiltration of surface waters to considerable depths, where they undergo mineralization and/or thermalization processes. In this respect, at the contact between the Plopiș Mountains and the Derna Hills, near the Black Forest vacation village (in the commune of Popesti), there is a *bicarbonated feruginous mineral spring.* Another important hydrogeological feature is the famous intermittent karst spring Izbucul Călugări, located in the Vașcău limestone Plateau.

4.6.2. Surface water network

The main rivers of Bihor County are allochthonous (they have their sources in mountain areas located in other counties), but the tributaries are autochthonous and mostly have permanent flow, due to relatively high annual precipitation rate and contributions from groundwater recharge (Figure 32).

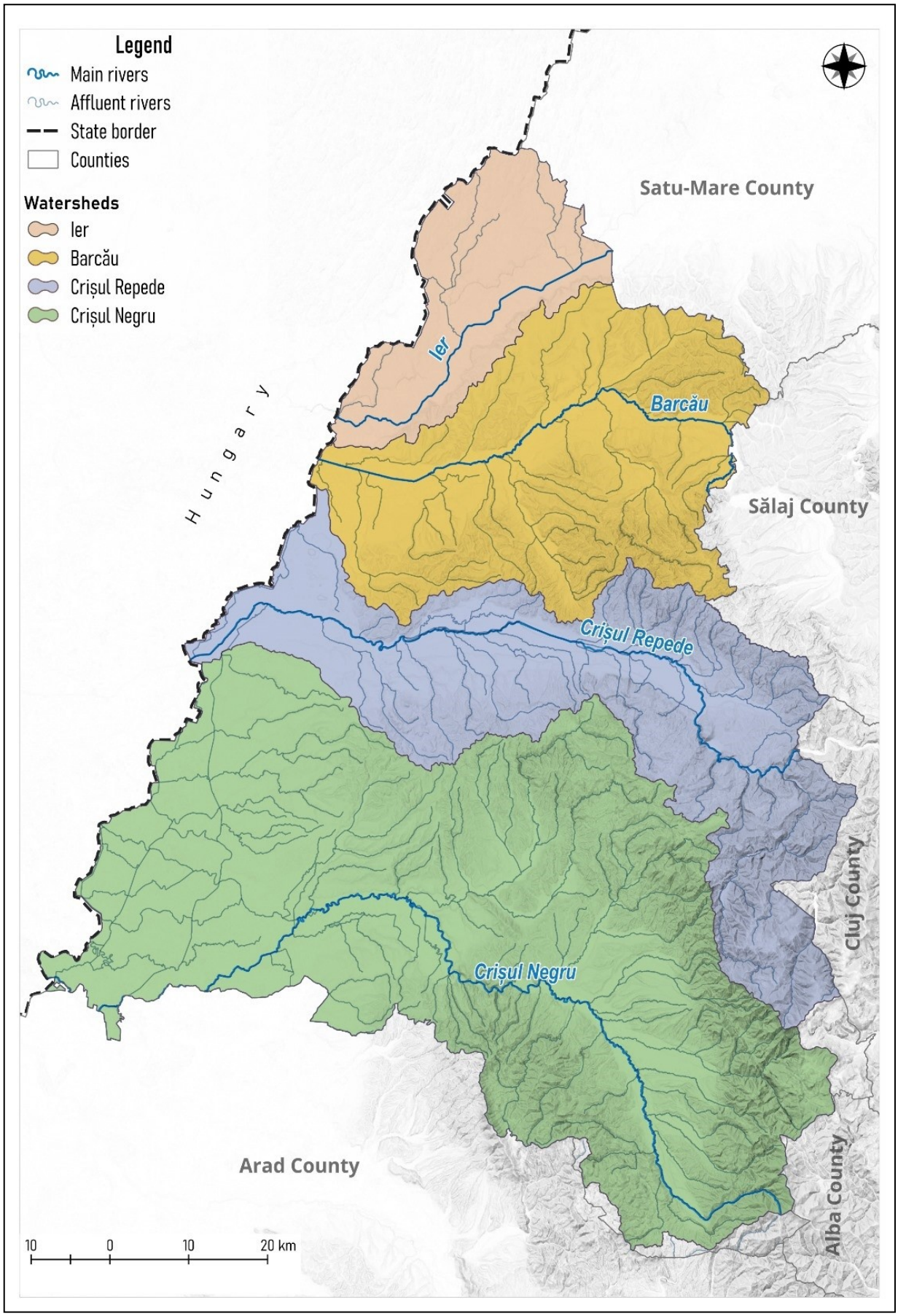


Figure 32. Watersheds in Bihor County and the surface water network.

The Ier (Eriul) is a tributary of the Barcău and flows westward into Hungary, 9 km from the border. It enters Bihor County upstream of Sălacea and drains the plain of the same name in a southeastward direction from Carei. In specialized literature it is usually treated separately because of its particularities. It is a typical river of the western Romanian plain: it has a wide valley with low drainage slopes, until recently marshy and flooded up to Diosig. Thus, a *complex of pools and marshes* has formed in its wide meadow. Nowadays the Ier Valley is drained and dammed, especially in the Diosig-border section, and a series of *reservoirs* have been built for flood control (Vășad, Galoșpetreu, Valea lui Mihai, Șimian, Cadea, etc.). The river collects 11 tributaries and has a flow of 1.7 mc/s at the entrance into Bihor County (at Andrid) and 2.9 mc/s at the exit from the county (at Ianca) (Berindei et al., 1972; Ujvari, 1972; Bradu et al., 2010).

The Barcău is a river in the northern part of the Crișuri catchment area, which flows 134 km across Romania. It originates in the eastern Plopiș Mountains at approximately 700 m altitude and enters Bihor County after crossing the Marca gorge (88% of its drainage basin is in Bihor). The Barcău is know in the county for its flood potential, especially during spring, when snowmelt coincides with liquid precipitation. The multiannual average flow in spring is 2.2 mc/s (frequently causing floods with material damage in particular), in winter 1.8 mc/s, and in summer and autumn the average flow is similar (between 1.2 and 1.3 mc/s). In order to prevent flooding, both *permanent (Suplacu de Barcău)* and *temporary (Tăuteu) reservoirs have been constructed* for excess water storage. There are also a number of permanent or non-permanent reservoirs on the tributaries of the Barcău to attenuate flood waves (Ciutelec, Borumlaca, Sântimreu, Uileacu de Munte, Eger, Paleu, Boianu Mare, etc.) (Josan et al., 2004).

The Crișul Repede drains the northern slopes of the Gilău, Vlădeasa and Pădurea Craiului massifs. It springs at an altitude of 710 m, near Izvorul Crișului, from a hilly area on the northern edge of the Huedin Depression. It flows into Bihor County downstream of Negreni, near the confluence with the Iad Valley, where it flows for 97 km and has 63% of its drainage basin area. In its lower course has been dammed for 23 km on the right bank and 11.8 km on the left bank. The average drainage gradient across the county is 2.7%. The most important tributaries are: Iad, Brătcuța, Mișid, Izbândiș, Cropanda, Medeș, Chijic (Baba), Tășad and Peța on the left bank, and on the right bank Borod (Berindei et al., 1972; Ujvari, 1972; Bradu et al., 2010).

Several *reservoirs* with complex functions (flow regulation, drinking water supply, hydropower production, recreation) have been built on its main course: at Săcădat, Tileagd and Fughiu, and in its wide floodplain there are numerous ballast lakes located.

The Crișul Negru is considered the most important river of the county because of its catchment size area, but also because one-quarter of its surface is situated within Bihor. It springs below the Bihor peak at an altitude of 1460 m, crosses the Beiuș and Holod Depressions, as well

as the Crișuri Plain, where it is dammed for 52.5 km on the right bank and 37.5 km on the left one. The river spans a total lenght of 139 km, with an average gradient of 9.5%. The most important tributaries on the right side are: Crișul Băița, Sighiștel, Crăiasa, Crișul Pietros, Nimăiești, Roșia, Holod, Râpa and Gepiș (Valea Nouă), and on the left side the valleys: Briheni, Tărcăița, Finiș, Valea Mare, Șoimi (Berindei et al., 1972; Ujvari, 1972; Bradu et al., 2010).

Despite massive hydro-ameliorative works in the Crișuri Plain, some areas remain persistently waterlogged due to the phreatic level being very close to the land surface. In such situations, artificial ponds have been established, primarly for fish farming in Cefa (about 600 ha of water), Homorog (about 95 ha), Tămașda (200 ha).

Other lacustrine units are represented by numerous smaller *permanent accumulations*, with functions for flood control and recreation, found throughout the plain and hilly area, such as: Alceu, Leș, Șauaieu (Nojorid commune), Vițeilor, Popii, Steluța (Cetariu commune), Paleu, Diosig lakes, etc. There are also several other reservoirs created exclusively for tourism purposes: the Săldăbagiu de Munte/Hanul Pescarilor reservoir (Paleu commune), the King's Land Country and Camelot tourist complexes (Ineu commune), Merita lake (Toboliu commune), etc.

A particularly notable natural feature is th *Peța thermal lake* in the balneoclimatic resort of Băile 1 Mai (Haieu village in the Sânmartin commune) formed along the Peța thermal stream. The creek and the lake are fed from a thermal collector of Lower Cretaceous age through sub aqueduct springs: *Ochiul Țiganilor,* considered the source of the Peța stream, nowadays completely blocked; *Ochiul Pompei* (provides thermal water for the wave pool), *Ochiul Mare* is the one that fed the thermal lake (Șoldea, 2003). Nowadays, the lake holds water only intermittently.

4.7. Biogeographical and pedological characteristics

From a biogeographical point of view, Romania occupies a transitional position between two major Paleoarctic regions: the Euro-Siberian, characterized by coniferous and deciduous forests and the Central-Pointe-Central Asian, where steppe and scrubland ecosystems dominate (the Geography of Romania, 1983). The bio-pedogeographical envelope of a given area faithfully reflects its local physical-geographical factors, among which relief and climate play a significant role. The geographic conditions in the western part of the country, manifested over the last century, have shaped the current distribution of flora, fauna and soil types in Bihor County (Figure 33).

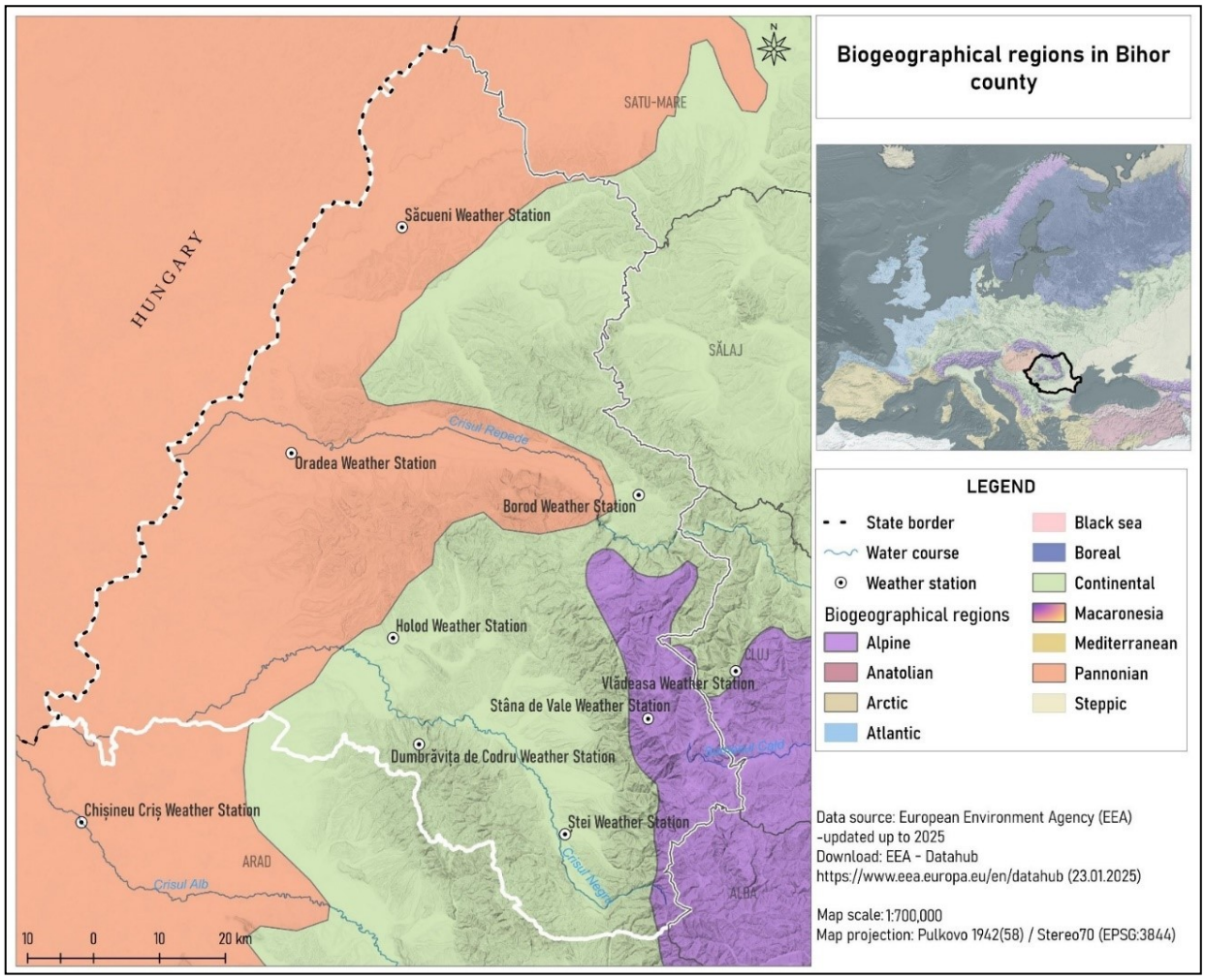


Figure 33. Biogeographical regions in the Bihor County area.
(source: www.eea.europa.eu/en/datahub, accessed on 23.01.2025)

4.7.1. Vegetation

From the point of view of *geobotanical regionalization*, Bihor County is part of the western region which includes the Banat-Crisana Plain (Western Plain) where the *zonality* in the distribution of the vegetation cover is manifested and the Carpathian region which includes the hills genetically linked to the mountainous area, here the *vegetation* is *spatialized* (The Geography of Romania 1983).

In Bihor County, the vegetation cover is *vertically* distributed as follows: the alpine vegetation, present in the understory of subalpine meadows, followed by the forest massifs (with several understories developing in the mountains, but also in the hills), and forest-silvosteppe vegetation in the plains.

The subalpine vegetation can be found on the highest peaks of the Bihor and Vlădeasa Mountains (1500 - 1800 m) and is well represented by *Juniperus sibirica* (dwarf juniper) bushes

associated with *Vaccinium myrthillus* (juniper) and *Vaccinium vitis-idaea* (cranberry), among which rare specimens of *Picea excelsa* (spruce), sometimes *Larix decidua* (larch). These plant formations form extensive mats on the slopes of Piatra Grăitoare, Bohodei, Vlădeasa, Buteasa, etc. Pinus mugo (juniper) is rare and occurs in a few patches in the Vlădeasa massif and in the upper basin of the Șteule Valley, where it is associated with *Alnus viridis* (mountain alder). The grass carpet is represented by species such as *Agrostis rupestris* (rock grass), *Festuca supina* (rock *fescue*), *Nardus stricta* (pig's-tail), *Poa pratensis* (common thistle), *Rifolium pratense* (clover), *Thymus serpyllum* (thyme), etc.

The forest vegetation has the largest spatial extent and has two well-defined forest floors. At higher altitudes (between 1300 and 1500 m) the ***boreal floor*** (coniferous forest) develops, below it follows the ***nemoral floor*** (deciduous forest) with the *beech forest* sub-floor between 700 and 1000 - 1200 m altitude and, finally, the *sessile oak forest* sub-floor between 300 and 700 m. All the forests are tristratified, i.e. they consist of a tree layer, a shrub layer and a grass layer.

The Boreal Forest belongs to the shady and dark coniferous forests that do not allow the development of many species. Emblematic for the Romanian Carpathians are the spruce forests (pure or mixed with other coniferous species).

In Bihor County *the spruce (spruce, red fir) forests* develop insularly in the form of bands surrounding the alpine sub-layer. Their spatial extent is related to microclimatic sequences, latitude and anthropogenic interventions. Among conifers, spruce stands occupy the largest areas and hold a great economic importance. They are well represented in the basins of the Iad and Someșul Cald rivers. These forests have a relatively simple structure, predominantly spruce *(Picea abies),* mixed with fir *(Abies alba) in* the lower part and gradually giving way to subalpine vegetation in the upper part. In the *Stâna de Vale Depression*, *the Picea abies columnaris* variety frequently occurs, which has a narrow, downward-oriented crown with short branching.

The fir forests are scattered in the mass of mixed beech - resinous forests. They also show a simple structure in which fir *(Picea alba)* is mixed with spruce, beech, mountain pine. Scattered among the spruces and firs are rare examples of larch *(Larix decidua)* and yew *(Taxus baccata).* Larches can be found in several forest stands in the upper Bulz and Boga valleys.

The boundary between coniferous and deciduous forests in Bihor County fluctuates between altitudes of 600 and 1300 m, depending on relief, microclimate and substrate that sometimes determine the occurrence of vegetation inversions.

Related to excess water, in the Padiș area of the Bihor Mountains, *peat bogs (active peat bogs, oligotrophic bogs)* associated with small black water pools are found. These bogs are characterized by nutrient poverty and form on impermeable horizontal surfaces where precipitation exceeds 600 mm/year. Thus in the Bihor Mountains, bogs have formed on a siliceous

substrate on almost horizontal terrain (such as the Izbuce bogs on the border between Bihor and Cluj counties) or in karst areas where the bottom of the sinkholes is impermeable with clay (Padiș, Barsa, Onceasa, Vărășoaia). The peat in these bogs has an average thickness of about 4 m and forms the habitat for specific vegetation, with some endemic or protected species, such as the carnivorous plant dew dew (*Drosera angelica rotundifolia*). The flora of the tinoaves consists of oligotrophic, slow-growing plants, but especially of species of the *Sphagnum* moss, which forms the basis of the entire flora. The juniper (*Pinus mugo*) also grows here at the lowest altitude in the country (www.parcapuseni.ro).

In Bihor County, ***deciduous forests*** occupy the lands located between 300 and 1300 m in the Plopiș Mountains, Pădurea Craiului Mountains, Codru-Moma Mountains and the Western Hills. ***The beech forests*** represent the upper limit of the nemoral stage which is separated from the boreal stage by a strip of beech - spruce mixture (Gheorghe and Ionescu, 2016).

The beech forests have a simple structure in which the dominant species is beech (*Fagus silvatica*), which forms pure forests (beech forests) or mixed with hornbeam. There are high-altitude beech forests, mountain beech forests and hilly beech forests (well represented in the hills bordering the Beiuș Depression). Characteristic for the lower limit of the meadows is the descent and deep penetration into the goruneta where they occupy shaded slopes and sheltered valleys (Chiriță et al., 1981).

Between 300 and 600 m there is the ***sessile oak floor***, where the sessile oak *(Quercus petraea)* grows, together with quite a lot of mixed species, especially hornbeam *(Carpinus betulus)*, juniper *(Acer campestre*), the Enlgish oak *(Quercus robur*), the Turkey oak *(Quercus cerris),* mixed with elm *(Ulmus campestris)*, ash *(Fraxinus excelsior*), lime, cherry, etc.

The Turkey oak *(Quercus cerris*) and the Hungarian oak *(Quercus frainetto)* forests develop on the perimeter of the submesophyll-termophilous oak forests in the nemoral floor. They are found in low fragmented lowland areas as well as on low piedmont hills at altitudes between 100 and 300 m. Out of season, they penetrate into the silvosteppe (on the northern slopes) and into the oak tree floor on the southern slopes (www.geomorphologyonline.com).

In the lowland area up to 300 m above sea level there is **the silvosteppe zone** where steppe meadows and thermophilous oak forests dominated by Turkey oak *(Quercus cerris)*, the Hungarian oak (*Quercus frainetto*) in the upper part and pedunculate oak *(Quercus pedunculiflora, Quercus robur).* However, the forest has undergone profound anthropic changes, so that the natural vegetation can still be found only in patches (e.g. Rădvani forest in Cefa commune, Cighid forest in Ciumeghiu commune). Among the edifying species that form the grass cover of the forest are: *Agropyron pectiniforum, Festuca valesiaca,* species of the genus Stipa, Lolium, etc. However, these meadows have been almost entirely cleared to make way for agricultural crops.

The intrazonal vegetation is conditioned primarily by the geological substrate and less by the climate. In Bihor it occupies restricted areas within vegetation stages or zones and is formed by associations of cliffs and scree, mountain springs and streams, oligotrophic and eutrophic swamps, salinized or sandy soils. For Bihor, the Carei - Valea lui Mihai (Nirului Plain) is of particular interest, where mosaic ***psamophylous vegetation*** developed depending on the depth of the water table and the degree of sand stability. Here acacia (*Robinia pseudoacacia*) forests have been planted to stabilize the sands. On the interdune, marshy interdune areas, a vegetation cover with distinctive features compared to the adjacent lowland areas is developing. In addition to a number of species occurring in the adjacent marshes and swamps, a large number of plants grow here which are generally widespread in the upland areas *Betula pubescens, Calamagrostis stricta, Calamagrostis canescens, Menyanthes trifoliata.* The preservation of these flora elements in the sandy area of the Nirului Plain was conditioned by two factors: less anthropogenic intervention in the sandy area and in particular the topoclimatic conditions (www.uvvg.ro).

In the southern and south-eastern part of the Salonta Plain***, halophilous meadows*** with species of the poverty species such as *sărățica*, together with *Eleocharis palustris*, *Puccinela distans* etc. occur (Posea, 1999; Monography of Bihor County, 2010).

In the karst plateau of Padiș (Ponorului Fortresses), due to special microclimatic conditions, a ***northern*** type of ***vegetation*** developed at unusually southern latitudes occurs together with some alpine species growing here at a low altitude. In large sinkholes also, due to thermal stratification of the air, the beginning of the growing season is delayed in the lower part. At the mouths of the caves there is a vegetation characteristic of shady and wet areas (Bleahu and Bordea, 1981).

The azonal vegetation is represented by marsh and aquatic vegetation and by the llanos that form aspen and willow meadows (meadow forests) partly replaced by secondary grasslands. Recent *stands* are highly mixed clumps of trees, but old stands are differentiated by biotopes. On the montane level, these forests consist mainly of white alder (*Alnus incarna*), with a low participation of spruce and fir. In the hills, the dominant species is black alder (*Alnus glutinosa*), with white poplar (*Populus alba*) and willow (*Salix fragilis*) as secondary species. The shrub layer is well developed and consists of elder, hazel, hawthorn, hawthorn, hawthorn, sometimes tamarack maple and buckthorn. The ditches along the lowland rivers consist of poplar species (on the ledges) and willow in the meadows.

Palustrine vegetation occurs in disjunct areas localized on the shores of ballast lakes, fish ponds, in negative relief microforms where groundwater is shallow. It is made up of associations of hygrophilous plants (*Carex riparia, Carex curvula, Carex vulpina, Scirpus silvaticus, Scirpus*

lacustris, Juncus effusus, Typha latifolia, Iris pseudocorus, etc.). Most often associated with aquatic vegetation.

In addition to this, *the segetal and ruderal anthropophilous vegetation* is found over large areas, its establishment and maintenance being linked to human activity, as it accompanies agricultural crops, human settlements, roadsides.

4.7.2. Fauna

Similar to the vegetation, the fauna is spatially arranged in *stages* that were formed as a result of the rise of the Carpathian chain and *biogeographical zones* as a result of Romania's latitudinal position in the European continent. The mountain fauna is arranged in altitudinal formations as follows: the alpine stage above 2,200 m, the sub-alpine stage between 1,850 and 2,200 m, the boreal stage between 1,850 and 1,250 m and the nemoral stage below 1,250 m, continuing in the hilly region (Drugescu, 1994). The geographical position of Bihor County determines, from a zoogeographical perspective, the presence of Central-European terrestrial faunal elements in the hilly and mountainous regions and Pannonian elements in the Crișuri Plain (Berindei et al., 1972).

Due to the mobility of the faunal species, the delimitation of the stages covers a broader altitudinal range than in the case of vegetation zones. In Bihor County, the alpine stage is absent, yet specific elements of ***the subalpine (sub)stage*** are present, characterized by a reduced number of species adapted to the harsher physico-geographical conditions. Representative species include: the mountain lizard *(Lacerta vivipara*), the common viper *(Vipera berus*) in mountain meadows, the mountain fynx *(Anthus spinoletta spinoletta)*, the stone butterfly *(Tichodroma muraria muraria)*, to which are added various coleopterans (beetles), lepidopterans (butterflies). The black goat *(Rupicapra rupicapra*) has been reintroduced into the upper basin of the Crișul Pietros: Boga, Groapa Ruginoasa, Ponorului Fortresses, Scărița.

The faunal stage of coniferous forests is characterized species strongly attached to local biotic and abiotic conditions. These include the striped mouse *(Sicista betulina),* the common rat *(Clethrionomys glareoulus)*, numerous birds such as the red crossbill *(Loxia curvirostra),* the black woodpecker *(Dryocopus martius*), etc. The western capercaillie *(Tetrao urogallus),* reintroduced in the 1980s in mountain are, is a bird characteristic of old spruce forests and their marginal areas. In addition, there are numerous insects (coleoptera, hymenoptera, gastropods, etc.).

Boundary mololids present more favorable living conditions for herpetofauna than compact molid. At the forest edge, in addition to amphibian species such as the alpine newt *(Triturus alpestris*), yellow-bellied newt *(Bombina variegata*), red mountain frog *(Rana temporaria*), reptile species can also be observed, such as the water lizard *(Anguis colchica*), the

legless lizard *(Anguis fragilis*), the mountain lizard *(Lacerta vivipara)*, the field lizard *(Lacerta agilis*), the viper *(Vipera berus)*. The avifauna is relatively poor in terms of both number of species and number of individuals, the most representative nesting species being the blackbird *(Turdus torquatus*), the dunnock *(Prunella modularis*), etc.

The aquatic fauna of the mountain rivers is characterized by the presence of native trout *(Salmo trutta fario*), rainbow trout *(Salmo irideus*), mountain trout *(Barbus meridionalis petenyi*), the graylings *(Thymallus thymallus)*, the European bullhead *(Cattus gobio*), the red drum *(Phoxinus phoxinus)*, the common nase *(Chondrostoma nasus)*, and the stone loach *(Noemacheilus barbatulus*) (Măhăra, 2010).

Mammals such as the bear *(Ursus arctos*), the Carpathian lynx *(Felix lynx),* the wolf *(Canis lupus)* are rarer in the County. But the fauna of large mammals of hunting interest is well represented by populations of roe deer *(Capreolus capreolus*), red deer *(Cervus elaphus*), wild boar *(Sus scrofa)*, etc.

The faunal floor of the meadows has improved living conditions, but the faunal species found here are also found in the oak tree forest. Among the birds, there are the mountain woodpecker (*Parus montanus*), the common firecrest *(Regulus ignicapillus*), the hazel grouse *(Tetrastes bonasia*), the white-backed woodpecker *(Dendrocops leucotos*), etc. Among the mammals, the pine martin *(Martes martes)*, the hazel dormouse *(Muscardinus avelanarius*), the wild cat *(Felis silvestris)*, the ferret *(Mustela putorius*) and the otter *(Lutra lutra)*. These are complemented by a wide range of insects.

The faunal floor of oak trees is the best represented, indicating very favorable living conditions, the zoocenosis approaching maximum parameters in terms of quantity and quality (the Geography of Romania, 1983). Common here are the toad (*Rana dalmatina*), the European turtle dove *(Streptopelia turtur*), the song thrush *(Turdus philomelus*), the blackbird *(Turdus merula*), the wild cat *(Felis silvstris)*, the garden dormouse *(Elyomis quercinus*), and many insects.

In the rivers of the Crișana Hills there are the chub *(Leuciscus cephalus),* barbel *(Barbus barbus*), the common nase *(Chondrostoma nasus).*

Zonally, the ***fauna of the forest*** is less varied than that of the hilly forests, and as a result of the expansion of agricultural crops, its range has been greatly restricted. The European ground squirrel *(Citelus citelus*), the European hamster *(Cricetus cricetus*), lesser blind mole-rat *(Spalax leucodon hungaricus)*, the hare *(Lepus europeus)*, the field mouse *(Apodemus agrarius)* are specific. Birds include: quail (*Coturnix coturnix),* starling (*Sturnus vulgaris*), turtle dove *(Columba oenas*), nightingale *(Luscinia megarhynchos)*, partridge *(Perdix perdix*), quail *(Coturnix coturnix)*, red-footed falcon (*Falco vespreminus*), the pheasant *(Phasianus colchicus*), accompanied by reptiles, a wide range of invertebrates, insects, etc. Long thought to be extinct in the Salonta - Cefa

area, the great bustard *(Otis tarda)* has reappeared, and the sand lizard *(Eremias arguta deserti)* can be found on the sands of the Nirului plain (Carei Plain – Valea lui Mihai).

In lowland waters, carp *(Cyprinus caprio)*, perch *(Lepomis gibbosus),* catfish *(Silurus glanis)* and pike *(Esox lucius)* dominate.

*Cave fauna***.** In Bihor County, as a result of the endocarburization process, numerous caves and caverns were formed that harbor a cavernicolous fauna of North-Egeid origin. The endocarst of Bihor Mountains, Craiului Forest Mountains, Codru-Moma Mountains shelters a large number of troglobionte forms and represent conservative centers. The subterranean invertebrate fauna is very well represented. Many species are endemic and many inhabit only one or two caves (www.parcapuseni.ro).

4.7.3. Soils

The different local or regional combination of natural pedogenetic factors in the lowland and hilly areas has generated a pedogeographic envelope with distinct pedogeographic features compared to the mountainous area. In Bihor County, the soil envelope is characterized by a wide variety of soils, determined by local climatic conditions, soil material, vegetation and relief, which determine a certain vertical distribution of soil classes.

Thus, in the *lowland floor*, cambic chernozems, clay chernozems, alluviosols, preluvosols, eutricambosols, gleiosols and locally stagnosols predominate. The soil cover of the *hillsides* is characterized by the presence of preluvosols, luvosols, eutricambosols, districambosols, and stagnosols (occupying depressional areas), while regosols are found on the steeper slopes. *The uplands* are characterized by a wide variety of soils: eutricambosols, districambosols, spodisols, rendzins, regosols, lithosols, nigrosols and humosols.

Human activity has had a strong influence on soil evolution processes. The clearing of mountain and hilly forests has led to surface and deep erosion processes. In low-lying areas, the process of secondary hardening was triggered and the cultivation of soils led to physico-chemical changes in the upper horizon.

The soils of the ***Crișuri Plain*** are characterized by diversity, their genesis being linked to the evolution of the Tisza Plain. On the whole, alluviosols, chernozem soils and phaeozems are dominant in the *low plain*, while in the *high plain* phaeozems, preluvosols and eutricambosols are dominant, which are favorable for agricultural crops, as they have high fertility. An important differentiation occurs on the West - East alignment from the silvosteppe (with cambic chernozems, clay chernozems, phaeozems, alluviosols, psamosols) to the high plains to the hills (where the soil

cover is characterized by the presence of preluvosols, luvosols and eutricambosols). There is also a N (cernisols) - S (luvisols) differentiation (Berchez, 2019).

In a climate characterized by an average annual temperature of 10-11° C, precipitation of about 600 mm, on parent rocks consisting of clays, clays, fluvial and loessosic deposits, several ***classes of soils*** are identified in the Crișuri Plain***:*** *Cernisols* (represented by typical, cambic, argic, stagnic, gleic, salinized and alkalized cernosols, all subtypes of phaeozems) and *Luvisols* (represented by all taxonomic units - Preluvosols, Luvosols and Planools) found mainly in the high plains and on the upper river terraces (Berchez, 2019) *; Cambisols* (eutrichambosols and districambosols); *hydrisols* (stagnosols and gleiosols); *vertisols* (through the types vertosol and pelosol); *salsodisols* resulting from secondary salinization processes due to hydro-amelioration works (solonols predominantly in the Salonta Plain); *protisols* of the alluviosoil type common in riverbeds and psamosols characteristic of the Nirului Plain (Carei Plain – Valea lui Mihai) where on dunes there are typical and moliceous psamosols, and on interdunes psamosols with different degrees of gleization (www.kmnp.hu; Berchez, 2019).

The soil cover of the ***Bihor hills*** has distinct features compared to the mountain or lowland soil. There is a certain uniformity of the soils formed mainly on detrital sedimentary materials, but a differentiation from N to S can be detected, as well as in altitude. Several classes are present, of which *the luvisols* (represented by all soil subunits) and *cambisols* (eutricambosols, specific to altitudes above 500 m) have good natural fertility. To these are added: *Cernisols* (different subtypes of phaeozems); *Hydrisols* (stagnosols and gleiosols), which are much more restricted in their distribution, being specific to depressional areas or low areas under the influence of the water table; *Protisols* and soils affected by erosion, respectively *antrisols* (regosols and erodosols), on slopes affected by landslides (for example, the right slopes of the Criș Repede and Barcău rivers).

In the ***mountainous area*** of Bihor County, under a forest vegetation in different mixtures, there are different subtypes of eutricambosols and districambosols, rendzine, regosols and lithosols occupying altitudes up to 1300 m (up to the transition to the vegetation stage of coniferous forests).

Spodisolsols and umbrisols occupy the areas corresponding to subalpine spruce, meadows and scrublands. This stage covers the altitudinal range between 1300 and over 1800 m. *Spodisols* occupy smaller areas compared to cambisols. Among these, prepodolosols occupy the lower part of the alpine plateau, but occur predominantly under mixed beech and coniferous meadows or forests with well-developed acidifying vegetation, especially ericaceae, on eruptive and metamorphic rocks. These soils occur particularly in the Bihor and Vlădeasa Mountains. Under forest vegetation consisting of spruce forests, less frequently spruce and fir, the dominant soil type is podzolo.

On the clayey-sandy loam deposits of the depressions, *luvisols* dominate. Subalpine meadow soils occur on the highest peaks of the Bihor and Vlădeasa Mountains and belong to the classes *protisols* (represented by lithosols, regosols), *spodisols* and *cambisols* (by districambosols). *Umbrisols* are less widespread, occupying higher areas of coniferous forests and mountain meadows (Figure 34).

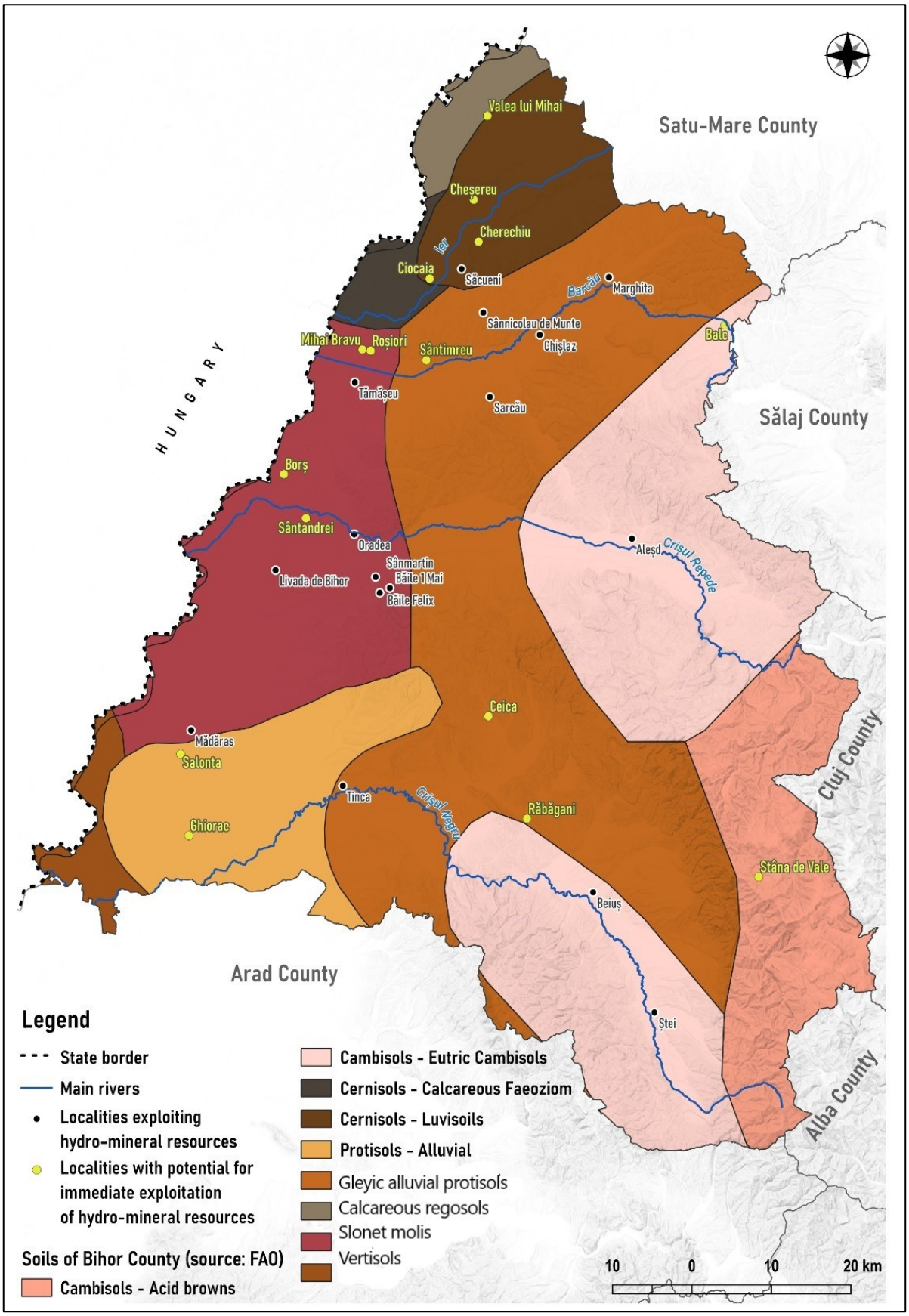


Figure 34. Bihor County soils.

(source: www.fao.org www.fao.org, accessed on January 19, 2025)

4.7.4. Protected natural areas

With Romania's integration into the European Union in 2007, the area and number of protected areas in Bihor County has increased significantly, occupying the second place in the country, being surpassed only by Alba County. The area of protected areas totals about 337,779 ha, which is 44.7% of Bihor County's total area (7,544 kmp).

Bihor hosts 64 *nature reserves of national interest*, including two zoological reserves (Cefa, Săcueni), four geological and geomorphological reserves (Pietrele Galbenei, Piatra Bulzului, Izbucul de la Călugări, Groapa Ruginoasa), eight paleontological, 14 botanical, 16 are mixed-types and 20 speleological reserves. Among these, 21 are classified as Category III by the International Union for the Conservation of Nature, holding the status of natural monuments. Some caves within these reserves are partially classified as Class A, indicating they have sectors of exceptional value which, due to their scientific interest or uniqueness of resources, are considered part of the national and international speleological heritage (www.mmediu.ro). In addition, by the Bihor County Council has designated *16* other *protected areas of local importance*, including one zoological reserve, one geological reserve and 11 botanical reserves (dendrological parks).

Nature reserves are currently included in *two nature parks* and in the 37 Natura 2000 sites within Bihor County, where they represent fully protected areas.

Among the *Natura 2000 sites* in Bihor*,* 37 have been officially declared: eight are Special Protection Areas for Birds (SPA) (four of these also have areas in neighboring counties), 14 sites are of Community Importance (SCI). The most extensive protected areas are occupied by Natura 2000 sites, covering 36.2% of the county's surface area, followed by the two nature parks (8.6%), nature reserves of national interest (1.2%) (Figure 35).

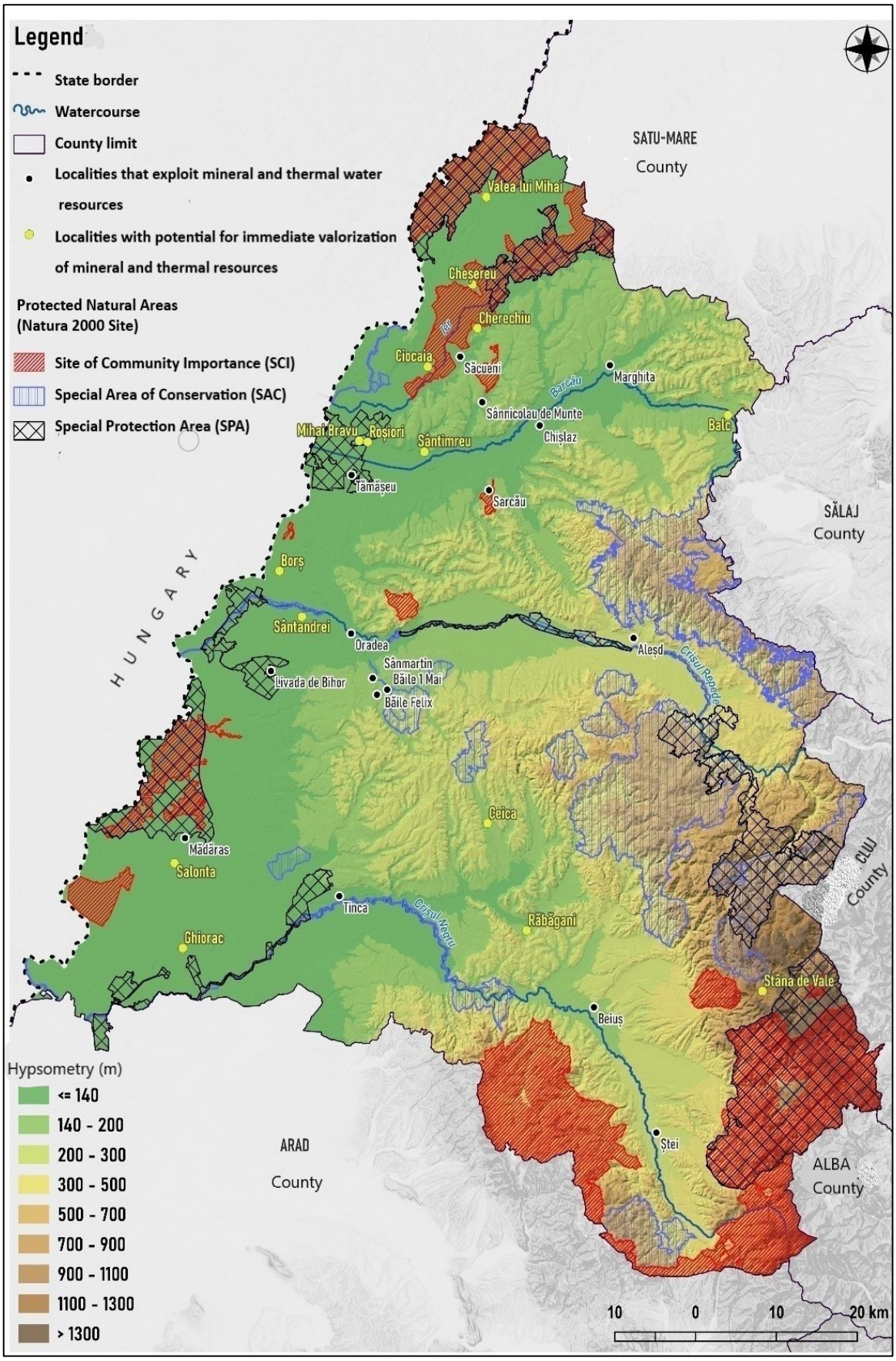


Figure 35. Protected natural areas in Bihor County.

(source: https://mmediu.ro/)



Figure 36. Examples of unsustainable exploitation of thermal water in protected areas: the case of nature reserves: a) at the Peța stream in the Băile 1 Mai balneoclimatic resort[20] and b) at the mesothermal springs from Răbăgani[21].

Some of the protected plants with ***monument of nature*** status in Bihor are: the thermal water lily of the 1 Mai resort *(Nymphaea lotus var thermalis*), which current survival status of the species is uncertain (Figure 36), the Transylvanian lilac of the Iad Valley *(Syringa josikaea*); the wild peony *(Peonia officinalis*) on Păcău Hill (in the Șoimi - Borz gorge); the thorn *(Ruscus aculeatus*) growing in the forests of Câmpani de Pomezău, Șomleu Hill, Cordău, Drăgoteni, Hidișelul de Jos, Sâmbăta, Valea lui Mihai; the globeflower *(Trollius europaeus*) at Sudrigiu, Săldăbagiu de Munte, lily of the forest *(Lilium martagon)* rare in the forests of Stâna de Vale and around the Focul Viu cave in Padiș, the variegated tulip *(Fritillaria meleagris*) in the Criș Repede gorge, the tree ivy *(Hedera helix*) at Drăgești, the chestnut *(Castanea sativa*) at Dobrești, the Turkish hazel *(Corylus colurna*) in the park of the Baroque complex in Oradea. There are also secular trees, such as the oaks of Băile 1 Mai, Cetariu, Otomani, Pădurea Mare (Marghita), Remetea (pedunculate oak - *Quercus robur*, with a diameter of 170 cm, 25 m high and about 400 years old), the mammoth trees (*Sequoia gigantea*) of Oradea, the arboreta of the dendrological parks in Sâmbăta, Batăr, Cadea, Valea lui Mihai, Balc, University of Oradea.

In Bihor County, W.W.F. (World Wild Found - Romania) has identified 1,363 ha of virgin forests (www.wwf.ro).

Due to the landforms diversity, geological structure and favorable climatic conditions, Bihor County benefits from a favorable natural setting that supports a variety of balneary resources. The presence of hydromineral resources and beneficial climatic factors have favored the existence of a balneoclimatic potential, which is reflected in numerous resorts and locations of interest. The main balneoclimatic resources (hydromineral waters and bioclimate) of the county and how they are valorized will be further studied.

[20] The thermal lake has dried up and the endemic species here are extinct due to overexploitation of thermal water
[21] In Răbăgani, a swimming pool was built within the perimeter of the protected area, which was demolished.

5. The assessment of balneoclimatic potential of Bihor County

The characteristics of the natural setting hold a fundamental role in the existence and utilization of balneoclimatic resources (hydromineral waters and the bioclimate).

Balneoclimatology has evolved into a medical specialty actively involved in the health improvement process, offering prophylactic and therapeutic benefits. It is also a significant branch of tourism, contributing importantly to the economy. Within this health-promoting and tourism context, the primary natural therapeutic factors involved are hydromineral resources and the bioclimate (Moțica, 2018).

5.1. The assessment of balneary potential of Bihor County

Balneology studies the application in medical practice of natural factors such as mineral waters, therapeutic gases, muds, bioclimate, etc. which, through the prophylactic and therapeutic effects of balneary treatments, represent an old remedy for contemporary health. Balneotherapy with thermomineral water is one of the most widely used methods for both prophylactic and therapeutic purposes (Protano et al., 2024).

Balneotherapy is one of the most frequently used non-pharmacological approaches, as a remedy for various pathologies in many countries in Europe and the Middle East, as well as in Japan and Israel (Morer et al., 2017).

Evaluating the value of balneotherapy is a complex problem. In general, balneotherapy is recommended to be accompanied by other therapeutic procedures (massage, electrotherapy, physiotherapy, etc.), in order to be more efficient in improving sanogenic disorders and pathologies. Balneary treatment usually consists of a health holiday lasting about two to three weeks (Bender et al., 2005).

The therapeutic value of balneotherapy is probably the result of a combination of mechanical (hydrostatic force), thermal (temperature of the thermomineral water) and chemical (chemical composition of the mineral water or mud) effects. The increased buoyancy and hydrostatic pressure during immersion in thermal mineral water cause many physiological changes, including stimulation of diuresis, natriuresis and cardiac output. Hydrostatic pressure and temperature can have beneficial influences on muscle tone, pain intensity and joint mobility. Heat increases the secretion of adrenocorticotropic hormone, cortisol, prolactin and growth hormone, although it does not alter the circadian rhythm of these hormones (Fioravanti et al., 2017).

Given these properties, the scientific community has focused its attention on the positive effects of balneotherapy, producing a growing body of evidence that balneotherapy is an effective

method for managing the symptoms of several pathologies such as *rheumatic conditions* (Guillemin et al., 2001; Farcas, 2005; Forestier, Erol Forestier and Francon, 2016; Filatova et al., 2017; Ahlquist et al., 2020; Ciurba et al., 2023; Silva et al., 2023), *neurological disorders* (Pospíšil et al., 2007; Dogaru et al., 2016; Cherevaschenko et al., 2018; Uivaroșan et al., 2018, 2019; Iosub et al., 2024a), *post-traumatic sequelae* (Koleva et al., 2015; Enescu et al., 2016); c*ardiovascular diseases* (Schott, 1891; Oláh et al., 2011; Zapolski et al., 2024), *gynecological pathologies* (Horejsí et al., 1981; Fiaschetti et al., 1982; Kauffels and Mesrogli, 1996; Habek et al., 2021; Wójcik et al., 2023; Ciurba et al.,2025), *dermatological conditions* (Péter et al., 2017; Huang et al., 2018; Gebretsadik, 2023; Protano et al., 2024), *respiratory disorders* (Khaltaev et al., 2020; Zajac, 2021; Ferrara et al., 2025), *metabolic disorders* (Gin et al., 2013; Lv et al., 2021) *endocrine disorders* (Stanciu et al., 2023; Dogaru et al., 2025), *musculoskeletal pain* (Pérez-Fernández et al., 2019; Maindet et al., 2021; Ducamp et al., 2022; Borze (Ursu) et al., 2025; Ariani et al., 2025) etc.

5.1.1. Current research status on balneotherapy

In presenting studies and research in the field of balneology, we will start from general research to reach studies related to Bihor County. Many authors consider that balneology and balneotherapy were individualized only in the second half of the 19th century, although the origins are very old. Thermal baths have been known since antiquity to the Greeks, Etruscans and Romans, but later they were forgotten.

In 1837, Episcopescu studied the metallic waters of Greater Romania. Gross conducted a detailed study on the thermal and mineral waters of Bihor County, publishing the results in 1844 in a work edited in Hungarian *Anagyvaradi sz. Laszlo furdorol Biharmegye asvanyos vizeirol*.

Exploration studies and geological research of geothermal deposits began in Romania in 1962 by Blidaru et al. The first geothermal wells were drilled in the Western Plain (Oradea, Felix, Călacea and Timişoara) (Blidaru et al., 1962; Mitrașcă, 2006; Bîdiliță, 2009).

Pricăjan, in his 1972 work, presented a synthesis of the natural and geological conditions in the areas where the main mineral and thermal water deposits in Romania are located. Among these the Western Plain and the Apuseni Mountains were presented. Another study was carried out by Țenu (1981) in the northern half of the Western Plain of Romania which included the geological, hydrogeological and geothermal characterization of the area, the hydrochemistry and isotopic composition of the hyperthermal water deposits. Posea (1997) carried out the most extensive work dedicated to this large plain in the west of the country. Bendea et al. (2003) in the work *Geothermalism and thermal waters,* presented notions of a course structured in five chapters, and of interest for the thesis topic is the chapter *Thermomineral waters in Romania*, which

presented elements of geology, hydrogeology, thermalism and the physicochemical characteristics of the thermal waters of the Western Plain, and in the third part (Exploitation of geothermal resources in the Western Plain) presented the development of the exploitation and capitalization of geothermal energy in Bihor county. Sebeşan et al. (2015) presented the physicochemical characteristics of the geothermal fluids coming from the drillings 1021 from Tămășeu and 605 from Mihai Bravu.

Studies on the chemical composition of thermal waters from the Bihor County area were included in several doctoral theses: Stănășel, 2002; Mitrașcă, 2006; Roba, 2010. Other authors Orășeanu and Malacu (2016) produced a report on the monitoring of the dynamics of the thermal aquifer Oradea - Băile Felix - Băile 1Mai during September 2014 - February 2016, concluding that the dynamic level of the groundwaters from the studied boreholes is different due to the karst peculiarity of the aquifer.

In addition to these works, studies that addressed the balneoclimatic tourism of Bihor County are noteworthy.

Currently, research on natural therapeutic factors is based on several fundamental scientific pillars such as hydrogeological investigations, clinical, socio-economic, bioclimatic studies.

Vlaicu et al. (2016) highlighted the development and decline periods of the Stâna de Vale resort, which was once emblematic for the Apuseni Mountains and Bihor County, and finally, they propose some simple solutions for revitalizing the resort. Gaceu et al. (2009) in their work *The touristic potential, landscaping and advertising possibilities of Băile Tinca spa* highlighted the remarkable natural and anthropic tourist potential of the Băile Tinca resort, favored by the thermal mineral waters, the climate, the varied and rich vegetation and fauna. Teodoreanu, Gaceu (2013) presented a rich source of information on the valorization of the natural wealth given by the climate and therapeutic waters in Romania. They also highlight both the benefits of natural conditions in maintaining and restoring the body health, as well as their pathogenic effect by triggering possible negative reactions of the body. Orășeanu (2016) described the thermal waters of Băile Felix and Băile 1 Mai as the result of a mixture between hot waters rising on fractures (with different hypotheses regarding their origin and flow directions) and cold waters circulated on the Galbena fracture system. Haidu et al. (2023) highlighted the positive and negative effects that the exploitation of geothermal waters for balneology could have on the three specific components of sustainability: the environment, the population and its health status, as well as the local economy.

Linc et al. (2023) analyzed from a physical, chemical and microbiological point of view some groundwater resources with natural mineral load from three locations in Bihor County (two boreholes from Tămășeu and Sântimreu and a spring from Pădurea Neagră), as well as the impact of their consumption on human health.

Recent studies on the therapeutic use of local geothermal waters can be found in authors such as Ciurba et al. (2023) who evaluated the effectiveness of mineral water in patients with knee osteoarthritis. Iosub et al. (2024) conducted a clinical study that aimed at the influence of thermal water balneotherapy on pain, depression and self-esteem in patients with herniated discs. Borze (Ursu) et al. (2025) present a clinical study that highlighted the effectiveness of thermal water in fibromyalgia.

In the international literature, there are numerous studies on thermal waters, such as: Gianfaldoni et al. (2017) briefly described the history of balneology from its origins to present, considering that thermal waters and balneotherapy are an important cultural background throughout the world. Munier (2017) presented both the past and present thermal baths and mineral waters of France region of Lorraine. Also, in terms of balneotherapy, this region has internationally renowned thermal establishments (Amnéville-les-Thermes, Bains-les-Bains, Contrexéville, Plombières-les-Bains, Vittel) which have managed to adapt to the social changes that have occurred over the years to offer their guests a rich and varied range of treatments.

Another study shows that mud therapy and balneotherapy have been shown to be effective in the treatment and prevention of knee osteoarthritis by reducing pain, medication use, functional limitations, and improving patients' quality of life (Fraioli et al., 2018). Huang et al.'s (2018) research refers to the favorable climate of thermal balneotherapy centers that have been shown to have beneficial effects on psoriasis and atopic dermatitis (thermal spring waters can reduce skin inflammation) and describes their use in three different locations, each with a unique climate and different chemical properties of the mineral water used in balneotherapy: the Dead Sea in Israel and Jordan, the La Roche-Posay thermal center in France, and the Blue Lagoon in Iceland.

Ziemska et al. (2019) show that the use of natural medicinal resources in the form of treatments in resorts, under the supervision of specialists combined with the curative properties of the climate, contributes not only to reducing the treatment time for many pathologies and improving the results of therapy.

In Bihor County (which is notable for its wealth of hydromineral resources with a long history of their exploitation) thermal waters represent the main balneary resource, followed by cold mineral waters and therapeutic muds (Figure 37).

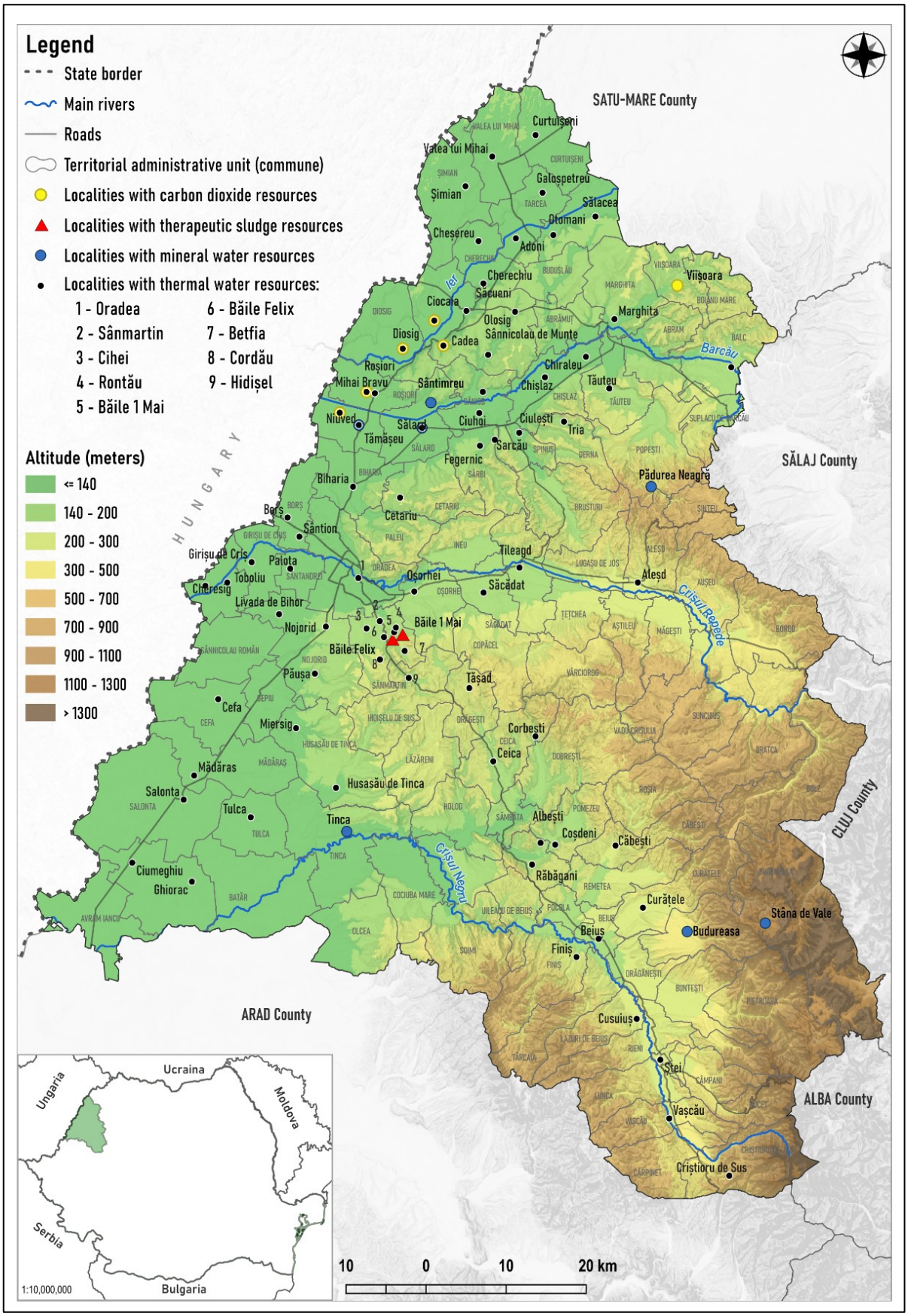


Figure 37. Bihor localities with hydromineral resources, carbon dioxide resources and therapeutic mud resources.

5.1.2. Legislative framework for balneary exploitation of hydromineral resources

In nature, water cannot be found in a pure state because chemical substances are dissolved in the form of salts, ions, gases, microelements. Thus, all waters have a certain degree of mineralization and are in fact mineral waters. Pricăjan (1972), an author with numerous research in the field, considers mineral waters those coming from underground or surface which, due to special mineralization or physical qualities, can be used in balneary treatments or in industry as raw material, including thermal waters which are used as a source of energy.

Mineral resources subject to the Mining Law no. 85/2003 (amended and supplemented by *Law no. 275/2020*) are represented by: coal, ferrous and non-ferrous ores, aluminum and aluminum-bearing rocks, noble metals, radioactive, rare and dispersed earths, halide salts, non-metallic useful substances, useful rocks, precious and semi-precious stones, peat, therapeutic muds and peats, bituminous rocks, non-combustible gases, geothermal waters and their accompanying gases, natural mineral waters (gaseous and still), therapeutic mineral waters, as well as the mining residual product from tailings dumps and tailings ponds. The provisions of the Mining Law also apply to drinking and industrial groundwater for prospecting, exploration, determination and recording of reserves (www.consiliulconcurentei.ro).

Natural mineral water, unlike other types of water (spring water, table water) is extracted from recognized and approved underground sources, and its controlled origin ensures stability, temperature and constant mineral salt content, regardless of surface climatic conditions, protecting it from all risks of pollution. Thus, natural mineral water has a specific content of dissolved mineral salts, trace elements or other constituents with beneficial effects on health.

By order *no. 87 of May 20, 2008*, with subsequent amendments and additions, the technical instructions regarding the classification and evaluation of natural mineral water resources, therapeutic mineral water, geothermal water, their accompanying gases and non-combustible gases were approved, which establish unitary principles used in the exploration and exploitation of natural mineral water resources, therapeutic mineral water, geothermal water, their accompanying gases and non-combustible gases.

The technical norms for the exploitation and marketing of natural mineral waters are established by *Government Decree no. 1020/2005*, which transposed several European directives. These norms establish the list of constituents in natural mineral waters that may pose a potential risk to public health, their permitted limit values, the deadline for introducing these values and the labeling requirements for certain constituents that must be naturally present in the water and not as a result of contamination of the source (www.namr.ro).

According to these rules, only waters recognized by the National Agency for Natural Resources or by the competent authority of a member state of the European Union can be marketed under the name of natural mineral waters in Romania. Natural mineral water has no content limits for the majority chemical constituents. On the other hand, compounds with toxic potential are strictly regulated. Contamination indicators (indicator of original purity) have the most restrictive values of all bottled waters (Feru, 2012).

In October 2019, the Hydromineral Resources Law was submitted to the Senate for approval, but it was also included in the legislative program of the Romanian Government in December 2021.

5.1.3. Thermomineral, cold minerals waters and therapeutic muds resources

The formation of artesian or ascending geothermal waters in the Pannonian Basin, including Romania's Western Plain, was the consequence of geological events related to the evolutionary antagonism between the Pannonian microplate and the surrounding Carpathian orogen, influenced by the upward movement of the asthenosphere. The upward trend of the asthenosphere resulted in the expansion and at the same time the heating and thinning of the lithosphere (Bódi et al., 2015; Borović et al., 2016).

Currently, Romania has numerous natural mineral water resources for food consumption, which are distributed in 14 counties, including Bihor County. Although Bihor County is not particularly known for its cold mineral waters, it does have several sources of still mineral water, used either for food consumption or other purposes, such as the Izvorul Minunilor from Stâna de Vale, the Cuciului spring for Hera water nearby (both located in Budureasa commune) and several sources of carbonated mineral water at Tinca (used in balneotherapy, bottled in the past), Tămășeu (bottled in the past), Sălard, Sântimreu and Pădurea Neagră.

In the northern part of Bihor County, there is a geothermal field that extends from Satu Mare County to Cherechiu - Valea lui Mihai and the surrounding villages. Another field is associated with the porous sedimentary aquifer of Miocene age in Săcueni area, that extends eastwards towards Marghita and Balc, being bordered to the south by the Diosig uplift and the Biharia - Mihai Bravu horst, the western extension of the Plopis Mountains. In the central plains of Bihor County, lies the Oradea aquifer, composed of altered limestones and dolomites from the Middle Triassic and the Băile 1Mai - Băile Felix aquifer formed by limestones from the Lower Cretaceous (Gheorghe and Grăciun, 1993), bordered to the south by the Inand - Salonta basement elevation. In the Beiuș Depression, drilling has revealed artesian or ascending thermal waters and in fractured and altered Triassic dolomites and limestones (Gilău et al., 2001). In the southern part

of Bihor County lies the Ciumeghiu - Mădăras geothermal field, which extends eastward to Tinca, composed of Pannonian aquifers.

The subsurface of Bihor County contains various natural resources of significant economic importance, such as *coal deposits*, concentrated in the Barcău basin (lignite) and the Borod basin (brown coal); *crude oil deposits* (especially in the Barcău basin), *geothermal water deposits* (with a more diffuse territorial distribution, being found mainly in the plain area, but also in intramontane depressions (Beiuș and Oradea - Bratca Depressions), *carbon dioxide deposits* (associated with mineral water deposits, especially north of Oradea). To these are added a few point-like occurrences of *cold natural mineral waters*. Related to the above-ground manifestation of thermal waters in the area of the Băile Felix - Băile 1Mai balneoclimatic resorts, *therapeutic muds* are found (Figure 37).

The energy crisis that loomed on the horizon of the mid-20th century led to the intensification of geophysical prospecting and drilling to find new hydrocarbon resources, but also alternative energy sources. Thus, in parallel, geothermal water deposits were discovered in the territory of Bihor County and, associated with them, those of mineral waters and carbon dioxide.

Overall, a number of 81 localities with hydromineral resources were identified in the area of Bihor County, of which seven localities have mineral water resources and 75 localities have geothermal resources. In the locality of Tămășeu, both thermal water and mineral water resources are found. These resources are found across all landforms, though most of them are located in the plains.

Thermal mineral water resources

There are numerous criteria for classifying mineral waters, but according to temperature (one of the most important physical characteristics), *cold mineral waters* (with temperatures below 20°C) and *hot or thermal mineral waters* (with temperatures above 20°C) are identified (Preda et al., 1981; Pricăjan et al., 1981). According to regulations, thermal waters are those considered to have a temperature above 20°C (Technical Instructions of May 20, 2008 on the classification and evaluation of resources/reserves of natural mineral water, therapeutic mineral water, geothermal water, the gases that accompany them and non-combustible gases)[22]. However, in the work Hydrogeology of the karst in the Apuseni Mountains (Orășeanu, 2016, 2020), waters with a temperature between 12°C and 20°C are considered to be hypothermal. Also, for Brașov County,

[22] Integral part of Order No. 87 of May 20, 2008 for the approval of the Technical Instructions on the classification and evaluation of resources/reserves of natural mineral water, therapeutic mineral water, geothermal water, accompanying gases and non-combustible gases

in a doctoral thesis, Lupu (Mereț) (2017) mentions that in Codlea there are hypothermal waters with a temperature of 18.4°C and higher than the average temperature of the warmest month of the year.

Thermal waters are groundwater heated above 20°C and are carriers of geothermal energy; therefore, they are also called geothermal waters. These waters are found both in platform regions and in mountainous ones where the sedimentary cover is thicker and meets the conditions for the accumulation and thermalization of groundwater (Airinei, 1981).

In Order no. 87 of May 20, 2008, geothermal waters are understood as the useful terrestrial mineral substance, used for energy purposes or as therapeutic mineral waters, with a source temperature above 20°C.

In the specialized literature, the parallel use of the terms geothermal water and thermomineral water is noted. However, one can note a more frequent use of the term geothermal water in the technical-industrial fields (to highlight the thermal character and the fact that it comes from deep: geo = earth) and that of thermomineral water in the tourist and balneary fields (to emphasize the existence of mineral substances dissolved in hot water) where, simplified, one frequently speaks only of thermal water.

The use of geothermal energy depends on the parameters of the geothermal source, namely its temperature and volume, and the potential flow rate. Depending on these parameters, geothermal energy can be used to produce electricity and heat, but it can also be used in other areas such as agriculture (greenhouses, rice fields, aquaculture, pisciculture), industry (drying of raw materials and finished products), balneology (thermal baths and treatment centers), residential consumers (for heating, domestic hot water, etc) (Trașcă - Chiriță, 2016; Ciurba et al., 2023; Haidu et al., 2023).

In the Oradea - Satu Mare area, three thermal aquifers are identified, namely the Lower Pontian aquifer, the Lower Cretaceous aquifer and the Triassic aquifer.

The *Lower Pontian aquifer* is found at a depth of about 1000 m, has waters with temperatures at emergence of 50 - 80°C, of great economic importance; they are found throughout the entire area of Bihor County. Lower Cretaceous and Triassic aquifers develop locally, in the Băile Felix - Băile 1 Mai area at about 100 m depth and in Oradea at about 3000 m depth. Radiocarbon dating indicates that the waters in the Lower Pontian aquifer are approximately 35,000 years old, which suggests that these waters are trapped without any noticeable recharge from the surface (Preda et al., 1981).

The *Triassic thermal deposit of Oradea* is delimited by peripheral faults (Velența fault, Sântandrei fault, Nojorid fault) where it is under pressure, the drills operate under artesian pressure.

The water has a temperature between 72 and 105°C. The lower Pontian deposit of Săcueni is part of the regional hydrostructure of the entire Pannonian Depression and covers an area of 2500 km2. The *lower Pontian thermal aquifer* system of Săcueni is located at depths between 1250 and 1700 m. The wells have encountered about 30 - 40 aquifer layers. The total thickness, including impermeable intercalations, reaches 500 - 800 m (Roba, 2010) (Figure 38). This aquifer manifests itself through eruptive flows.

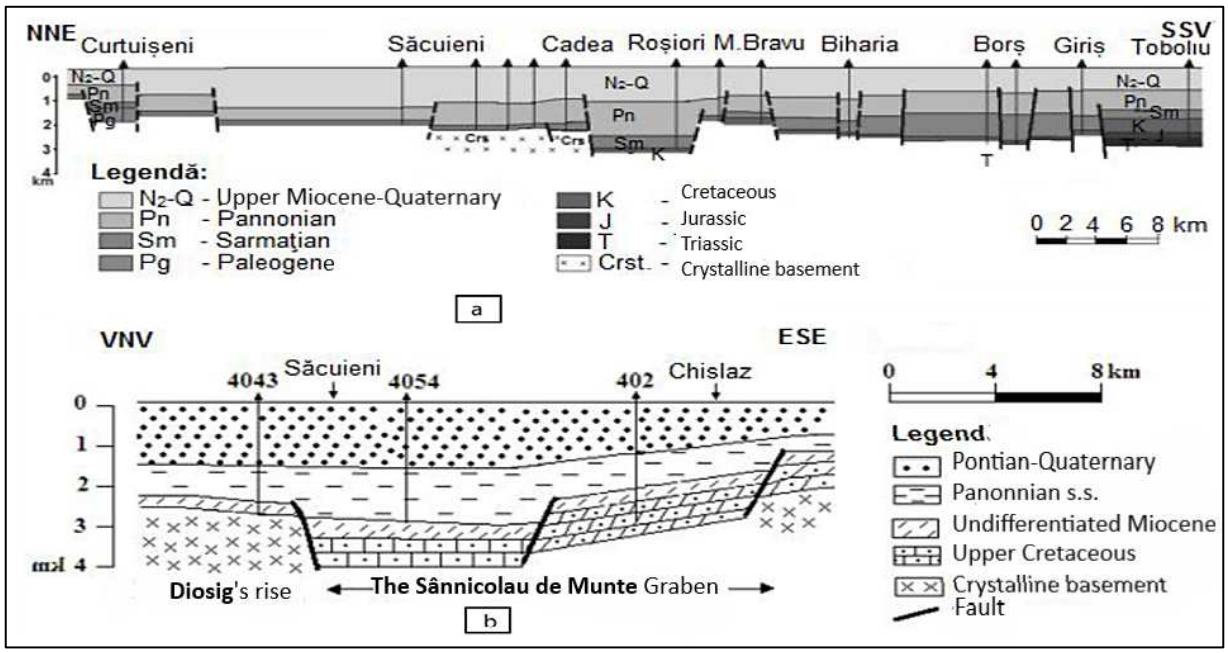


Figure 38. Geological section through the lower Pontian thermal aquifer Săcueni: (a) detail of the geological section Săcueni (b) the horst and graben structure of the basement.
(source: Roba, 2010).

Thermal waters can originate from meteoric (vadose) sources, resulting from infiltrated precipitation up to a maximum depth of 12 km where the critical temperature of 365°C is reached (at this temperature, regardless of pressure, water turns into vapor and returns to the surface). These waters are heated due to the geothermal gradient, with temperatures rarely exceeding 45° - 50°C. Thermal waters of juvenile origin have a relatively constant temperature and their own chemical composition, different from that of the rocks in the emergence area. In general, they are hyperthermal waters. Fossil (sedimentation) waters usually accompany oil and gas deposits (as is the case of those in the Oradea - Satu Mare area) (Preda et al., 1981).

During circulation through rocks, waters dissolve and carry various salts in solution and suspension form. Once on the surface, these substances precipitate and form deposits around the spring outlets in solid form or muds used, sometimes, therapeutically. Such mud deposits are found in Băile Felix and Băile 1 Mai. Almost all mineral and thermal springs often exhibit radioactivity

due to the presence of radon, thoron and actinon dissolved in the water (Preda et al., 1981).

Iron ion (Fe^{2+}, Fe^{3+}). Widely distributed in the lithosphere, iron is present in all mineral waters. Ferruginous mineral waters with therapeutic effects contain over 10 mg/l iron. These waters also consistently contain carbon dioxide.

Oil drilling and hydrogeological drilling have revealed thermomineral (geothermal) waters in all the basement and basin formations throughout the *Pannonian Depression*. The Triassic and Jurassic deposits yield thermal waters at Oradea and the Cretaceous ones at Băile Felix - Băile 1Mai. The Upper Pannonian produces bicarbonate waters at Cadea (with a temperature of 65°C), Sânnicolau de Munte and Biharia (with a temperature of 56°C) and at Tămășeu (with a temperature of 55°C). The thermality of these waters is primarly attributed to the geothermal gradient.However, some researchers have raised the possibility of deep magmatic sources (or "magmatic hearts") that release superheated vapors. These vapors may ascend and interact with shallow groundwater, heating it and leading to artesian discharge. As evidence, (Păucă, 1958, cited by Preda and Țenu, 1981), points to the carbonated springs at Tămășeu and Sălard – located in the middle of the plain – which exhibit high radioactivity and temperatures reaching 125˚C at relatively shallow depths of around 2,500 meters.

On *the eastern edge of the Pannonian depression*, along the fault lines that separate the mountain area from the plain, the thermal waters are calcium and magnesium bicarbonated (at Băile Felix and Băile 1 Mai), with a low concentration of salts (about 1 g/liter). North of Crișul Repede (Borș, Derna, Mihai Bravu, Sâniob, Abrămuț) in the Pannonian deposits (Pontian) concentrated chlorosadic, bromo-iodinated waters are found, with a temperature between 70 - 80°C.

The presence of thermal waters in the Borod basin was identified by the 4784 Tileagd well that opened the limestones between 1509 and 2168, flowing water with a temperature of 56°C. Well 4785 Aleșd delivers thermal water with a temperature of 44°C from open calcareous and dolomite rocks between 674 and 1028 m (Țenu, 1981, cited by Orășeanu, 2020).

The Beiuș Basin is the area with the most thermal aquifers outcrops among the Neogene basins, as it includes both the necessary conditions for the presence of thermal waters with high temperatures, a foundation with productive reservoir rocks and great depths. The thickness of the Neogene deposits reaches up to 1600 m. Thermal springs from the Anisian dolomites emerge at both the periphery and center of the basin with temperatures up to 24°C. At Beiuș, well 3001 delivers water from the Triassic collector, with a temperature of 84°C from the interval 1850 and 2500 m (Orășeanu, 2020).

Natural cold mineral water and carbon dioxide resources

Carbonated waters form when vadose waters become enriched with juvenile carbon dioxide, in concentrations of at least 1g/liter. Carbon dioxide is widely distributed in Romania's subsurface and is consistenly associated with Neogene eruptive masses, where they have reached the surface or remained somewhere within the earth's crust. It is considered part of the Neogene postvolcanic activity in the East Carpathian and Apuseni Mountains, with deep extenstions reaching beneath the Western Plain. This is a useful mineral substance of economic interest when it is accumulated in deposits of free (dry) carbon dioxide, in which case it can be extracted through wells (Pricăjan et al., 1981).

Carbon dioxide (CO_2) mineralizes both groundwater and deep aquifers from the Pliocene and Quaternary deposits of the Western Plain. It ascends along basement fault lines from deep undergound. In Bihor County, carbon dioxide deposits are located in the northern part, in the Viișoara gas structure (at Viișoara), the Săcueni structure (at Ciocaia), the Diosig structure (at Diosig and Cadea) and the Mihai Bravu structure (at Mihai Bravu and Niuved) (Figure 38).

In the Săcueni area, at Ciocaia, carbon dioxide emerges naturally in strong bubbling springs and is exploited for food purposes (by processing raw natural gas, carbon dioxide of 99.98% purity is obtained). In the Mihai Bravu - Niuved and Viișoara areas, carbon dioxide was extracted from depths of around 600 m and used industrially to enhance crude oilrecovery in the field. This method involves gas injection (the "gas-lift" technique), where carbon dioxide is pumped underground at high pressure to displace and lift crude oil to the surface (Linc et al., 2007). Currently, both the crude oil and carbon dioxide wells in the Mihai Bravu - Niuved area are under conservation. Since 2020, there is an environmental authorization for the exploitation of of raw carbon dioxide in the Diosig - Cadea perimeter (www.anpm.ro).

Natural mineral waters. The term "mineral water" has had several definitions over time. The German school classifies these waters according to the chemical composition given by the solubilized minerals and the presence of carbon dioxide, and the French school according to the therapeutic effects (Feru, 2012). In Romania, there are also several definitions regarding natural mineral water. Vernescu (1988) reviews several definitions used in the Romanian space, which he considers do not fully capture all the characteristics of mineral water and proposes the following definition: mineral water "is natural underground or surface water, either athermal or thermal, with varying contents of salts, chemical elements, gases and radioactive substances, that exceeds at least one of the established minimum thresholds".

STAS 4621-69 defines ”mineral water as underground or surface water, thermal or cold, with a variable content of salts, gases or radioactive mineral substances, characterized by therapeutic properties or possibilities for industrial exploitation”.

The Mineral Water Guide states that in Romania, before the 1990s, in order to bottle a mineral water, it had to contain a quantity of dissolved salts greater than 1000 mg/l, a carbon dioxide content greater than 500 mg/l and have therapeutic effects that were mentioned on the label (Feru, 2012). According to Government Decision (HG) 1020 / 2005, which implements Directive 80/777/EEC (with subsequent additions), a distinction is made between natural mineral waters and medicinal waters terms. Thus: ”Natural mineral water is microbiologically pure water that originates from an underground aquifer or water table and is extracted via one or more natural springs or drilled boreholes”.

Natural mineral water has no content limits for the majority chemical constituents. However, compounds with toxic potential are strictly regulated. Contamination indicators (markers of original purity) have the most restrictive values among all bottled waters. All natural mineral waters currently on the market must be recognized by publication in official monitors, both at national and European levels, mentioning the commercial name, the extraction source and the bottling location (Feru, 2012). Most natural mineral waters bottled in Romania are carbonated calcium -hydrogen waters, with secondary magnesium or sodium content. Sodium-sulfate or sodium-chloride waters are rare and usually have low mineralization (oligomineral waters) (Feru, 2012).

In the Western Plain, specifically in Bihor County, due to the presence of carbon dioxide rising from deep fault lines in the basement rock, oriented east-west, several locations with bicarbonated waters exist north of Oradea (Sălard, Sântimreu, Tămășeu), as well as in the south of the county, at Tinca. Initially, these waters were used for both drinking (Tămășeu, Sântimreu, Tinca) and therapeutic purposes (Tinca). However, due to declining flow rates and stricter legislative conditions regarding the bottling and marketing of natural mineral waters, bottling was abandoned. Nevertheless, the local population or those in transit continue to be supplied with mineral water from the boreholes in Tămășeu and Sântimreu (Linc et al., 2023). In the Tinca balneoclimatic resort, these waters are recommended for external cure, and three public restrooms are available.

In the mountainous area, within *the Bihor Mountains*, flat mineral waters have been identified on the territory of the Budureasa commune (Cuciului Spring and Minunilor Spring). A special note is presented by the spring located in *the Plopiș Mountains* in the Pădurea Neagră holiday village (near Voivozi village) where carbonated water emerges.

In the Tămășeu - Sântimreu - Sălard sector, the hydromineral deposit contains bicarbonated, magnesium - rich waters, with a carbon dioxide content of over 1.5 g/l. The mineralized aquifer layer, found in polygenic sands was opened at a depth of 120 m and discharges freely with low flows (below 0.2 l/s). In the 1970s, this aquifer was exploited through the bottling station at the Tămășeu railway station (Pricăjan, 1972). Currently, water from the Tămășeu-Sântimreu-Sălard aquifer discharges unused through the wells at Tămășeu (Figure 39) and Sântimreu (Figure 40).



Figure 39. Natural mineral water well in Tămășeu (Tămășeu commune).



Figure 40. Natural mineral water drilling in Sântimreu (Sălard commune) in 2021 and 2022.

Regarding the natural mineral water from Tămășeu, Szabó (2018) mentions: "After the opening of the railway traffic on the Oradea - Valea lui Mihai line, in 1877, a well was drilled near the station to feed the locomotives. The water that flowed from the well was mineral water. Balneological studies conducted at that time showed the presence of soluble lithium salts in a higher than average quantity. The mineral water was intercepted at a depth of 276 m, its commercialization began in 1912. In the 1960s, it was still bottled and was commercialized under the name Lithium". Currently, there are two boreholes in Tămășeu at a distance of a few meters from each other. These are positioned in the built-up area of the homonymous village, on its outskirts, in the vicinity of the disused railway station, in the meadow of the Barcău River, at about 107 m altitude.

Every year, the waters of Lithinia, Hera and Izvorul Minunilor are mentioned in ***the List of Natural Mineral Waters Recognized in Romania***, although currently only Izvorul Minunilor is bottled and marketed (as both still and carbonated natural mineral water).

The 2014-2020 Local Development Strategy of Sălard commune mentioned that, prior to World War II, the water from the Sântimreu spring was bottled. Hungarian historical documents mentioned by the doctor Szabó (2018) reveal that in the Barcău meadow, as early as the 1800s, and perhaps even earlier (Dani and Nagy, 2017), there were several natural springs of effervescent

sour waters on the territory of the village. These waters were used for a time in local baths (Szalárdi fürdő), as well as for making beverges by mixing them with wine.

In 2018, three boreholes were drilled in Sălard to supply drinking water to the villages of the homonymous commune. One of the boreholes, after reaching a depth of 200 m, probably intersected a carbon dioxide pocket, causing the water column to erupt. In April 2021, it was observed that the water was flowing freely and was slightly carbonated. In October 2021, the well erupted again and to prevent another eruption, it was sealed (Figure 41, Figure 42, Figure 43). At the exit of Sălard village, towards Marghita, there is another borehole that once brought carbonated mineral water to the surface, but it is now clogged.



Figure 41. Sălard. First water eruption of July 2018. (www.ebihoreanul.ro)



Figure 42. Sălard. Drinking water drilling in April 2021



Figure 43. Sălard. The second water eruption of October 2021. (www.ebihoreanul.ro)

In the journal *Hydrogeological Studies*, a study entitled "Hydrogeological and hydrochemical research in the Oradea - Aleșd map paper" (Mihăilă, 1971) includes some of the limited information available regarding natural mineral springs (carbonate) in the area between the Pădurea Neagră locality and the homonymous holiday village (Figure 44). The study specifies that in the crystalline rock complex, water accumulated from precipitation circulates through the alteration sector, forming emergences in certain places, with flow rates varying between 0.02 and 0.05 l/s. The mineralization of the water occurs through the mixing of infiltrated meteoric waters with carbon dioxide rising from depth along fracture lines. Part of the carbon dioxide dissolves in the water as carbonic acid, while the rest is released in the form of carbon dioxide. The main characteristic of these waters is their high carbon dioxide content (132.7 - 409.2 g/l). Downstream from the former glass factory, six springs with low flows (0.02 - 0.05 l/s) are present.

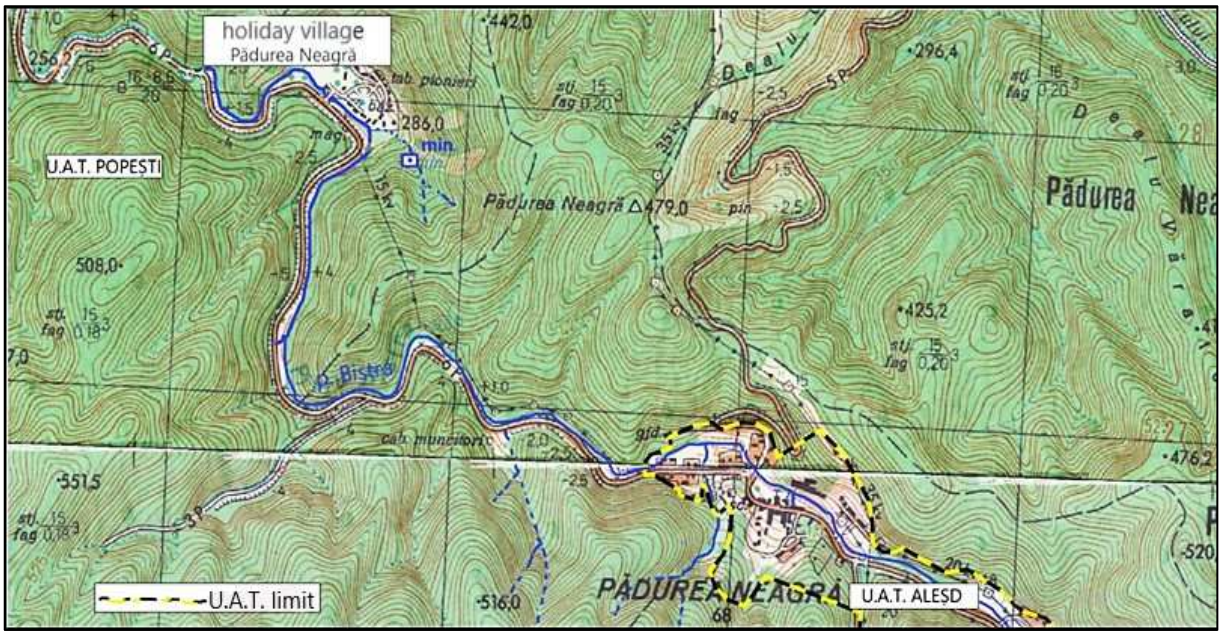


Figure 44. Location of the carbonated mineral spring captured in the Pădurea Neagră holiday village (Popești commune).

One of these springs, located near the school camp (former children's sanatorium), is captured and has a flow rate of 0.02 l/s (Figure 45).

Other mentions of this carbonated mineral spring are found by authors Pricăjan (1972) and Țenu (1981), who mention that carbon dioxide dissolves in the groundwater from the cracks in the superficial alteration sector of the Plopiș crystalline and forms an emergence with carbonated water, with a flow rate of approximately 2.5 l/min (Figure 46).



Figure 45. The carbonated spring captured in the Pădurea Neagră holiday village (Popești commune).



Figure 46. Another spring with flat mineral water from the Black Forest (Popești commune).

In Tinca, several known sources of bicarbonate exist, inlcuding sodium or sodium chloride, weakly calcium and magnesium-rich, and ocasionally sulfated and iodized mineral water. These

mineral water accumulate in deep aquifers within Pliocene strata, as well as in the phreatic aquifer layer of the lower terrace of the Crișul Negru River (Pricăjan, 1972).

In 1880, a deposit was discovered through a well dug for mineral waters, which later formed the basis for the development of balneary activity in the locality. The waters with curative properties were discovered in 1884, through the "Old Well", which still flows today from a depth of 270 m[23]. It was during this period that the first baths and treatment centers were established.

Known for both external and internal therapeutic treatment, as well as for previously bottled water, the Tinca resort lies on the border between two depressional basins: the Beiuș and Zarand basins, separated by the Codru-Moma Mountains. Thus, the subsoil of the resort consists of formations belonging to the Apuseni Mountains, covered by Neogene sediments, particularly Pliocene in age. Bicarbonated mineral water - sodium-rich or chlorosodic mineral water, weakly calcium and magnesium-rich, and sometimes sulfurous and iodized, accumulates in both Miocene and Pliocene formations, as well as in the alluvial deposits of the Crișul Negru River.

Currently, there are five mineral water sources in Tinca, two of which are thermal, reaching temperatures of up to 38 - 40°C.

Over a century ago, the resort had two wells (one with a large diameter and the other similar to those used for drinking water) as well as a well dug in 1880 to a depth of 270 m. Although the wells are close together, they provide water of various types and mineralizations. The well known as Spring No. 1 produces alkaline water used for internal treatment (Munteanu, 2013). Two other wells – Spring No.2 (6.1 m depth) and Spring No.3 (6.25 m depth) - crossed the alluvium of the Crișul Negru terraceand are terminated in Pontic marls. The first one, located near fractures, produces water used in the baths mixed with the water of spring No. 4 (Figure 47). The second well, flowed until 1960, provides sulfurous water, also used for bathing. In 1958, the Bucharest Institute of Balneology and Physiotherapy drilled two boreholes at Tinca: one at a depth of 264 m (Spring No. 4), and another at 314.38 m (Spring No. 5) (www.bailetinca.ro).

[23] www.bailetinca.ro



Figure 47. The natural mineral water fountains from the Băile Tinca.

Spring No. 4 has a high mineralization, with a pronounced chlorosodic content, due to the water circulation within Badenian deposits. The water is partially used to prepare heated mineral baths, and was previously bottled. The water of Spring No. 5 has a temperature of 26°C, contains small amounts of methane, and is currently used in the resort's flower greenhouse, but not being included in the balneary circuit. The presence of carbon dioxide in the mineral waters at Băile Tinca is attributed to the existence, at depth, of a horst structure bordered by tectonic fractures, which facilitate the ascent and diffuse migration of gases, which enrich the underground circulating waters infiltrated on the edge of the baths.

During 1981 - 1982, the National Institute of Recovery, Physical Medicine and Balneoclimatology executed two additional drillings: a borehole F3 at a depth of 631 m and borehole F4 at a depth of 550 m. These revealed the same type of water as previous wells, but were not put into operation due to interference with nearby sources.

Another category of natural mineral springs includes those considered to have still water (non-carbonated). In Bihor County, several such springs emergence within the Budureasa commune, such as the Cuciului spring, which supplies the still mineral water Hera and the well-known Izvorul Minunilor spring, located in the mountain resort Stâna de Vale (Figure 48).

The study *Hidrogeologia carstului din Munții Apuseni* (The Hydrogeology of the Karst in the Apuseni Mountains) by Orășeanu (2016) explains the genesis of the major springs in the southwest of the Vlădeasa Massif (Izvorul Minunilor, Ciucului, Pescăriei, Rampei) Their formation is linked to the presence of carbonate rocks, which function as drains for the waters accumulated in other types of rocks. The water from Izvorul Minunilor emerges from a dolomite outcrop, which, although reduced in extent at the surface, is well developed in the subsurface and serves as a drainage for the aquifer accumulations in the formations above. The water is of calcium bicarbonate type, with a very low mineralization, having a neutral-weak alkaline character. It is

non-radioactive, biologically pure, colorless and has a pleasant taste. Research on the behavior of the chemical constituents in the spring water indicate a very good stability of the chemical composition. It was approved as still water in 1984 and recertified in 2001 by the National Agency for Mineral Resources and since then, it has been bottled under the name *Izvorul Minunilor* (Orășeanu, 2016) at the industrial platforms in Rieni and Sudrigiu.



Figure 48. The oligomineral spring with flat water "Izvorul Minunilor" in the balneoclimatic resort of Stâna de Vale, Budureasa commune.

The Cuciului spring produces tasteless, odorless water with no visible sediment (turbidity 0). It falls into the category of oligomineral waters (fixed residue 98.3 mg/l) of the calcium bicarbonate type. It was certified as still water by the National Agency for Mineral Resources in 2005 and marketed under the name Hera spring (Orășeanu, 2016). It was bottled at the same industrial platforms until 2018.

Therapeutic mud resources

As water circulates through the rocks, it dissolve and carries various salts, both in solution and in suspension. Once they reach the surface, these substances precipitate, forming solid deposits or muds around the emergences, some of which are used therapeutically. Such muddy deposits are found in Băile Felix and Băile 1 Mai (Preda et al., 1981; Pricăjan et al., 1981).

Therapeutic muds (peloids) are substances from the mud sediments category, whose genesis results from peloidogenetic processes occuring in aquatic environment, frequently saline-lacustrine ones. In these settings, biochemical processes play a critical role in defining both the physicochemical characteristics and types of therapeutic effects relevant to medical balneological practice.

In Bihor County, such muds are found only in the commune of Sânmartin, in the area of the balneoclimatic resorts of Băile 1 Mai and Băile Felix, particularly in the meadows of the Peța and Hidișel streams, where they developed into swampy sectors in which peat formations accumulated. Better known, those from Băile 1 Mai were exploited for balneal treatment together with the thermal water.

In his 1985 publication, *Substanțele minerale terapeutice din România* (*Therapeutic mineral substances from Romania),* Pricăjan briefly presents the peat deposits in the Peța and Hidișel meadows, based on two earlier prospecting works from 1962 and 1979 stoed in the archive of the I.G.P.S.M.S. (Geological Prospecting Enterprise for Solid Mineral Substances) Șoldea (2003) also references a well for mud exploitation. The following summary of therapeutic mud deposits is based on Pricăjan (1985) (Figure 49). The thickness and approximate extent of the peat bog at Băile 1 Mai, were first estimated in 1962, during drilling carried out to evaluate reserves. Shallow drilling resumed between 1977 and 1979, focusing on three perimeters within the two resorts: one in the east of Băile 1 Mai, in the Jariște Valley floodplain, near Lake Peța (also researched in 1962) (marked with the number 1 on the map), another in the meadow of the Hidișel stream, north of the Băile Felix resort (marked with the number 2) and the third along the Hidișel stream, at the southern boundary of Băile Felix resort (on the map it is marked with the number 3).

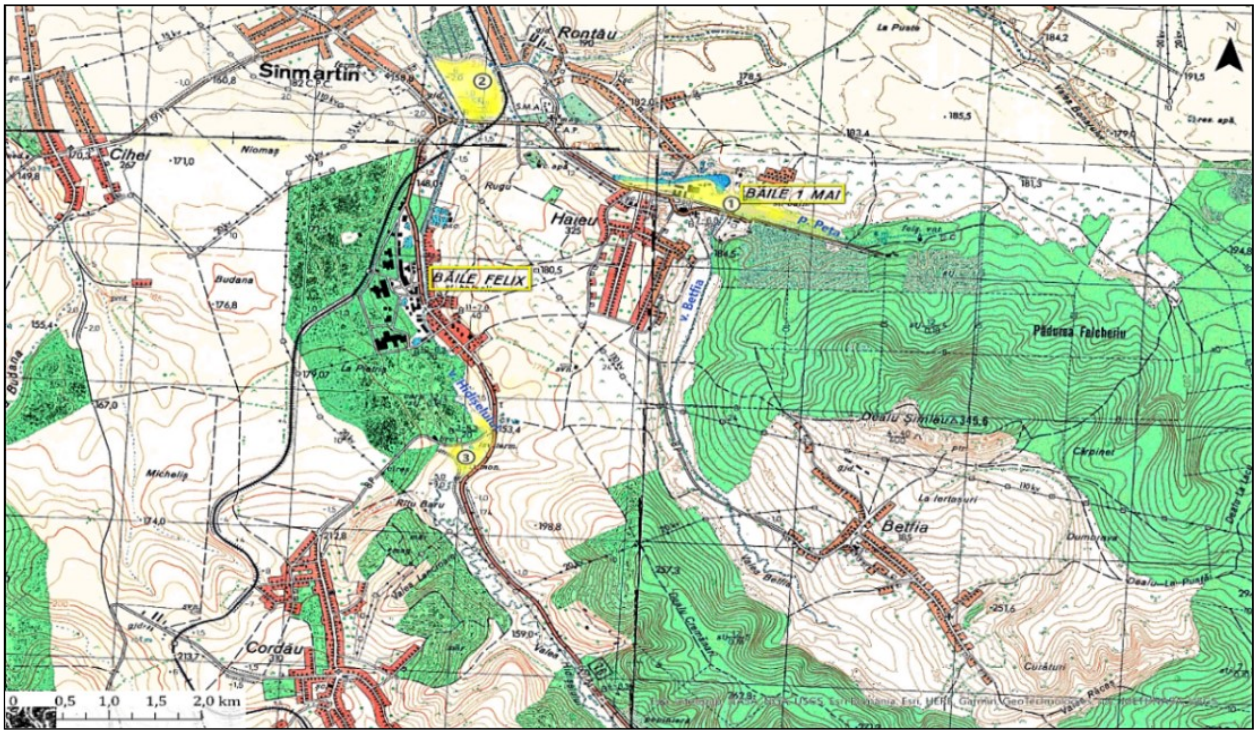


Figure 49. Sapropelic mud resources from the balneoclimatic resorts of Băile 1 Mai and Băile Felix.
(according to Pricăjan's instructions, 1985, on topo map sheets at a scale of 1: 25.000)

In ***the Băile 1 Mai perimeter***, the drillings advanced to a depth of 10 m encountered a peat layer with a thickness of between 0.2 - 2.4 m and another layer of mud of 0.1 - 1.4 m located immediately below the peat layer. In some drillings dug near the Ochiul Țiganului spring, in the range of 0.8 - 2.3 m, an upper peat layer with a thickness of 0.4 - 1.0 m was found, separated from the lower layer by calcareous tuffs with numerous traces of fossil flora and fauna. The peat deposit is delimited to the west and north by the stream and Lake Peța and further by the Jariștei Valley. To the east, 600 m away from the lake, the area begins to thin out, with its southern boundary marked by the road connecting the resort to the forestry canton. The roof and bed of the deposit are generally composed of brownto eggplant-colored clays, while in the area of Ochiul Țiganului, is the strata are composed of calcareous tuffs and, occasionally, yellow sands. Based on the drilling results, the total volume was estimated at 10,000 m^3 of therapeutic mud and over 22,000 m^3 of therapeutic peat.

The analysis bulletins characterized these muds as sapropelic,with an advanced degree of humification (tendency of degradation with bitumen formation) and limited or insufficient hydration. This mud and peat deposit was formed during the Quaternary, originating from rich vegetation maintained by the thermal springs of a lake, that once had a much greater extent than it does today.

The perimeter north of Băile Felix contains a deposit formed by a peat layer with lateral transitions into mud, with a thickness ranging from 0.1 to 1.4 m. In most drillings the peat layer measures only 0.3 - 0.4 m and presents discontinuous development, allowing for the identification of three distinct lenses.

The peat extension from the confluence of the Hidișel and Peța streams (north of Băile Felix) is delimited to the south by the Oradea - Băile 1 Mai road, to the east by the Oradea - Vașcău railway, to the north by the Peța stream, and to the west by the Hidișel stream. The roof deposits have a thickness of 1.2 - 3 m, composed of clayey dust, dusty clays or fine dusty, clayey sands. The underlying strata (bed) are more varied, including clays, sandy dusts, clayey sands and even fine and coarse sands. The analyses indicate a sapropelic mud with an advanced degree of humification and hydration at the limit or insufficiently. The drillings indicated the existence of a total volume of peat with therapeutic mud properties exceeding 6000 m^3.

5.1.4. Physico-chemical properties of geothermal waters in Bihor County

Interest in the exploitation of geothermal waters began to be evident in the mid-20th century, when, immediately after the execution of a drilling well, physico-chemical analysis were carried out and their results published (Țenu, 1981; Airinei, 1987; Cineti, 1990).

In order to synthesize the physical and chemical characteristics of geothermal waters from the deposits of Bihor County, data from test reports were taken into account, obtained from economic actors who provided this information upon request, as well as from specialized literature. The physico-chemical composition of thermal waters from 20 localities was compiled and centralized (Table 18).

Table 18. Physico-chemical properties of the thermal resource from several localities of Bihor County.

Localities / Chemical properties of thermal waters	Aleșd	Mădăras	Sânnicolau de Munte	Livada de Bihor	Tămășeu	Săcueni	Chișlaz	Beiuș	Marghita	Sarcău	Ștei	Chereșeu	Cenaloș	Valea lui Mihai	Mihai Bravu	Răbăgani	Ciocaia	Ciumeghiu	Borș	Adoni
Water temperature(^{0}C)	-	46	57	-	61	90	-	70	70	-	-	-	-	20	60	24	67	-	-	-
Turbidity (NTU)	2,27	-	-	0,31	-	-	0,22	0,54	-	-	38,9	-	-	-	-	-	-	-	-	-
Conductivity (pS/cm)	948	1324	4940	772	4139	11350	3450	472	8600	38512	1063	5900	40000	6800	5020	absent	10990	absent	absent	3650
Salinity (%)	0,5	absent	2,6	0,4	absent	absent	1,8	0,2	absent	absent	0,9	absent	absent	absent	7	absent	absent	absent	absent	
Hardness (Σ Ca2+, Mg2+)	17,29		1,51	19,47	1,34	1,26	1,79	12,7	1,96	165,31	60,92	2,02	60,20	2,97	1,54	absent	1,26	15,6	absent	1,68
pH (unit pH / temp)	7,06	7,6	7,95	6,61	7,82	7,45	8,4	7,4	7,8	6,8	7,3	7,85	6,90	8	7,9	absent	7,8	87,6	7,4	7,7
TDS (total dissolved solids) (mg/l)	457	675	3200	371	2800	4330	1750	225	2052	29910	878	4300	19852	absent	2100	absent	8790	absent	absent	1919
Cation																				
Sodium (Na^+) (mg/l)	absent	328,2	1125,0	absent	791	1640,0	834	41,7	900	10640	absent	1642,0	7400,0	1100	922	62,8	3850	1500	4483	748
Potassium (K^+) (mg/l)	absent	8,0	16,4		12	17,20	8,20	25	8-18	400,00	absent	19,80	120,00	80	9,5	2,2	23,05	absent		85
Calcium (Ca^{2+}) (mg/l)	absent	8,0	32,7	110,07	8,2	4,40	7,60	50,40	3,5-7,8	38512	292,80	7,41	216,03	7,48	3,91	68,5	4	13,6	75,15	5,3
Magnesium (Mg^{2+}) (mg/l)	39,93	2,7	9,9	17,63	5,3	3,89	3,15	24,78	2-5	343,87	86,50	4,26	130,36	8,39	8,6	12,1	2,18	2,2	22,19	4,0
Iron (Fe^{2+}) (mg/l)	absent	0,1	0,07	absent	0,156	0,20	0,17	363	0,64	10,39	3,861	0,25	7,40	absent	0,36	absent	0,17	absent	absent	absent
Total iron (mg/l)	0,422	absent	absent	0,051	absent	absent	0,086	0,195	absent	absent	absent	absent	absent	absent	absent	absent	absent	1,05	absent	0,38
Fluoride(F-) (mg/l)	absent	absent	absent	absent	absent	absent	absent	absent	absent	absent	1,933	absent	absent	absent	absent	absent	absent		absent	
Ammonium (NH^+_4) (mg/l)	0,317	2,9	traces	traces	10,33	12,42	12,0	<0"05	6-9	74,14	<0,05	11,54	3,42	absent	absent	absent	absent	12,5	absent	11,54
Anion																				
Bicarbonates (HCO_3^-) (mg/l)	230,45	805,2	2659,6	297,17	1160	3032,8	1,656	239,7	130-475	5,34	124,44	2945,4	3721,9	1713,5	991	366,1	8091	3423	1628	2013
Nitrites (NO_2^-) (mg/l)	< 0,02	absent	traces	traces	1,99	0,21	<0,02	<0"02	absent	absent	<0,02	0,15	absent	absent	0,57	absent	absent	absent	absent	0,06
Nitrates (NO_3^-) (mg/l)	< 0,1	5,0	7,9	37,54	absent	0,10	<0,1	<0, 1	0,36	absent	0,434	0,12	0,19	0,36	0,34	absent	absent	absent	absent	0,06
Tone (SO_4^{2-}) (mg/l)	302,5	8,9	11,2	43,12	17	traces	<8	38,80	traces	8,62	1041,2	traces	30,45	10	44	48	12,35	62,3	139,	absent
Chloride (Cl^-) (mg/l)	43,91	63,8	278,0	35,28	915	824,44	299,15	<5,0	631,90	16902	<5	886,67	10106	760,4	414	7,1	831	333	6075	14,8
Alkaline (mval/l)	3,77	absent	absent	4,57	absent	absent	27,15	3,93	absent	absent	absent	absent	absent	absent	absent	absent	absent	absent	absent	absent
Metasilicic acid (H_2SiO_3) (mg/l)	absent	21,7	24,6	absent	absent	absent	absent	absent	absent	absent	absent	absent	absent	33	absent	absent	absent	absent	absent	absent
Metaboric acid (HBO_2) (mg/l)	absent	absent	24,9	absent	31,62	98,50	25,40	absent	15-27	194,13	absent	107,67	103,10	30,25	absent	absent	absent	121,6	absent	22,4
Silicone dioxyde (SiO_2) (mg/l)	absent	absent	44,083	absent	41,3	50,44	41,59	absent	40-45	55,04	absent	65,40	38,00	absent	absent	absent	absent	77,6	absent	22,4
Free carbon dioxide CO_2	absent	absent	absent	absent	1190	1570	absent	absent	absent	absent	absent	absent	absent	absent	447	absent	absent	absent	absent	absent
Permanganate index (mgO,/l)	absent	absent	absent	0,57	absent	absent	0,9	0,5	absent	absent	<0,5	absent	absent	absent	absent	absent	absent	absent	absent	absent
Organic substances (O_2) (mg/l)	absent	absent	1,6	absent	32,46	59,56	0,50	absent	35,44	19,2	absent	59,09	54,18	28,96	38,07	absent	60,5	128	absent	absent
Phenol	absent	absent	0,73	absent	0,62	5,19	0,30	absent	0,56	1,30	absent	4,65	4,50	0,51	1,14	absent	4,5		absent	5,36
Totalmineralization (mg/l)	absent	absent	4192,6	absent	4504,7	5704	2932,1	463,2	3047,8	32542	absent	5690,7	24877	3661	2771	597,8	13791	5536	12,79	2899

Source: Test report (Aleșd, Mădăras, Livada de Bihor, Beiuș, Marghita, Ștei); Gilău et al. (2001).

In Bihor County, the characteristics of geothermal (thermo-mineral) waters are fairly similar. This similarity depends on the continuity or interconnection between aquifers, regardless of their geological age. From a qualitative point of view, the common constituents—though present in varying proportions depending on the deposit - include Cl^-, NO_2^-, NO_3^-, HCO_3^-, CO_3^{2-}, SO_4^{2-}, PO_4^{3-}, Ca^{2+}, Mg^{2+}, Na^+, K^+, etc. However, there are some specific features of the physicochemical characteristics, closely related to the type of drained rocks, as well as to the influence of hydrocarbon and carbon dioxide deposits (Haidu et al., 2023).

The physicochemical properties of the reservoirs exploited by drilling determine their therapeutic suitability for treating various pathologies through balneary procedures. Thus, the presence of minerals in thermal water provides antioxidant properties, neutralization of free radicals, and reduction of sunburn risk (Posea, 1997).

5.1.5. Physico-chemical properties of some cold mineral waters from Bihor County

In order to highlight the physicochemical properties of cold mineral waters from Bihor County, an interdisciplinary study was conducted, which analyzed samples of cold natural mineral waters from three locations in Bihor County (two boreholes in Tămășeu and Sântimreu and one in the Pădurea Neagră holiday village) (Linc et al., 2023). Interest was given to these waters because they have been known and used for a long time, but have now fallen into obscurity in terms of their use either as drinking water or as waters with therapeutic properties.

The mineral waters from Tămășeu and Sântimreu, brought to surface through boreholes, have been used by locals for their therapeutic properties, especially since the late 19th and early 20th centuries. Then after the Second World War, they were less used, so that, currently, locals know little about the properties and qualities of these waters. However, until Romania's entry into the European Union in 2007, these waters were used for individual consumption, but the opening of many hypermarkets that offer a wide variety of bottled waters at relatively low prices, combined with the tendency of some local mineral waters to develop a reddish coloration over time, has considerably reduced the frequency of local supply flow from these sources. Currently, both locals and tourists continue to supply themselves, even sporadically, with natural mineral water from the drillings in Tămășeu and Sântimreu, as well as from the spring in Pădurea Neagră.

The study of these waters focused on the main physicochemical indicators (pH, conductivity, calcium, magnesium, potassium, sodium, lithium, iron, manganese, chloride, sulfate, nitrates, nitrites, HCO_3^-, CO_2, H_2S, dry residue at 180°C). In order to microbiologically characterize the samples of cold natural mineral water from Tămășeu, Sântimreu and Pădurea Neagră, six indicators were selected in order to determine the existence of pathogenic

microorganisms that could pose a danger to human health. The study also included a survey applied to residents in order to assess perceptions regarding the consumption of cold natural mineral water from the three sources analyzed.

The hydrochemical properties result from the analysis of pH and total mineralization. Thus, the pH values varied between a maximum value specific to the mineral water from Tămăseu (with a pH of 7.5) to a minimum value found for the water from the Pădurea Neagră spring (slightly acidic, with a pH of 6.5). The natural mineral water from Sântimreu registered a pH value of 6.84 units. The lower pH value observed in the Pădurea Neagră spring is the result of a significant anion footprint (Linc et al., 2023). Bodor et al. (2021) consider that long-term consumption of water with low pH can influence the solubility and bioavailability of some nutrients.

Total mineralization is a defining parameter that provides information about the potential use of mineral water as well as about the technical aspects that are necessary in exploitation. The quality of mineral waters depends on the concentration of dissolved mineral salts. For this indicator, it was found that the highest mineralization (7128 mg/l) was obtained in the water from the Tămășeu well, and the lowest value was obtained for the water from the Pădurea Neagră spring (3086 mg/l) (Figure 50).

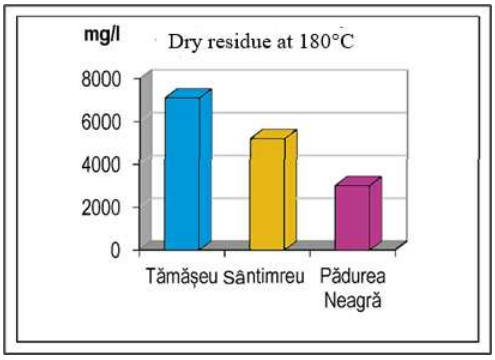


Figure 50. Dry residue at 180°C.

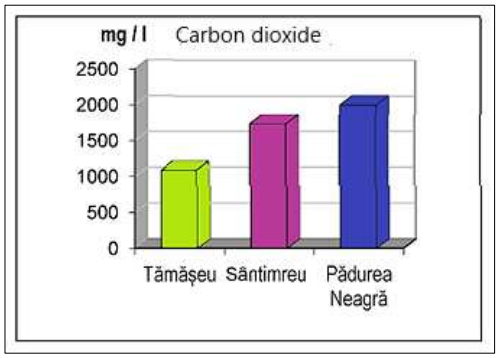


Figure 51. Carbon dioxide content.

Considering the salt content, the natural mineral waters from the three localities – Tămășeu, Sântimreu and Pădurea Neagră - are classified as highly mineralized waters (with residue content over 1500 mg/l) and acidified natural mineral waters (the water from the Pădurea Neagră spring which exhibits the highest concentration of carbon dioxide (as of 2004, mg/l) (Figure 51). The acidified mineral waters from Pădurea Neagră and Sântimreu spontaneously release carbon dioxide.

Regarding ionic compositions, the greatest non-uniformity in terms of cations concentrations, there are variations between the predominant characters of the mineral waters from the three locations.

Calcium and magnesium cations levels are elevated in Sântimreu and Pădurea Neagră waters. The consumption of mineral waters, especially alkaline mineral waters rich in bicarbonate and calcium, has a positive impact on bone mass and density, contributing to osteoporosis preventions. Therefore, calcium-rich mineral waters are recommended as calcium supplements (Heaney, 2006; Wynn et al., 2009; Vannucci et al., 2018). Magnesium is a cation present in natural mineral waters, typically found alongside calcium. It is an element with multiple functions in the human body, essential not only for the mineralization and health of the bone system, but also for the proper functioning of the muscular system (influences muscle contraction), the vascular system regula tion (mediates vasoconstriction and vasodilation) and nervous system activity (nerve impulses transmission and ion exchange through cell membranes) (Heaney, 2006; Vannucci et al., 2018).

Regarding *sodium*, concentrations higher than 200 mg/l can influence the taste of the water (this is not the case for the waters analyzed in this study), since the concentration of the cation was in the range from 47.8 mg/l (Tămășeu), to 45.3 mg/l (Sântimreu) to 9.2 mg/l (Pădurea Neagră). Sodium is one of the key components of blood plasma, lymphatic fluid, extracellular fluid and amniotic fluid which, together with potassium, ensures the maintenance of the body's water balance (Kodintsev et al., 2022).

Lithium in cold mineral waters is linked to the presence of clayey muds where it was retained during its underground circulation. Among the waters studied, the highest lithium concentration (4.4 mg/l) was determined in the mineral water from the Tămășeu well, which may place this water in the category of lithium-bearing waters. The bioavailability of lithium in mineral waters is very high, and studies have shown that the consumption of lithium-rich mineral waters can reduce the risk of suicide and prevent neurological disorders such as dementia or Alzheimer's disease (Munteanu, 2013; Seidel et al., 2019).

Iron was found in significant amounts in the sample taken from the Pădurea Neagră spring (0.57 mg/l). Iron participates in a wide variety of metabolic processes, including oxygen transport, deoxyribonucleic acid synthesis, and electron transport. Iron deficiency in the body can cause anemia (Abbaspour et al., 2014). Iron overdose can cause serious health problems, such as liver cancer, diabetes, liver cirrhosis, cardiac and central nervous system pathologies, as well as infertility.

Regarding anions, the bicarbonate anion (HCO_3^-), was found to be predominant, followed by chloride (Cl^-) and sulfate (SO_4^-). anions. The predominance of bicarbonate anions over those of strong acids (chlorides or sulfates) was found in all mineral waters analyzed. The bicarbonate ion is produced when water reacts with carbonate rocks such as limestone and dolomite. The mineral water from the Pădurea Neagră spring has the highest bicarbonate concentration, followed by that from

Tămășeu and Sântimreu. An appreciable amount of sulfates was found in the water from the Pădurea Neagră spring.

Mineral waters rich in sodium or potassium bicarbonates can neutralize gastric acid, thus increasing the gastric pH value in adult patients. Given their high tolerability, such mineral waters could be considered an alternative to pharmaceutical treatments. In addition, depending on the time of administration (before or during a meal), carbonated alkaline waters can reduce or stimulate gastric secretions, influencing gastrointestinal motility and gallbladder activity (Munteanu, 2013; Dumitrescu et al., 2022; Labenz et al., 2023). Therefore, it could be considered an alternative to hypocholesterolemic drugs (Capurso et al., 1999; Mennuni et al., 2014; Crespo et al., 2021). In addition, bicarbonate-sulfate-alkaline-terous mineral waters have antitoxic and trophic effects on the liver (Costantino et al., 2020).

A special case is the hydrogen sulfide-smelling water from Sântimreu. In addition to the effects determined by the existing cations and anions, hydrogen sulfide contributes to the properties of this water. Sulfurous waters stimulate gastric and biliary secretion through choleretic and cholecystokinetic effects. Hydrogen sulfide has a protective role on the intestinal flora against chemical aggressions and, therefore, heals mucosal wounds and reduces local inflammation. Sulfur is a constituent of some amino acids (e.g., cysteine), and through the thiol group of hydrogen sulfide, crenotherapy with sulfurous waters can heal lesions of the respiratory tract mucosa (bronchitis, chronic rhinitis, chronic obstructive bronchopneumonia) (Carbajo et al., 2017; Munteanu et al., 2021; Dumitrescu et al., 2022).

As a general characteristic of the analyzed natural mineral waters, according to the *Piper and Stiff diagrams* (Figure 52, Figure 53), the hydrochemical fingerprint is as follows: in the mineral water from Tămășeu, sodium bicarbonate (Na-HCO_3^-) is predominant; the mineral water from Sântimreu is of a mixed calcium-magnesium bicarbonate type (Ca-Mg HCO_3^-); in the mineral water from Pădurea Neagră, calcium bicarbonate (Ca-HCO_3^-) is predominant.

The dominant hydrochemical type is specific to the aquifers in the three analyzed areas due to the fact that most of them are concentrated in carbonate-rich reservoirs. The mineralization of a groundwater source may vary within the limits defined by the local lithology, and according to the specialized literature, these variations can fall within the range of 15–25%.

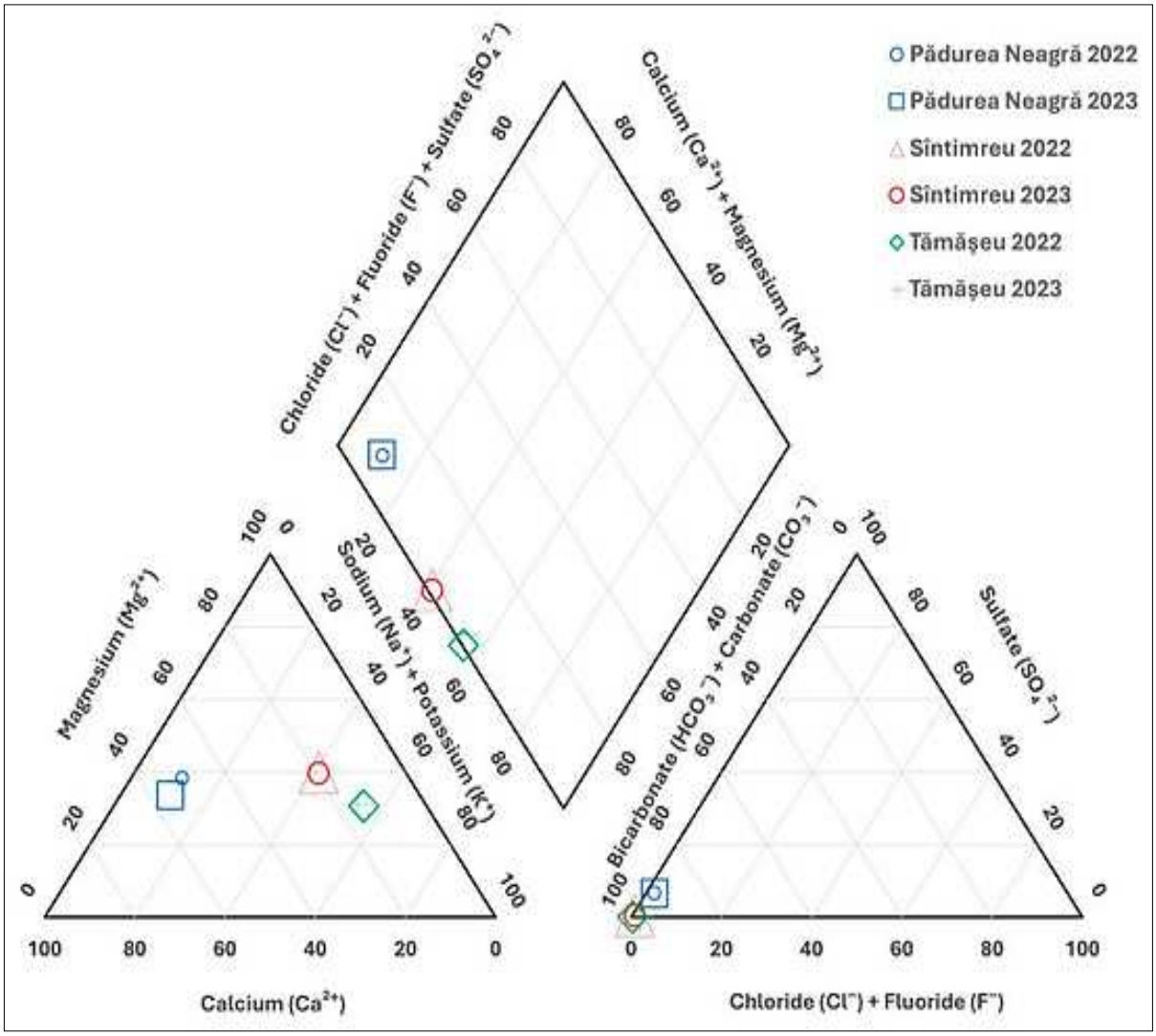


Figure 52. Piper diagram of the studied natural mineral waters.

(Source: Linc et al., 2023)

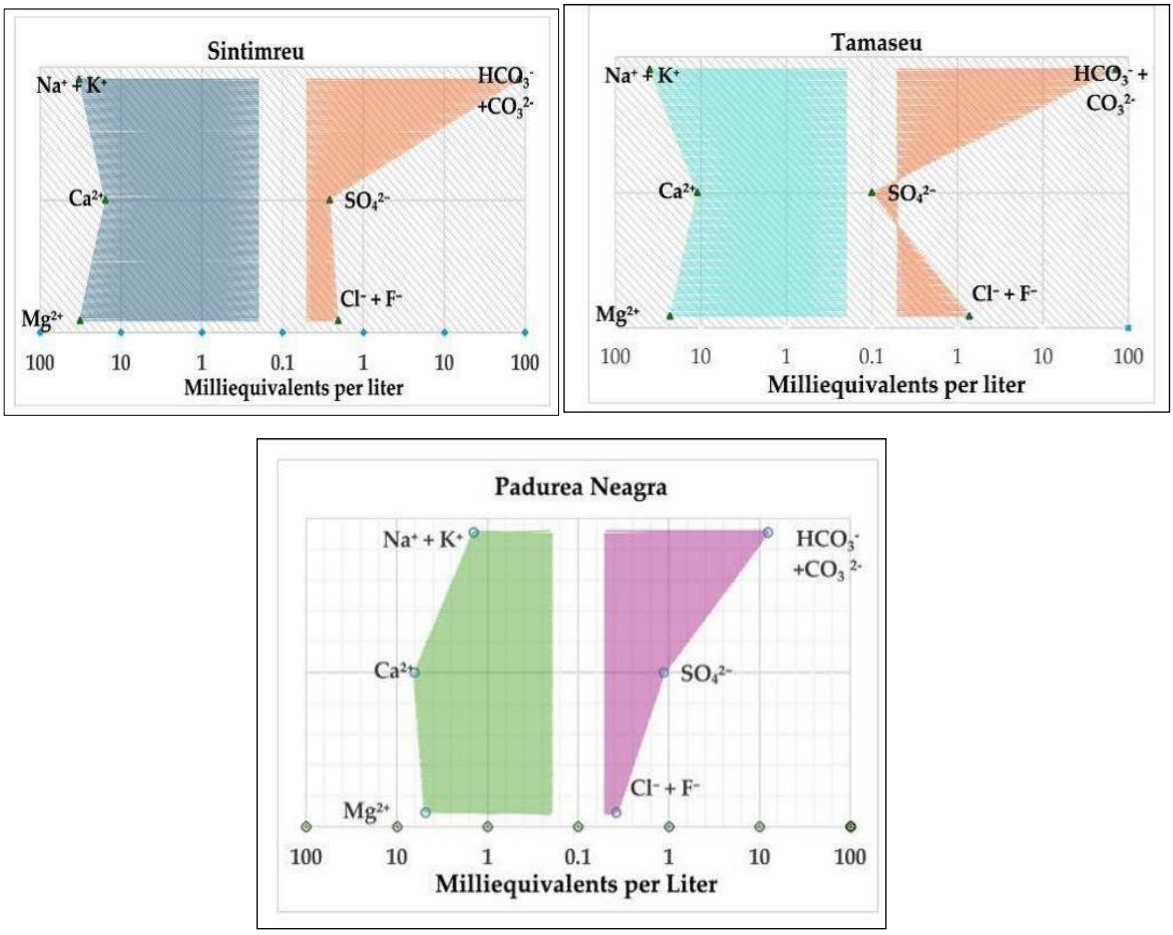


Figure 53. Stiff diagram of the studied natural mineral waters.

Referring to medical studies that show the high bioavailability of minerals in various mineral waters, they constitute accessible sources of calcium, magnesium, sodium, iron, bicarbonate and sulfates with effectiveness in the prophylaxis or treatment of various pathologies. An important role for every sustainable social and economic system, as well as for maintaining human health, is played by water quality.

5.1 6. Determination of the microbiological load in cold mineral waters from Bihor County

Regarding the microbiological characterization of natural mineral water samples from Tămășeu, Sântimreu and Pădurea Neagră, six indicators were determined (Table 19): total colony count (CFU) at 22°C and 37°C, coliform bacteria and Escherichia coli, intestinal enterococci, Pseudomonas faeruginosa and Clostridium perfringens (Linc et al, 2023). In the studied samples, it was found that there were no pathogenic microorganisms that could pose a danger to human health.

Table 19. Specific microbiological indicators of mineral waters from Tămășeu, Sântimreu and Pădurea Neagră.

Biological Indicator Total colony count at 22 °C	**Unit CFU/mL**	**Results**			**G.D. 1020/2005**	**Law 458/ 2002**
		Tămășeu	**Sântimreu**	**Pădurea Neagră**	**(Government Decision)**	
Total colony count at 37 °C	CFU/mL	0	0	0	100	100
Total coliforms and Escherichia coli	CFU/250 mL	0	0	0	20	20
Clostridium perfringens	CFU/50 mL	0	0	0	0	0
Pseudomonas aeruginosa	CFU/250 mL	0	0	0	0	0
Intestinal enterococci	CFU/250 mL	0	0	0	0	0
iological Indicator	Unit	0	0	0	0	0

The microbiological and physico-chemical characteristics of the mineral waters from Tămășeu, Sântimreu and Pădurea Neagră comply with the quality conditions imposed by the current legislation specific to both drinking water and natural mineral waters, so they can be included in the category of natural mineral water sources recognized in Romania.

5.1.7. Personal contributions regarding the therapeutic potential of cold mineral waters from Bihor County

Over time, the cold natural mineral waters from the Bihor plain have been used for both consumption (Tămășeu, Sântimreu, Tinca) and balneal treatment and crenotherapy (Tinca, Tămășeu, Sălard) (Linc et al., 2023). Following the disappearance of some springs due to frequent floods on the Barcău River (Sălard), frequent changes of owners (Tămășeu), decreased flows (Tămășeu) and the tightening of legislative conditions for bottling and marketing of mineral waters, the bottling of these waters was abandoned (Szabó, 2018).

Public perception regarding the quality and health effects of cold mineral waters from three mineral water sources in (Sântimreu, Tămășeu and Pădurea Neagră) was analyzed by applying a questionnaire.

Respondents reported varying concerns regarding the quality of local mineral water, as shown in (Figure 54).

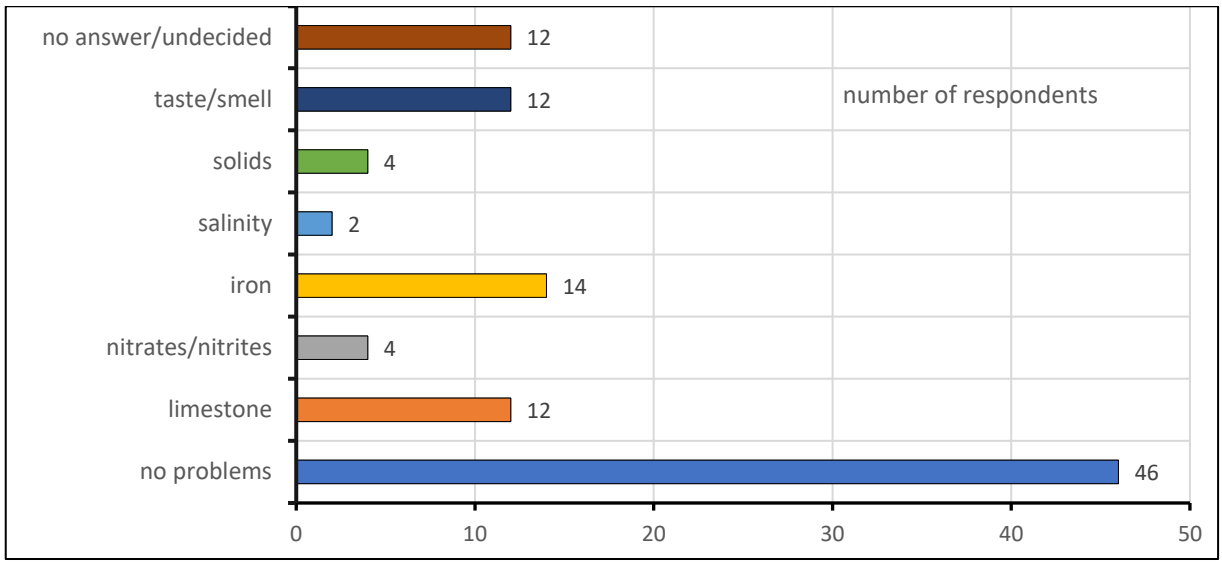


Figure 54. Respondents' response regarding the quality of mineral water from Tămășeu, Pădurea Neagră and Sântimreu.

To a large extent, respondents considered that local mineral waters are problem-free (46 respondents), some respondents (12) considered that mineral water has a taste or smell, another part considered that local mineral water contains solid particles of iron (14 respondents), nitrates or nitrites (4 respondents), limestone (12 respondents), and the smallest part of respondents (2) considered salinity to be the factor that influences the quality of local mineral water.

Regarding the identification of the main source of drinking water of the surveyed residents, our analysis showed that 20% use mineral water from Sântimreu, 18% consume water from Pădurea Neagră, 6% use water from Tămășeu, and 46% consume water from other sources such as from trade or from their own well.

Regarding the symptoms they experienced after consuming mineral water from the local well or spring, 38% of respondents did not give any answer, 28% of them stated that mineral water gives them a sense of well-being, good mood and vitality, 20% of them considered that they felt more energetic, and 20% of respondents stated that digestive problems decreased. Smaller percentages of those surveyed showed that their urinary problems (2%) and biliary disorders (2%) decreased, as well as the activity of the cardiovascular system (2%) improved (Figure 55). Some respondents stated that their liver diseases decreased. As mentioned, some respondents stated that they do not consume mineral water (especially water from the Tămășeu well) because it causes them gastric disorders.

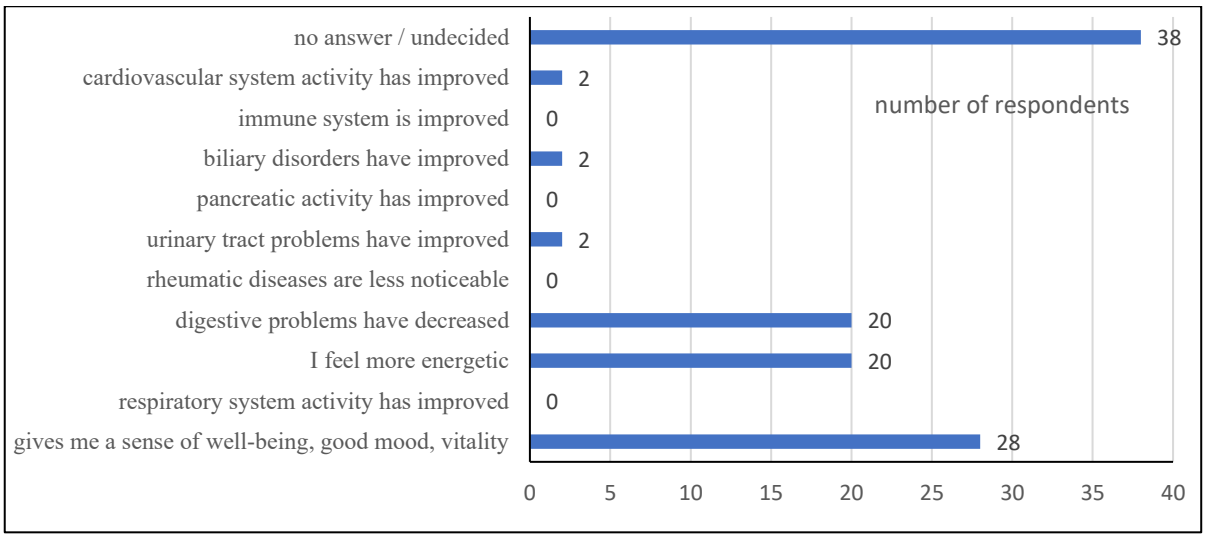


Figure 55. The health effect perceived by the population after consuming mineral water.

5.1.8. The effects of mineral water crenotherapy on human health

As a therapeutic tools, mineral waters are most frequently used in internal cure (crenotherapy) as well as in external applications, through techniques customized according to the type and stage of pathologies, also in associated conditions. Crenotherapy, a branch of balneotherapy, is the procedure by which mineral waters are used in internal therapeutic cure by ingestion. This method is performed in balneary resorts (where these natural mineral resources exist), and the ingestion of mineral water takes place at the source (spring), according to the specifications recommended by the specialist doctor and according to the pathological particularities of the patient (Dumitrescu et al., 2022).

The effects of crenotherapy are influenced not only by the chemical composition of the water used, but also by the method of its administration. Related to their chemical composition, there are indications for therapeutic cures in which simple alkaline or bicarbonate waters are used. The ingestion of these waters may have an inhibitory role on chlorhydropeptic secretion (when ingested an hour and a half before a meal) or may have a stimulating role (administered during a meal), also influencing gastric motility and the biliary tract, such as bile fluidization, depending on the method of administration (Teleki et al., 2012). The recommended treatment consists of two cycles of crenotherapy over the course of a year, but even better results can be obtained by performing therapy cycles one year after the end of the previous cycle (Mennuni et al., 2014).

There are certain digestive, hepatobiliary, metabolic and urinary disorders for which crenotherapy with mineral waters can contribute to a better outcome, by complementing the effects of basic dietary, pharmacological and surgical therapies (Dogaru et al., 2018).

In digestive disorders, crenotherapy with bicarbonate waters can neutralize gastric secretion, accelerate gastric evacuation and cause the release of gastric peptides (gastrin and endorphins) (Grassi et al., 1992). They are indicated in hydrochloric-peptic hypersecretion and gastroesophageal reflux disease (Grassi et al., 1987). Sulfated waters stimulate intestinal motility and are mainly indicated in chronic primitive constipation, having an osmotic effect and facilitating the release of cholecystokinin, due to the action of sulfate on the cells of the endocrine-paracrine system. Chloro-sodium waters stimulate intestinal peristalsis and intestinal secretion of water and electrolytes. To stimulate gastric secretion, cold bicarbonate waters, rich in gases, are administered in small sips (Fraioli et al., 2010). Other effects of crenotherapy are anti-inflammatory by rebalancing the composition of the microbiome associated with the gastric mucosa, which is usually destabilized during inflammation (Barnich et al., 2021).

In *biliary disorders,* the role of crenotherapy with bicarbonate mineral water is significant, due to the actions exerted on choleresis and the cholagogue action, contributing to the removal of gallbladder hypomotility and the correction of the tendency to form biliary sludge (Dogaru et al., 2018). Sulfate-bicarbonate-calcium-magnesium mineral waters primarily act on proximal and distal choleresis and on gallbladder motility, causing the contraction of smooth muscle in the gallbladder wall. The action of sulfate-bicarbonate mineral waters in the treatment of motor dysfunction of the biliary tract with hypokinesia and/or gallbladder hypotonia is choleretic in nature, due to the release of cholecystokinin from the paracrine endocrine digestive system. This effect is triggered by the presence of SO_4^{2-} and Mg^{2+} ions, leading to gallbladder contraction and relaxation of the sphincter of Oddi[24] (Mennuni et al., 2015).

Crenotherapy has an effect on *metabolic disorders* by influencing the lipid profile. It has been shown to reduce total circulating triglycerides, influence blood pressure, HDL-cholesterol and decrease glucose levels, polydipsia (increased fluid consumption) and polyuria (elimination of a large amount of urine), as well as reduce the need for insulin (Costa-Vieira et al., 2019). Bicarbonate waters neutralize metabolic acidosis in decompensated diabetes (Petraccia et al., 2006). In the case of gout (excessive accumulation of uric acid), crenotherapy is an effective adjunct to pharmacological and dietary therapy; sulfurous waters have hypoglycemic and antioxidant properties. Consumption of sodium chloride mineral waters with sulfate can contribute to the activation of carbohydrate metabolism (Costantino et al., 2020). During physical activity, bicarbonate waters restore fluids and salts, facilitate the elimination of nitrogen residues and counterbalance metabolic acidosis, typical of the athlete's stress syndrome (Petraccia et al., 2006).

[24] The sphincter of Oddi is a neuromuscular structure located at the junction of the bile and pancreatic ducts with the duodenum.

Ferruginous waters, which are usually carbonated waters, are considered stimulators of the activity of hematopoietic organs and contribute to the stimulation of general metabolism (Dogaru et al., 2018).

On *urinary disorders*, crenotherapy with bicarbonate mineral water can help reduce urine acidity and thus prevent the formation of uric acid-containing kidney stones, stimulates diuresis (volume of urine excreted) and uricuria (elimination of uric acid through urine), alkalizes urine and reduces uricemia (concentration of uric acid in the blood) (Petraccia et al., 2006). Sodium-rich bicarbonate mineral water during meals increases urinary sodium excretion without changes in potassium and mineral excretion, can slow the decline in glomerular filtration rate (Schoppen et al., 2008). It stimulates the volume of blood flow in the kidneys, which leads to increased diuresis and increased mineral load in the final urine (Pabisiak et al., 2020).

Contraindications of waters with low mineral content are for water retention, renal failure, cardio-circulatory decompensation; sodium-rich waters are contraindicated in hypertension; sodium-chlorinated waters in acid hypersecretion, peptic ulcer and hypertension; sulfurous waters in respiratory diseases with bronchospasm; bicarbonated waters in gastric hypochilia; sulfated waters, in digestive diseases with ulcerative lesions.

Prophylaxis through crenotherapy is indicated in people with risk factors for digestive disorders, with an inadequate diet and consumption of irritating foods (alcohol, coffee, spices) or exposed to stress. Hepatobiliary diseases are currently on the rise, being mainly favored by increased environmental pollution, alcohol and drug consumption. Spring mineral therapy can provide beneficial effects in chronic inflammatory diseases with immunological pathogenesis by inhibiting the immune response at the local level (Albertini et al., 2007).

5.1.9. The COVID-19 Pandemic: Effects on balneary tourism and patient profile – Personal insights

A retrospective study was conducted by analyzing the existing data in the annual balance sheet register for a period of 11 years (2010 - 2020) from the Balneary Treatment and Work Capacity Recovery Society (Hotel Ceres) in Băile 1 Mai. Data on the frequency and type of patients were extracted from the annual balance sheet register, which resulted in a centralization of the number of patients each year, as well as a classification of patient categories according to the type of treatment tickets, which identified the profile of the beneficiaries of balneary treatment.

The data from the patient registers were analyzed for a period of one year in order to identify the typology and frequency of pathologies of the beneficiaries of balneary treatment.

From the analysis of the annual balance sheet register, during the period covered by the study (2010 - 2020), it resulted that 131,875 patients benefited from balneary treatment. The largest number of patients who benefited from balneotherapy (13,515) was recorded in 2016, and the smallest number (5,252) was recorded in 2020. This was due to the imposition of the state of emergency and the state of alert, determined by the epidemiological situation created by the SARS-CoV-2 virus (Figure 56).

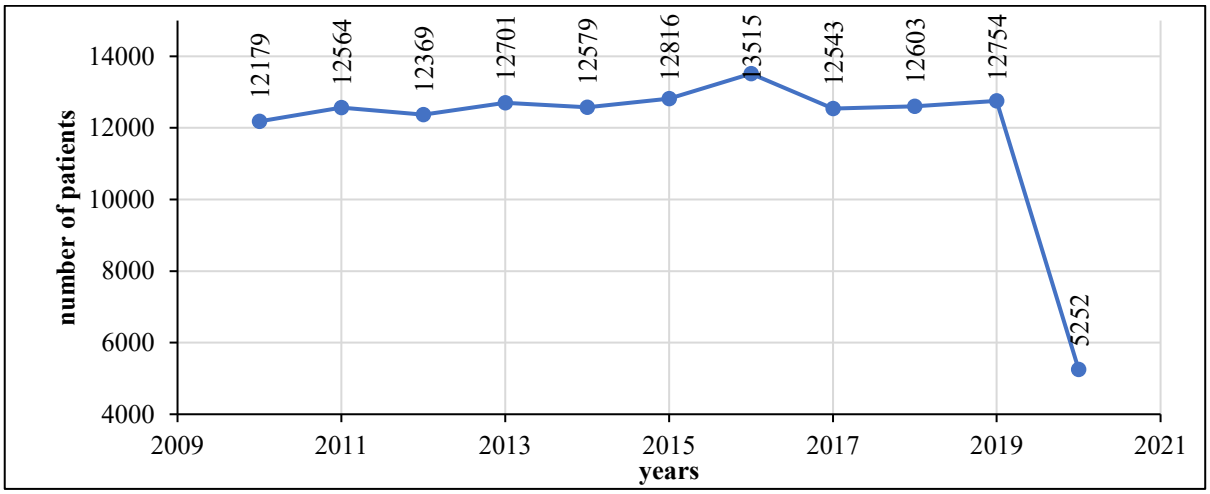


Figure 56. Annual number of patients who benefited from balneary treatment at the Balneary Treatment and Work Capacity Recovery Society (Hotel Ceres) in Băile 1 Mai between 2010 and 2020.

The influence of the COVID-19 pandemic, caused by the epidemiological situation, on balneary tourism can be easily observed through the low number of patients in 2020 compared to the rest of the study period.

The classification of patient categories was carried out according to the type of treatment tickets in order to identify the profile of patients who benefited from balneary treatment at the Society for Balneary Treatment and Recovery of Work Capacity in Băile 1 Mai (Figure 57).

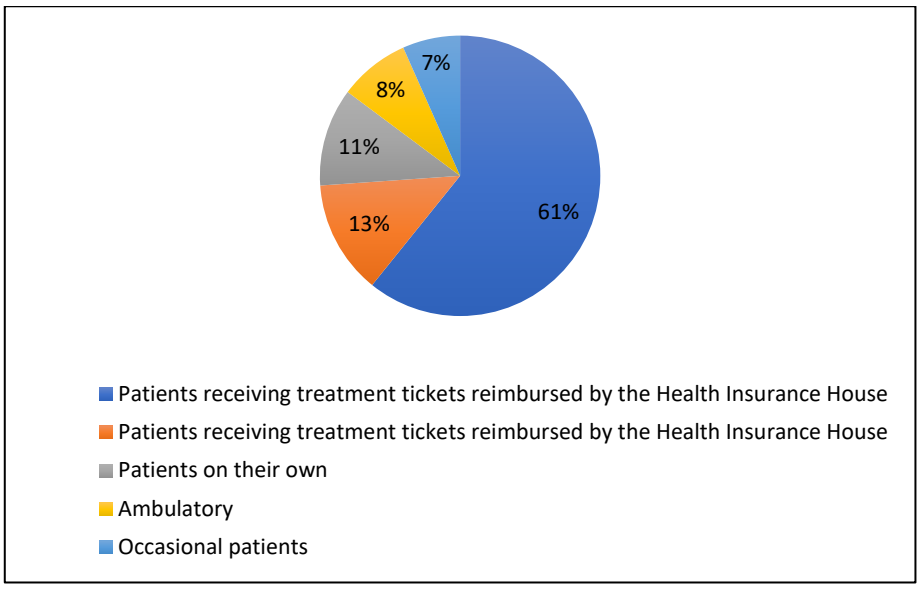


Figure 57. Categories of beneficiary patients depending on the type of treatment tickets from the Balneary Treatment and Work Capacity Recovery Society (Hotel Ceres) in Băile 1 Mai.

Regarding the classification of patient categories according to the type of treatment tickets, it resulted that the highest percentage (61%) included beneficiaries of treatment tickets settled through the County Pension House, followed by beneficiaries of treatment tickets settled by the Health Insurance House (13%), self-employed beneficiaries (11%) and outpatients (8%), and the lowest percentage was represented by occasional patients (7%).

This classification resulted in the fact that balneary tourism in the analyzed location is practiced by seniors, who benefit from state-subsidized treatment tickets through the pension house, through which they are settled for accommodation, meals and part of the balneary treatment.

In this context, it can be noted that seniors are much more concerned with improving the quality of life, affected by various conditions, in relation to prevention in professionally active people and less affected by pathological symptoms that occur with advancing age.

From the analysis of the patient registry for a period of one year, a classification of the *typology of pathologies* that had balneotherapy as a therapeutic indication at the Society for Balneary Treatment and Work Capacity Recovery in Băile 1 Mai was made, which resulted in arthrosis (osteoarthritis or degenerative rheumatic pathology) being the most frequent (1538 cases), followed by inflammatory rheumatic pathologies (636 cases), then neurological conditions (404 cases), depression and anxiety syndrome (371 cases) and the lowest frequency was that of metabolic pathologies (36) (Figure 58).

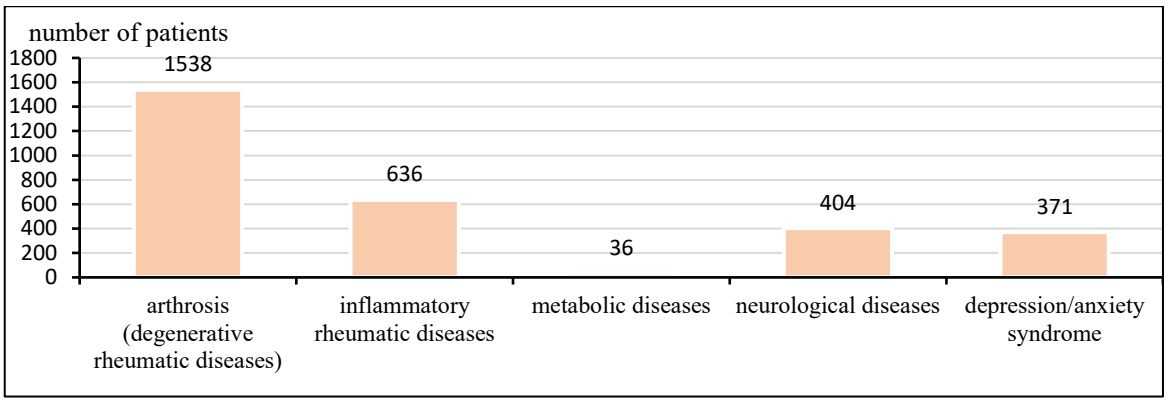


Figure 58. Types of pathologies that had balneotherapy as a therapeutic indication at the Balneary Treatment and Work Capacity Recovery Society (Hotel Ceres) in Băile 1 Mai.

Worldwide, osteoarthritis continues to be one of the main causes of „disabled years", a public health problem that is likely to increase in the future as the population ages (Forestier et al., 2016). It is a chronic pathology affecting the joints, which through progressive degeneration of the articular cartilage causes considerable pain and disability (Bijlsma et al., 2011).

According to data from the World Health Organization (2013), 9.6% of men and 18% of women over the age of 60 suffer from symptomatic osteoarthritis/osteoarthritis.

Thus, a classification of the types of osteoarthritis that had balneotherapy as a therapeutic indication was carried out at the Society for Balneary Treatment and Recovery of Work Capacity in Băile 1 Mai, in order to identify the frequency of the joint segment affected by this condition (Figure 59).

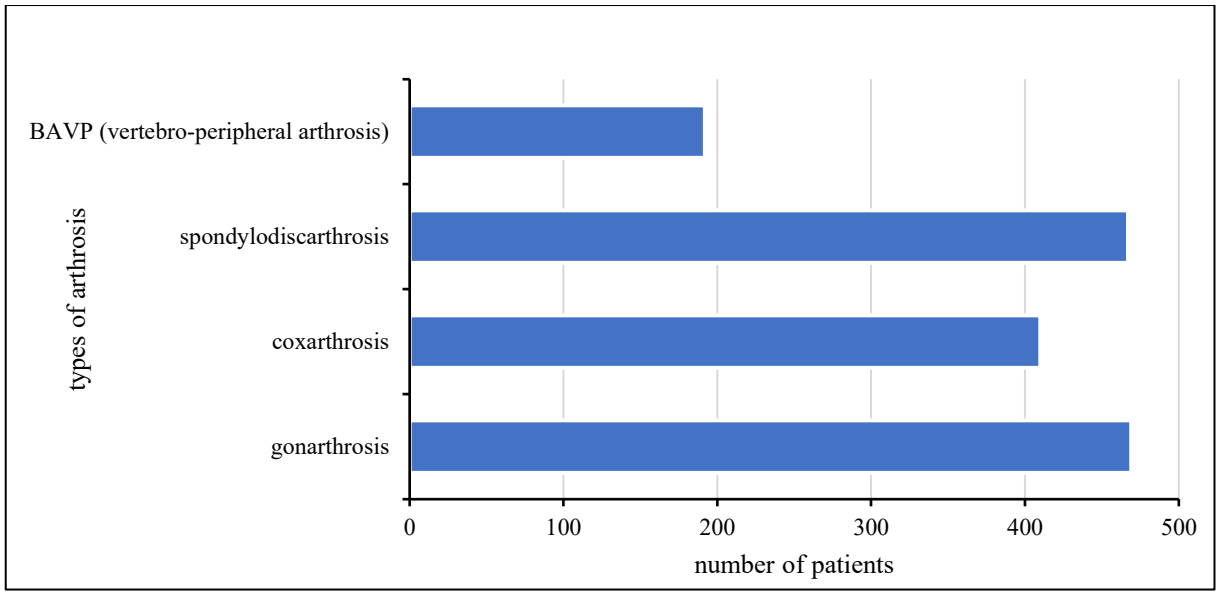


Figure 59. Types of arthrosis treated with balneotherapy at the Balneary Treatment and Work Capacity Recovery Society (Hotel Ceres) in Băile 1 Mai.

Gonarthrosis (knee osteoarthritis) was one of the most common degenerative joint pathologies, diagnosed in 481 patients, followed by spondylodiscarthrosis (455 patients), coxarthrosis (410 patients), and vertebro-peripheral osteoarthritis (192 patients).

5.1.10. Personal contributions on the effectiveness of mineral water balneotherapy in patients with gonarthrosis

Balneotherapy has been shown to alleviate the signs and symptoms of osteoarthritis affecting different joints, owing to the physical and chemical properties of thermomineral waters (Protano et al., 2023).

The impact of knee osteoarthritis is significant (60% of rheumatic patients) which underlines the socio-economic importance of this condition (World Health Organization). The prevalence of gonarthrosis, increases with age and exhibits marked gender differences. Notably, after the age of 50, women are considerably more affected of osteoarthritis of the knee (gonarthrosis) than men of the same age group (Jordan et al., 2007).

The pathogenesis of knee osteoarthritis is complex, involving processes of degradation of cartilage and subchondral bone, along with inflammation of the synovial sheath. Therefore, osteoarthritis affects the entire joint, impacting cartilage, synovium, subchondral bone, ligaments and muscles. Data show that the subchondral bone exhibits pathological changes that could be responsible for the damage to the overlying cartilage (Zhang et al., 2008).

During the remodeling process of subchondral bone, numerous mediators are released, including prostaglandins, leukotrienes, and growth factors, which affect the overlying articular cartilage, contributing to the onset of degenerative processes. On the other hand, inflammatory mediators released during the remodeling process by articular cartilage can also lead to subchondral bone damage in osteoarthritis (Pendleton et al., 2000).

A characteristic pathological change in subchondral bone is subchondral cysts, which occur in virtually all degenerative diseases, but are more frequently described in patients with knee osteoarthritis. Subchondral bone cysts are fluid-filled sacs found in the subchondral bone of the articular surfaces of joints (knees, hips, shoulders) as an adaptive change to joint overload. Other histopathological changes in the subchondral bone have been reported, such as increased trabeculae and bone volume, microlesions, and bone marrow edema-like lesions (Jordan et al., 2007; Ma et al., 2021).

Currently, there is no specific drug for osteoarthritis, and several interventions are recommended, such as patient education on orthopedic hygiene, non-pharmacological and pharmacological modalities. Over time, several studies have been conducted on the benefits of

oral and parenteral medications in knee osteoarthritis, but the results have been unsatisfactory. Nonsteroidal anti-inflammatory drugs, glucosamine, chondroitin sulfate, hyaluronic acid, and glucocorticoids have been proposed to reduce symptoms, such as reducing pain intensity, improving joint mobility, and reducing disability, but the results have been controversial (Pendleton et al., 2000; Jordan et al., 2007). As a non-invasive treatment modality, balneotherapy is used in various rheumatic conditions, including knee osteoarthritis (Ma et al., 2021).

Maccarone et al. (2023) demonstrated in their observational study the short-term effects of balneotherapy on pain, mood and quality of life in patients diagnosed with osteoarthritis in Italy.

In a systematic review of 17 studies, Protano et al. (2023) reported the effects of mineral water balneotherapy in managing the symptoms and signs of osteoarthritis. Pain and quality of life were the main parameters evaluated and both improved after mineral water balneotherapy, this improvement can be attributed to the physical and chemical properties of mineral water.

To highlighting the effectiveness of balneotherapy is superior to conventional physiotherapy in patients with knee osteoarthritis, a pilot study was conducted between June 2021 and August 2021, which began in the Băile Tinca resort where 58 patients with primary knee osteoarthritis were assigned to the experimental group (Ciurba (Pastor) et al., 2023).

Following the exclusion criteria, 49 patients remained in this group. Since there were not enough patients at Băile Tinca, due to the COVID-19 pandemic restriction, in order for the study to be effective, patients with primary osteoarthritis who agreed to enter the study from the Fiziohelp Med Salonta medical rehabilitation center were selected as a control group.

All study participants signed the informed consent before entering the study. Patients were evaluated before and after the balneary treatment. The study population was clinically examined in both locations, under the supervision of the same physician, specialized in physical medicine and rehabilitation. The protocol was approved by the Ethics Committee of the Băile Tinca Resort in July 2021 (opinion no. 85/07.07.2021).

The inclusion criteria were patients with primary osteoarthritis of the knee, unilateral or bilateral, according to the criteria of the American College of Rheumatology (Altman et al., 1986) osteoarthritic knee grade 2 and 3 according to the Kellgren-Lawrence[25] criterion; both sexes; aged between 40 and 80 years, volunteers. Patients with neurological deficits, fibromyalgia, inflammatory arthritis, microcrystalline arthritis, history of septic arthritis, lower limb trauma or

[25] Common method for classifying osteoarthritis severity.

surgery were excluded. No patient had received arthrocentesis (intra-articular puncture to evacuate fluid collections) and/or intra-articular steroid injection in the last 3 months.

The patient evaluations focused on several aspects that were presented in the chapter on research methodology and obtained data. The content of the study is presented in Figure 60.

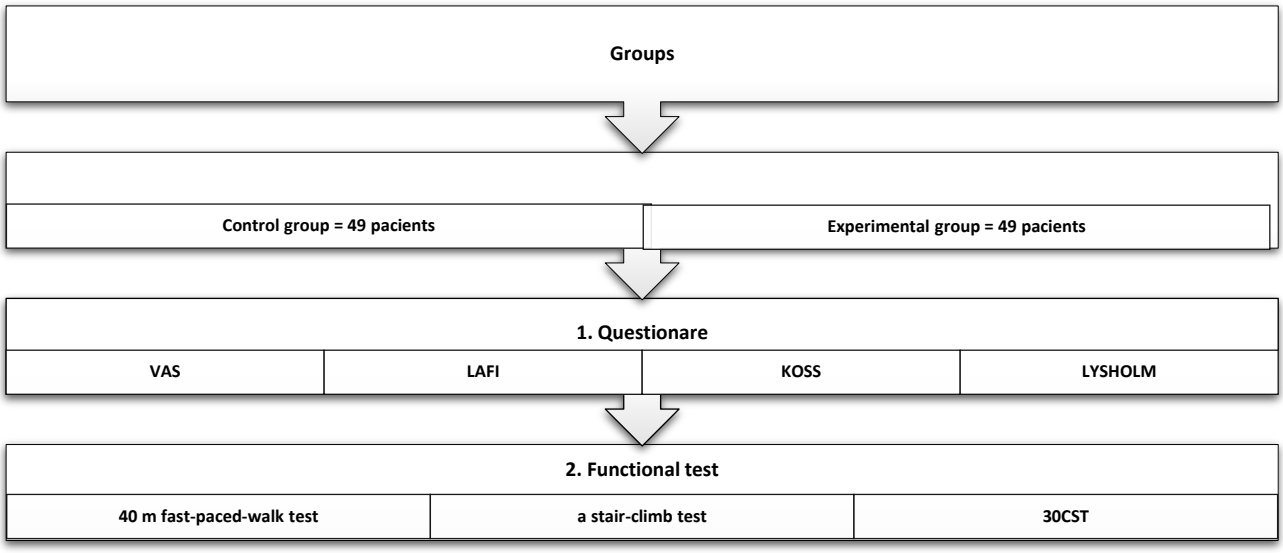


Figure 60. Pilot study content.

Note: VAS (Visual Analogue Scale, identifies pain severity); LAFI (Lequesne Algofunctional Index, identifies osteoarthritis severity); KOOS (Knee Osteoarthritis Outcome Score, identifies knee disability); LYSHOLM (Lysholm Scale, assesses knee function; secondary outcomes included functional testing, the 30-second chair sit test (30CST), the stair climbing test (SCT), and the 40-meter walk test (40WT).

The objective examination revealed: bilateral or unilateral knee involvement, presence of pain on palpation or joint mobilization, preserved or altered joint amplitude, knee stability in standing and walking, level of muscle tone, joint symmetry of the lower limbs, patient's weight. Somatometric measurements were performed with a scale to determine weight expressed in kilograms-force. Patients were assessed with minimal clothing. Height was determined in standing by stadiometer expressed in centimeters. Thus, the body mass index was calculated. Joint amplitude was measured using a goniometer.

Radiological aspects were highlighted on the knee radiograph by narrowing of the intraarticular space (osteophytosis, pseudocysts, etc).

The clinical evaluation was performed through functional tests and self-administered questionnaires (described in chapter 3.2.2. Methods used). The tests used are recommended and approved by the International Society for Osteoarthritis Research,

Therapeutic interventions in the subjects included in the study were performed as follows:

all subjects participated in 10 rehabilitation treatment sessions over a period of two weeks. The intervention consisted of electrotherapy and physiotherapy for both groups, and the experimental group additionally benefited from balneotherapy (Table 20).

Table 20. Applied treatment procedures.

Therapeutic procedures	**Băile Tinca** *Experimental Group*	**Fiziohelp Med Salonta** *Control group*	**Dosage**	**Frequency**	**Intensity**
Balneotherapy in mineral water heated to 37.5°C	✓	-	20 min.	1/day	-
Physiotherapy	✓	✓	30 min.	1/day	
TECAR	✓	✓	20 min.	1/day	30-100 %
Ultrasound	✓	✓	5 min.	3 MHz	1,2 W/cm^2

Note: TECAR = Capacitive and Resistive Energy Transfer

Capacitive and resistive energy transfer was performed with a BTL 6000 device, with a capacitive selection time of 5 minutes and a resistive one of 15 minutes, at an intensity ranging from 30 to 100% depending on the pain intensity threshold. Continuous ultrasound was applied using a BTL 5000 device at an intensity of 1.2 W/cm^2 and 3MHz, for 5 minutes.

The objectives of the physiotherapy programs were toning the lower limb muscles, increasing joint mobility, restoring lower limb stability and controlled mobility in walking.

The physiotherapy program consisted of 30-minute daily sessions and included passive and active exercises, joint mobilization techniques and stretching exercises. In addition, as the pain decreased, isometric and resistive exercises were added to the therapeutic program.

The ***individual balneotherapy*** procedure was carried out as follows: the tub was filled with 200 liters of heated mineral water and the patients took baths (immersion up to the armpits) for 20 minutes monitored by a therapist. The mineral water used comes from the Fântâna Veche borehole, with a depth of 270 meters, discovered in 1884. The temperature of the mineral water from Băile Tinca, at the spring, is 14°C, and the total mineral concentration is 4090.5 mg/l (www.bailetinca.ro).

A power sample size calculation was performed before the study was conducted to ensure at least 80% power to detect the expected effect size, taking into account factors such as significance level and data variability. This is an important step to ensure that the study is adequate to obtain significant results and to reduce the risk of type II errors. Type II errors occur when we conclude that there is no statistically significant effect, but the treatment is effective.

Continuous data are presented as a mean with standard deviation where they are normally distributed and as a median with 25th and 75th percentiles for non-parametric data.

The selection of statistical tests was guided by the nature of our data and the specific requirements of the study design. Each test was chosen for its ability to accurately analyze the type of data (parametric or non-parametric) and the number of groups involved in each comparison. This careful selection ensured the validity and reliability of our statistical analyses.

The linear ANOVA[26] model was used to compare the means of the different groups in the study. This test is appropriate for this study because it allows for the comparison of more than two groups simultaneously, which is essential for analyzing the effects of the intervention in the control and experimental groups, both before and after treatment.

For comparisons involving two independent groups, the Welch[27] *t*-test was used for normally distributed data and the Mann-Whitney U[28] test for nonparametric data. These tests are appropriate for the study given the different distributions of the data present and the need to compare two groups at the same time, such as pre-treatment versus post-treatment within each group.

To compare three or more groups where the data did not follow a normal distribution, the Kruskal-Wallis[29] test was used. This nonparametric method is appropriate for analyzing results where the assumption of normality is not met. For categorical data analysis, the $\chi 2$ test and Fisher's exact test were used, depending on the sample size. The $\chi 2$ test was used for larger samples, while Fisher's exact test was more appropriate for smaller samples or when expected frequencies were low, thus ensuring the accuracy of the results. All statistical analyses were performed using the Kaplan-Meier R statistical software (version 3.6.3), *the tidyverse, finalfit, mcgv, survival, stringdist, janitor*, and *Hmisc* packages, which provided robust tools for data analysis and improved the accuracy of the results.

The demographic characteristics of the experimental and control groups are summarized in Table 21. Data are presented as mean ± SD (standard deviation).

[26] Statistical method that compares means from multiple groups simultaneously.
[27] Nonparametric test used to compare two medians from two independent groups.
[28] Nonparametric statistical test used to compare two samples.
[29] Statistical test used to compare two or more groups for a continuous or discrete variable.

Table 21. Demographic characteristics of study participants.

	Total (no = 98)	**Pre-evaluation experimental group (no = 50)**	**Pre-evaluation control group (no = 49)**	***p***
Age (years)	69.0± 6.9	68.7±7.1	69.4±6.6	0.522
Women, n (%)	52.00 (53%)	26.00 (53%)	26.00 (53%)	1.000
Men, n (%)	46.00 (47%)	23.00 (47%)	23.00 (47%)	
BMI (kg/cm2)	31.6±4.1	32.6±4.3	30.6±3.6	0.001
Education (years)	11.6±2.5	11,26±2,51	11.3±2.6	0.450

Note: nr = number, *p* = statistical significance (p > 0.05 = statistically significant), BMI = body mass index

The experimental group had a significantly higher body mass index than the control group (p=0.001), but there was no significant difference in years of education, gender distribution or age between the two groups (p > 0.05).

The results show significant improvements in both groups for the visual analogue scale (p = 0.001), the Lequesne algofunctional index (p = 0.001) and the sit-stand test (p = 0.001). However, the mean difference was greater in the experimental group compared to the control group for these parameters (Table 22). The results of the walking test were significantly better in the experimental group (p = 0.001), while in the control group they did not improve (p = 0.688).

The stair climbing test, the knee osteoarthritis outcome score and the Lysholm index did not show significant improvements in either group.

Table 22. Effects of intervention on physical and functional outcomes in patients with knee osteoarthritis.

Variables	**Pre-test and post-test experimemtal group**			**Pre-test and post-test control group**		
	Average difference	Standard deviation	*p*	Average difference	Standard deviation	*p*
VAS	1.388	2.008	0.001	1.082	1.525	0,001
KOOS	-4,204	24,072	0,227	-2,796	19,119	0,311
LAFI	1,551	3,042	0,001	1,245	2,385	0,001
LYSOLM	-3,49	24,454	0,323	-2,878	14,867	0,182
30CST	-1,469	1,101	0,001	-1,102	1,327	0,001
40WT	4,1731	1,624	0,001	0,85	14,731	0,688
SCT	1,714	10,494	0,259	1,861	21,069	0,539

Note: VAS (Visual Analogue Scale, identifies pain severity); LAFI (Leqesne Algofunctional Index, assesses osteoarthritis severity); KOOS (Knee Osteoarthritis Outcome Score, assesses quality of life); LYSHOLM (Lysholm Scale, assesses knee function); 30CST (stand-sit test); 40WT (walking test); SCT (stair climbing test); *p* - statistical significance.

The intervention appeared to have a significant impact on the sit-stand test and the walk test scores in the experimental group and a large effect size. The control group showed substantial improvements in the visual analogue scale scores and the Leqesne algofunctional index, but the effect sizes were generally smaller than in the experimental group. The intervention did not have a significant impact on the knee osteoarthritis outcome index scores, Lysholm scale scores, and stair climbing test scores in either group (Figure 61).

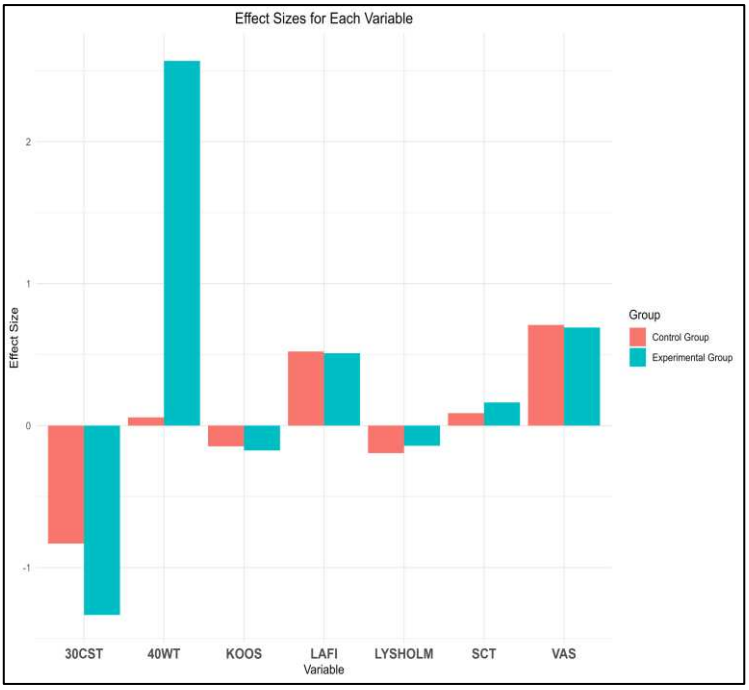


Figure 61. Assessing the impact of the mean difference of the intervention on various metrics in the experimental and control groups.

Note: VAS (Visual Analogue Scale, identifies pain severity); LAFI (Leqesne Algofunctional Index, assesses osteoarthritis severity); KOOS (Knee Osteoarthritis Outcome Score, assesses quality of life); LYSHOLM (Lysholm Scale, assesses knee function); 30CST (stand-sit test); 40WT (walking test); SCT (stair climbing test).

The visual analogue scale showed a significant correlation between pretest and posttest in the control group, and the Lysholm Knee Rating Scale showed a significant correlation between pretest and posttest in both the control and experimental groups. The sit-stand test, the walking test and the stair climbing test showed significantly stronger correlations between pretest and posttest in the experimental group compared to the control group.

The linear ANOVA test (a statistical method that simultaneously compares the means of several groups) shows that, after a two-week treatment, the participants who benefited from balneotherapy (with mineral water) showed better results compared to the control group in terms of pain intensity ($p<0.001$), knee function scores ($p<0.001$ for the Leqesne algofunctional index, the walking test and the Lysholm scale, and for the knee osteoarthritis outcome scale $p<0.05$). Stair climbing test results improved in both groups, but there was no statistically significant difference between them.

The pilot study indicates that balneotherapy, together with traditional physiotherapy and electrotherapy, has a significant contribution in the treatment of knee osteoarthritis. The combination of these treatment modalities could represent a powerful, multimodal strategy for pain relief and improvement of knee function in patients with osteoarthritis. However, more

extensive research is needed to confirm these findings and to establish the most effective treatment protocols for this condition.

Our results are similar to those of previous studies, in which patients reported a significant improvement in pain levels and mobility following mineral water balneotherapy (Fioravanti et al., 2012, 2017, 2017; Forestier et al., 2010; Ma et al., 2021; Masiero et al., 2018; Matsumoto et al., 2017).

The therapeutic effects of the mineral natural waters is determined by their specific chemical profile, which is capable of triggering a complex biological response encompassing analgesic benefits, anti-inflammatory and antioxidant effects, chondroprotection, and immunomodulation (Silva et al., 2020).

In addition to the hydromineral balneary resources, another essential element in maintaining and improving health is the bioclimatic characteristics of the region. Bioclimatic factors, such as temperature, humidity and the degree of air ionization, contribute significantly to the therapeutic potential of the county, thus completing its balneary offer.

5.1.11. Therapeutic effects of thermomineral waters from Bihor County

Thermal mineral water therapy (balneotherapy) produces numerous physiological effects and determine changes in the neuro-immune-endocrine system (Fioravanti et al., 2011; Ma et al., 2021)

In Bihor County there are both renowned balneary destinations (Băile Felix, Băile 1 Mai, Băile Tinca), as well as lesser-known locations like Sarcău (through the Adorianis), Marghita and Ștei balneary complex, where hydromineral resources are used for therapeutic purposes. These therapies are officially indicates fow a wide range of medical conditions, including: degenerative and inflammatory rheumatism, abarticular rheumatism, neurological and muscular disorders, conditions associated with metabolic diseases, gynecological conditions, as certified by the National Institute of Recovery, Physical Medicine and Balneoclimatology in Romania.

In addition to these destinations, several other locations with hydromineral resources have been identified: Balc, Borș, Ceica, Cherechiu, Cheșereu, Ciocaia, Ghiorac, Mihai Bravu, Răbăgani, Roșiori, Salonta, Sântandrei, Sântimreu, Stâna de Vale and Valea lui Mihai, which possess immediate therapeutic potential, due to the similarity in terms of water type, flow rate and temperature, with those mentioned above (Haidu et al., 2023).

As a form of complementary therapy, balneotherapy continues to demonstrate proven effectiveness in alleviating symptoms associated with various pathologies.

The effect of balneotherapy on chronic pain

One of the most common health problems in the industrialized world is low back pain, with a lifetime incidence of 60 - 80% and an annual incidence of 10 - 12% (Wu et al., 2020). Painful shoulder disorders are common musculoskeletal pain conditions that require medical intervention and care with a prevalence of between 21 and 34% (Chary-Valckenaere et al., 2018).

The effects of balneotherapy in the treatment of chronic low back pain are thermal, mechanical and chemical effects. The thermal effect is the result of heat acting in four ways: vasodilation, receptive control mechanism, increased beta-endorphin levels and muscle relaxation and sedation. By causing superficial vasodilation, the application of heat causes an increase in blood flow, reduces spasm and vascular stasis, removes nociceptive elements and free radicals, exerting a direct analgesic effect (Nasermoaddeli et al., 2005; Yurtkuran et al., 2006). The mechanical effect of mineralized water adapted to body parts, increases joint mobility and muscle tone, body fluids change their place from the extremities to the trunk, causing hemodilution and diuresis (Nasermoaddeli et al., 2005; Lange et al., 2006). The chemical effect is explained by the absorption of trace elements from mineralized water through the skin, modulating the immune system. These accumulate in the different layers of the skin and become a deposit that gradually releases mineral substances into the body to participate in systemic actions (Koçyiğit et al., 1999).

Data from several studies that have investigated the effectiveness of balneotherapy in chronic pain are found in Table 23.

Table 23. Examples of studies on the effectiveness of balneotherapy on chronic low back pain.

Study Study type	Samp size and characteristics	Balneotherapy	Interventions	Evaluation	Follow-up period	Study results and conclusions
Iosub et al. (2024) Observational study Baile Felix, Romania	43-experimental group	thermal water (36-37°C), 20 min/day, 2 weeks	physical therapy 30min /day	sociodemographic sheet, visual analog scale, Hamilton scale, Morris Rosenberg scale	2 weeks	Balneotherapy had a positive effect on patients with lumbar disc herniation, but it is no different from the effect of the physiotherapy program alone
	41-control group					
Iosub et al (2024) Baile Felix, Romania	85-experimental group	thermal water (36-37°C), 20 min/day, 2 weeks, Vojta therapy	physiotherapy 30 min/day, occupational therapy, massage 15 min, electrotherapy, stretching, laser	sociodemographic sheet, visual analog scale, Hamilton scale, Morris Rosenberg scale, Oswestry scale, Levene test	2 weeks	Balneotherapy and Vojta therapy improved posture at physiological levels, which in turn reduced depression associated with functional deficits characteristic of low back pain and increased self-esteem.
	67-control group	thermal water (36-37°C), 20 min/day, 2 weeks				
Kulaoglu et al. (2023) clinics Study Cumhuriyet University, Turkey	30 -experimental group	thermomineral water (40°C), 20 min/day, 5 days/week.	physiotherapy, tens (50-100Hz), ultrasound 1.5w / cm $^{2)}$, frequency 1Mhz, 6 min, 5 days / week 3 weeks	sociodemographic sheet, visual analogue scale, quality of life scale -sf -36, Oswestry disability index, test for psychological symptoms	3 weeks	the decrease in scores for all parameters was greater in the experimental group by 30.4% to 14.2%
	30-control group back pain					
Chary-Valckenaere et al. (2018) , Prospective study Amnéville les Thermes, Bourbonne les Bains, Plombières (France) Mondorf-les-Bains (Luxembourg)	92-experimental group shoulder pain	mineral water (36 °C), 15 min/ 6 days/week, mud (45 °C) 20 min, mineral water jet (39 °C) 7 min	physical therapy	sociodemographic sheet, function physics by DASH F- QD test, SF -36 quality of life index,	18 days 3 weeks 3 months 6 months after treatment	improvement in pain, disability and quality of life at 6 months, the mean change in F-QD score was significantly higher in the experimental group compared to the control group; analgesic use decreased significantly during balneotherapy, but not after 3 months and remained lower at 6 months
	93-control group shoulder pain	same treatment 6 months later	physical therapy			
Onat et al. (2014) Clinical study Ankara Hospital, Turkey	37- experimental group back pain	mineral water (38°C), 20 min/day	thermotherapy 20 min 5 days/week, tense (50–100 Hz); time 20 min/day; ultrasound (1 MHz; intensity, 1 W/cm2) 5 min/day.	sociodemographic sheet, visual analog scale, Oswestry disability index, sf-36 quality of life scale, Schober index,	3 weeks	improvements in scores pain, life quality, and functionality have proven to be superior in experimental group
	44- control group back pain					
Tefner et al. (2012) Clinical study Mátraderecske , Hungary	30-experimental group back pain	thermomineral water 30 min/day, 5 days/week.		sheet sociodemographic, analog scale visual, Oswestry disability index, quality of life scale -sf-36, Schober index, index EuroQol	15 days, 3 weeks 10 weeks	
	27-control group back pain		tap water (31°C), 30 min/day, 5 days/week, 3 weeks			
(Kesiktas et al., 2012) Clinical study Karaali, Turkey	25-experimental group low back and lower limb pain	thermal water (36°C), for 30 min /day, 5 /week	physiotherapy, tense, ultrasound, infrared	analog scale visual, Oswestry disability index, sf - 36 quality of life scale, Schober index, EuroQol-5D , muscle testing, medication anti-inflammatory (paracetamol)	2 weeks 3 months	force muscle, Schober test, index Oswestry, few SF-36 subscores showed improvement significant in the experimental group. The effect continued and at three months after treatment
	25-control group low back and lower limb pain					

The effect of balneotherapy on rheumatoid arthritis

Rheumatoid arthritis is a chronic, systemic autoimmune inflammatory pathology that primarily affects the joints. It is characterized by inflammation, synovial hyperplasia, manifesting itself through pain, swelling and reduced mobility (Karagülle et al., 2017; Radu and Bungău, 2021; Sagtaganov et al., 2024), which can determine cardiovascular, pulmonary and dermatological complications (Cojocaru et al., 2010). The evolution of rheumatoid arthritis is fluctuating with episodic exacerbations, and in the absence of effective treatment, symptoms gradually worsen, potentially leading to irreversible joint damage and diminished physical and psychological functioning (Chaurasia et al., 2020).

Although the mechanism underlying these anti-inflammatory effects remains unclear, but the most likely hypothesis is that vasodilation is able to increase the level of cytokines and other mediators in the inflamed segment. It is believed that thermal water therapy exert an immunomodulatory effect. Recently, it has been shown that thermal water therapy also induces a reduction in the levels of prostaglandin E2, leukocytes B4, interleukin-1b and tumor necrosis factor, important mediators of inflammation (Aleksić-Milenković et al., 2025). This may indicate that balneotherapy contributes substantially to the reduction of inflammatory processes at the molecular level or the reactivity of the immune system.

Oxidative stress has been shown to play a contributing role in the pathogenesis of rheumatoid arthritis. Oxidative stress is an imbalance between oxidants and the capacity of antioxidant defense systems. Normal metabolic processes in cells generate free radicals, reactive oxygen/nitrogen species, and their derivatives. These oxidant products can cause damage to cell membranes, lipids, nucleic acids, proteins, and matrix components. To protect cells from this damage, several endogenous antioxidant defense mechanisms have evolved. Once the generation of oxidant products exceeds the capacity of antioxidant defense mechanisms to neutralize them, oxidative stress occurs and causes damage to cellular components (Hitchon et al., 2004; Karagülle et al., 2017).

Recent studies have highlighted the antioxidant potential of balneotherapy. However, it is important to note that the success of balneotherapy is not a cure, but rather a single link in the complex chain of treatment (Aleksić-Milenković et al., 2025).

Data from several recent studies that evaluated the effect of balneotherapy in rheumatoid arthritis are presented in Table 24.

Table 24. Examples of studies on the effectiveness of balneotherapy in rheumatoid arthritis.

Study Study type	Samp size and characteristics	Balneotherapy	Interventions	Evaluation	Follow-up period	Study results and conclusions
Aleksić-Milenković et al. (2025) clinical trial Institute Niška Banja, Serbia	46-study group 16-stage low 16-moderate stage 14- in remission	thermal water (37°C), 15-20 min, 3 weeks.		sociodemographic sheet, visual analog scale, Beck depression index, DAS28 SE activity score, HAQ quality of life index, FACIT–F fatigue assessment, blood samples	3 weeks	Balneotherapy reduced the level of the pro-inflammatory cytokine IL-6, decreased disease activity, improved functional capacity, reduced fatigue and depression regardless of the stage of the disease
Romay-Barrero et al. (2022) prospective study Balneary resort Fitero Navarra, Spain	49- study group	thermal water (38ºC) for 15 min	current (40-42°C) 10 min, foot bath (38°C), 15 min, exercises in the bath (32-34°C) 20 min and steam bath (45˚C), 15 min	sociodemographic sheet, HAQ quality of life index, EuroQol 5D-5L quality of life,	1 month 3 months 6 months	Functionality improved after balneotherapy treatment by 80%, and the improvement was maintained for 3 months; pain was also improved at 6 months
Karagülle et al. (2018) clinical trial Balneary resort Tuzla, Turkey	experimental group 37- (6 months) 29 completed stage 2 (12 months)	water thermomineral (36–37°), 1/day 20 min	walk in open air treatment previously medicated	sheet sociodemographic, analog scale visual, quality LEARNING and Service physical HAQ, disease activity score DAS28, blood samples (ESR, C- reactive protein)	6 months 12 months	short -term beneficial effects and average of 2 weeks of balneotherapy added to pharmacotherapy ordinary observed in period initial 6- month evaluation period is maintained easy to moderate up to 12 months
Karagülle et al., (2017) clinical trial Health center Tuzla, Turkey	25- experimental group	water thermomineral (36–37°), 20 min/day, 12 days	treatment drug previously stable	sheet sociodemographic, analog scale visual, activity score DAS28 4, HAQ quality of life index, blood samples	2 weeks	balneotherapy has an antioxidant effect, reflected by growth radical scavenging activity non- enzymatic superoxide
	25- control group					
(Franke et al., 2007) clinical trial Resort Bad Brambach, Germania	67- experimental group	water mining 20 minutes. 15 meetings	physiotherapy, occupational therapy, bath galvanic 2/ week, massage 2/ week	sociodemographic sheet, visual analogue scale, medication consumption, blood tests	2 weeks 1 year	improvement pain and contribution reduced by medication up to 9 months in the experimental group,
	67- control group	carbon dioxide baths (35°C)				

The effect of balneotherapy on degenerative rheumatic pathologies

Osteoarthritis or arthrosis is the most common degenerative joint disorder and a major cause of disability with major socio-economic impact. By definition, osteoarthritis results from complex mechanical, biological, molecular and enzymatic interactions, all of which ultimately lead to joint tissue damage and affect the entire joint (Man and Mologhianu, 2014).

Awareness of the onset of osteoarthritis is important, as these changes may still be reversible and therefore, preventive treatment could be initiated to slow or reverse further disease progression (Man and Mologhianu, 2014).

Osteoarthritis therapy includes conservative (pharmacological and non-pharmacological) and/or surgical approaches. The goal of therapy is to relieve pain, maintain joint mobility and maximize joint and global function. The main conservative non-pharmacological treatments consist of some physical measures such as rehabilitation, support devices, exercises to increase muscle strength, flexibility and endurance, patient education through daily living suggestions and thermal therapy, which includes massages, hydrotherapy, mud therapy and balneotherapy (Protano et al., 2023). Balneotherapy, due to its numerous beneficial effects, has been recommended by the guidelines of the International Society for the Study of Osteoarthritis as a complementary non-pharmacological treatment for gonarthrosis, coxarthrosis and polyarticular osteoarthritis (Bannuru et al., 2019). In addition, balneotherapy is cited for its positive effects on osteoarthritis and in the recommendations of the European League Against Rheumatism for the approach of healthcare professionals to pain management in inflammatory arthritis and osteoarthritis. The American College of Rheumatology has made balneotherapy a conditional intervention in osteoarthritis (Kolasinski et al., 2020).

Balneotherapy improves the signs and symptoms of osteoarthritis affecting different joints, increases the activity of the enzyme superoxide dismutase and serum levels of interleukin-2 receptors. Sulfurous thermomineral water increases the production of oxygen and nitrogenous free radicals by polymorphonuclear leukocytes and decreases after incubation of these cells with a chondroprotective effect on chondrocytes and cartilage (Protano et al., 2023). Incubation of chondrocytes with sulfurous water inhibits the release of nitrous oxide, prostaglandins E2, metalloproteinases, TNF-α[30], Interleukin-6 and Interleukin-8, all molecules having a crucial role in the inflammatory processes and cartilage degeneration in osteoarthritis (Kuczera and Kokot, 1996).

[30] Proinflammatory cytokine produced primarily by activated monocytes and macrophages in response to infections

The high water temperature influences hyperemia in the periarticular sites (capsules, ligaments, tendons), which can contribute to the removal of inflammatory cytokines and chemokines, reducing pain. Finally, the high temperature causes a series of neuroendocrine reactions, stimulating the hypothalamic-pituitary-adrenal axis with the consequent release of adrenocorticotropic hormone and cortisol, well known for their anti-edema and anti-inflammatory action (Vescovi et al., 1990).

Data from several studies that found a significant improvement in the signs and/or symptoms of osteoarthritis, regardless of the anatomical location of the disease, following balneal treatment are summarized in Table 25.

Table 25. Examples of studies on the effectiveness of balneotherapy on degenerative rheumatic pathologies.

Study Study type	Samp size and characteristics	Balneotherapy	Interventions	Evaluation	Follow-up period	Study results and conclusions
Teległów et al. (2023) Clinical study Health center Solec Zdroj, Poland	35-experimental group osteoarthritis	mineral water (34–37°C) 15 min/day, 3 weeks	physiotherapy, massage, manual and laser therapy	blood samples	3 weeks	white blood cell levels decreased significantly, causing a positive impact on the chronic inflammation process among osteoarthritis patients in the experimental group
	13-control group osteoarthritis					
Ciurba (Pastor) et al. (2023) Pilot study Băile Tinca, Romania	49- experimental group	mineral water (37.5 °C), 20 min., 1/day, 2 weeks.	physiotherapy 30 min/1/day, tecar 20 min. 1/day, 30-100%; ultrasound (1.2 W/cm ^{2}, 3MHz), 5 min./day	sociodemographic sheet, somatometric measurements, visual analog scale, quality of life -SF-36, Lequesne algofunctional index, Lysolm knee function scale, walking test, stair climbing test, sit-stand test	2 weeks	pain index A indicated a correlation significantly between pretest and posttest in the experimental group versus the control group
	49-control group					
Tarcau et al. (2022) Prospective cohort study Baile 1 Mai, Romania	30-experimental group	thermal water (37 °C), 30 min/day 10 days	physiotherapy 45 min/day, tens 15 min, interferential currents 10 min, magnetotherapy 15 min/day, 10 days	sheet sociodemographic, SF-MPQ scale, analogical scale visual, Oswestry test, Schober test, functional tests	2 weeks 6 months	patients in the experimental group recorded significant improvements in all variables studied, and mobility and muscle strength increased after six months of combined treatment.
	30-control group		tens 15 min, interferential currents 10 min, magnetotherapy 15 min			
Tenti et al. (2020) study observational retrospectively Levico Terme Spa Center, Trento, Italy	212- osteoarthritis HAND	thermal water (36 °C), 5 min/day, mud (46 °C), 15 min/day, 2 weeks	daily activities at home	sociodemographic sheet, visual analog scale, quality of life -SF-36, functional index for hand osteoarthritis, analgesic medication, grip strength test	2 weeks	Short-term efficacy of balneotherapy with thermal water and mud in controlling pain and improving hand functionality
(Kovács et al., 2016) Zsóry Spa, Mezőkövesd, Hungary	22- experimental group	thermal water (36 °C), 20 min/3 weeks		sociodemographic profile, WOMAC stiffness score, quality of life EuroQol-5D	3 weeks and 12 weeks	after 12 weeks, pain, stiffness, function, and Womac scores and quality of life showed significant improvement in the experimental group compared to the control group
	22- control group		home exercises			
Fioravanti et al. (2012) prospective randomized study Siena, Italy	30-experimental group	mineral water, (38°C) 20 min, 1/day, 6 days/week, 2 weeks		sociodemographic sheet, measurements, somatometric, visual analog scale, Womac index, Lequesne index, quality of life - SF-36, analgesic medication	2 weeks and 3 months	reduction significant pain and improving significant capacity function and quality life at 2 weeks and 3 months compared to the beginning balneotherapy in the experimental group compared to the control group
	30- control group		routine daily at home			

The effect of balneotherapy on fibromyalgia

Fibromyalgia is a long-term condition of idiopathic origin, characterized by generalized skeletal muscle pain with tender points in certain anatomical locations, accompanied by other symptoms such as fatigue, sleep disorders, anxiety, depression, headaches, irritable bowel syndrome, etc. (Ardıç et al., 2007; Pérez-Fernández et al., 2019). It has been observed that patients with fibromyalgia have an increased sensitivity to stimuli that normally do not cause pain, a phenomenon known as allodynia (Vierck, 2006). Research has shown that neurotransmitters responsible for pain, such as substance P and serotonin, are involved in the exacerbation of symptoms (Meyer, Med, 2002). Reflex phenomena are considered among the most important factors triggering fibromyalgia and are associated with chronic deep pain produced by the activation of a pain-spasm cycle through the presence of repeated trauma or postural stress (Bradley, 2009). It has been suggested that biological, psychological and socio-cultural factors are possible contributors, including abnormal pain signaling, abnormal activity of the neuroendocrine and autonomic systems, genetic predisposition, certain environmental triggers and sleep disorders that hypersensitize pain (Gyorfi et al., 2022). Psychological factors should be considered alongside the management of fibromyalgia, as they significantly contribute to both symptomatology and treatment efficacy (Borze (Ursu) et al., 2025).

Globally, the prevalence of fibromyalgia is estimated to be between 2 and 4%, predominantly affecting women in a ratio of 7:1 (Clauw, 2014). In Europe, the prevalence varies, being reported between 2 and 6%, with a specific prevalence in France, Germany and Spain ranging from 1.4 to 5.6% (Kocyigit and Akyol, 2022).

In the management of fibromyalgia, treatment should include an approach that combines pharmacological interventions (anticonvulsants, serotonin and norepinephrine reuptake inhibitors and tricyclic antidepressants) (Rico-Villademoros et al., 2020), complemented by non-pharmacological interventions (behavioral therapy, nutritional therapy, physiotherapy, balneotherapy). These are more effective according to systematic reviews, since the combination of aerobic exercise with resistance and stretching reduces symptoms and the stress response. Balneotherapy has demonstrated efficacy in combating oxidative stress, a key factor in the pathogenesis of fibromyalgia, by balancing free radicals and antioxidants, thus reducing cellular dysfunctions, as supported by various in vitro and in vivo studies (Çetinkaya et al., 2020; Borze (Ursu) et al., 2025). Balneotherapy with natural mineral waters heated to 36 - 38 °C, offers a multifaceted approach to the treatment of fibromyalgia (Guidelli et al., 2012).

Balneotherapy has a high level of evidence in almost all treatment guidelines for fibromyalgia and has been reported by the European League Against Rheumatism as having an

important level of evidence. Many studies have shown positive effects of balneotherapy on fibromyalgia with an increased tendency towards oxidative stress compared to healthy individuals, with an antioxidant effect and shifts the balance towards reducing oxidative stress. Several studies have been conducted that have evaluated the unclear efficacy of balneotherapy on the oxidant-antioxidant system and positive anti-inflammatory effects by reducing free radical scavenging effects have been reported. Balneotherapy is widely prescribed in Europe, Japan, South America and North Africa and is recommended for fibromyalgia for its analgesic and relaxing effects (Ducamp et al., 2022).

Data from various studies that evaluated the effectiveness of balneotherapy in fibromyalgia can be found in Table 26.

Table 26. Examples of studies on the effectiveness of balneotherapy in fibromyalgia.

Study Study type	Samp size and characteristics	Balneotherapy	Interventions	Evaluation	Follow-up period	Study results and conclusions
Borze (Bear) et al., (2025) Clinical study Baile Felix, Romania	30- control group	water thermal (36-37°C) 20 min	physiotherapy 30 min, tension (80–130 Hz) 15 min, massage Swedish (10 min)	history sheet sociodemographic, severity index fatigue, quality sleep Pittsburgh	2 weeks	improving flexibility, relaxation extrinsic and muscle tone has an efficiency may good on quality sleep than therapy concentrated just relaxing intrinsic. It has not there none score change between evaluation initial and the final in the experimental group
	30- experimental group		20 minutes of relaxation intrinsically specific Parow 's,			
Ariani et al. (2025) Prospective study Italy	260- experimental group	thermomineral water (37-38°C) 10 min 1/day, 12 days or thermal mud (40-45°C) 15-20 min		visual analogue scale, SF-36 quality of life, FIQ fibromyalgia impact, WPI widespread pain index, CES-D depression assessment, STAI anxiety scale	2 weeks 1 month	improvements significant symptoms body and psychological both immediate after treatment, how much and in a month after treatment balneary
	260- control group		routine daily			
Ducamp et al. (2022) Multicenter study France	89- experimental group	water mineral (36°C) individually, 10-20 min, mineral mud (40-42°C), 10-12 min, massage 10 min and group water exercises mineral (32–34 °C), 20 min /3 weeks	walks in outdoors, education therapeutics	socio- demographic sheet, somatometry, visual scale analog, score FIQ, medication, kinesiophobia Tampa, Epworth drowsiness, limitation WOMAC functional	3 weeks 6 months 12 months	intensity pain, fatigue, drowsiness and the impact fibromyalgia have decreased significant in time treatment spa. At 6 months, 12 -month evaluation A plowing that MODs lifestyle were maintain
Maindet et al. (2021) Study clinical Aix-les-Bains, Allevard-les-Bains, Bourbon-Lancy, Lamalou-les-Bains, Uriage-les-Bains, France	98- experimental group	treatment mediated water mineral (36 °C), hydromassage baths, mud hydro - mineral, jet shower, water massage 2 hours/day, 18 days	conference therapeutics walk physical therapy	socio- demographic sheet, somatometry, visual scale analog, impact fibromyalgia FIQ, activity physics Baecke, evaluation STRs and emotions, quality life EQ- 5D - 3L, catastrophizing S- CFPI pain, Pittsburgh sleep index, Epworth sleepiness, Pichot fatigue, HAD depression, medication	18 days 3 months 6 months 9 months 12 months	FIQ, pain and medication use scores showed significant improvements. Severity of illness and fatigue remained low at 9 and 12 months in the experimental group
	100- control group	treatment delayed after 6 months				
Çetinkaya et al. (2020) Spitalul Traininghi, Iran	35- experimental group	water thermal (42±1°C) 20 min/day, 15 sessions	without other interventions	visual scale analog, impact fibromyalgia FIQ, quality life SF-36, Beck Depression Inde, severity fibromyalgia FSS, blood samples	3 weeks	improvements significant changes in pain parameters, depression and life quality after balneotherapy
	35- control group					
Pérez-Fernández et al. (2019) Clinical study Ourense, Spain	22- experimental group	thermal water (38°C) 14 baths, 30 min/day, 1 month	No other interventions	demographic data and epidemiological, visual scale analog, the impact fibromyalgia FIQ , blood samples, medication	1 month 3 months	after a month and at 3 months remained statistically significant may small than the initial average as well as medication intake decreased in experimental group
	23- control group		tap water			

The effect of balneotherapy on ankylosing spondylitis

Ankylosing spondylitis is the most common form of the spondyloarthritis group of rheumatic diseases. It is a chronic inflammatory pathology of unknown etiology, characterized by the involvement of the axial skeleton, sacroiliac joints or entheses, causing paravertebral muscle contractures and inflammatory activity that usually begins with insidious low back pain and stiffness (Cozzi et al., 2018; Bestaş et al., 2021). The main anatomopathological lesion is an inflammatory enthesopathy associated with adjacent osteitis with bone condensation and discitis. The inflammatory process causes erosion of the fibrocartilage, hyaline cartilage, ligaments and adjacent bone and can lead to fibrous and bony ankylosis (Yurtkuran et al., 2006). It occurs in approximately 23.8 per 10,000 Europeans and is more prevalent in men than in women (Van der Zee-Neuen et al., 2022).

The treatment of ankylosing spondylitis aims to reduce pain and inflammation, to prevent the progression of the pathology and to improve the quality of life. Treatment includes pharmacological (non-steroidal anti-inflammatory drugs, antirheumatic drugs) and non-pharmacological interventions (balneotherapy, physiotherapy, speleotherapy). Balneotherapy influences a polymorphic molecule, human leukocyte antigen B27 (HLA B-27), the major antigen of the class I histocompatibility complex. Although considerable research has been done in this regard, the exact role of HLA-B27 in the pathogenesis of SpA is still unknown. Balneotherapy can also stimulate cartilage metabolism by increasing insulin-like growth factor-1, reduce tissue anoxia and inflammation by inducing vasodilation, muscle contractures and pain induced by the pathophysiological phenomena of ankylosing spondylitis. The vicious cycle of contracture-pain-contracture can be broken by relieving muscle spasm (Ungureanu et al., 2023).

Examples of studies that have evolved the effectiveness of balneotherapy in ankylosing spondylitis (Table 27).

Table 27. Examples of studies on the effectiveness of balneotherapy in ankylosing spondylitis.

Study Study type	Samp size and characteristics	Balneotherapy	Interventions	Evaluation	Follow-up period	Study results and conclusions
Bestas et al. (2021) Clinical study Afyonkarahisar Turkey	20- experimental group	thermal water (39°C) 20 min/day, 20 sessions		socio-demographic sheet, somatometry, visual analog scale, spondylitis stage (BASDAI), functional index (BASFI), metrological index (BASMI), C-reactive protein score (ASDAS-SpondylitisCRP), enthesitis (MASES), quality of life (ASQoL), fatigue severity (FSS), Pittsburg sleep quality (PSQI) and chest expansion, blood samples	1 month 3 months	improvements in all treatment groups without distinction significantly between groups every 4 or 12 weeks. The experimental group showed an improvement A expansion thoracic at 4 and 12 weeks, improvement A fatigue and latently sleep in all groups, term sleep has improved significant only in physiotherapy group
	20- control group		hydrokinesiotherapy in water (33° C), 60 min/day			
	20- control group		physiotherapy, 60 min/day 20 min. massage			
Ozkuk, Uysal, (2020) Clinical study Bolu Karacasu Thermal Spring, Turkey	33- experimental group	thermomineral water (38-40°C) 20 min/day, 5 days/week	routine daily treatment previously continuous medication	socio- demographic sheet, somatometry, visual scale analog, index functional spondylitis (BASFI), Disease activity index BASDAI), quality of quality of life (ASQoL), blood samples	3 weeks	improvements significantly in scores pain, BASFI, BASDAI in the experimental group and none difference between blood sample groups
	27- control group					
Ciprian et al. (2013) Clinical study Padua, Italy	15- experimental group	thermal water (37-38°C) 10 min; sludge (40-45°C) 15 minutes,	physical therapy	socio-demographic sheet, somatometry, visual analog scale, spondylitis functional index (BASFI), spondylitis methodology index (BASMI), quality of life (HAQ)	2 weeks 3 months 6 months	improvement persistent quality life, improving mobility COLUMN spine and activity LEARNING daily in experimental group
	15- control group					
Yurtkuran et al. (2006) Clinical study Ataturk, Turkey	21- experimental group (G1)	thermal water (37°C) 20 min/day, 5 days/week, 3 weeks	physical therapy 20 min/day	socio-demographic sheet, somatometry, visual analogue scale, Schober test, occiput-wall distance, morning stiffness, Dougados functional index, blood samples	3 weeks 6 months	pain, duration of morning stiffness, occiput-wall distance, thoracic expansion, toe-floor distance and anteflexion improved significantly at the end of treatment in each group. Six months after treatment showed a superiority of groups G1 and G2 over (G3), in terms of morning pain, night pain and morning stiffness that persisted up to six months after treatment, except for those of toe-floor distance and Schober test
	20- experimental group (G2)		physical therapy 20 min/day, medication			
	20- control group (G3)		physical therapy 20 min/day medication			

The effect of balneotherapy in neurological disorders

The global burden of neurodegenerative disorders (Alzheimer's disease, Parkinson's disease and amyotrophic lateral sclerosis) is increasing significantly as life expectancy increases.

The Patients' Association, a non-governmental organization, estimates that there are over 72,000 Parkinson's patients in Romania. This estimate is based on the number of prescriptions for this condition reported by the National Health Insurance House (Roșca et al., 2021).

Currently, there is no cure for neurodegenerative disorders, which are characterized by the irreversible and progressive loss of neuronal cells in the brain. Therefore, interventions aimed at counteracting limitations and preventing disabilities, starting from the early stages, play an important role (Maccarone and Masiero, 2022).

Rehabilitation treatment in neurodegenerative disorders aims to maintain the highest possible level of mobility, activity and independence (Masiero et al., 2019).

In addition to neurodegenerative disorders, other neurological disorders are post-stroke sequelae often followed by sequelae such as sensory impairments, perception impairments, balance impairments, depression, aphasia, dementia, paralysis and cognitive function degeneration, all of which can persist for years requiring a complex rehabilitation plan. Stroke is the leading cause of disability after the age of 65 (Uivaroșan et al., 2019).

Although balneotherapy treatments have traditionally addressed patients with orthopedic disabilities, in recent times there has been an increase in real-life balneary rehabilitation applications in the neurological area (Maccarone and Masiero, 2022). The mechanism for the therapeutic effect of balneotherapy may be related to the chemical properties of hydromineral waters that can penetrate the nervous system and modulate the unbalanced neuroendocrine-immune system, thus improving clinical symptoms (Qiu et al., 2014). Balneotherapy is also valued for its physical anti-edema and anti-inflammatory, muscle relaxant, muscle trophic and analgesic and neuroprotective properties (Carroll et al., 2017).

Exemples of studii that have evaluated the effectiveness of balneotherapy in neurological conditions are presented in Table 28.

Table 28. Examples of studies on the effectiveness of balneotherapy on neurological conditions.

Study Study type	Samp size and characteristics	Balneotherapy	Interventions	Evaluation	Follow-up period	Study results and conclusions
Di Marco et al. (2022) Clinical study Padua, Italy	20- experimental group Parkinson's	thermal water (37-38°C), 12 sessions 45 min/day	physical therapy in bath, yoga	Status cognitive (MoCA), the disease assessment scale Parkinson's (PD-CFRS), quality life (PDQ-39), walking frozen (NFOG -Q), balance	4 weeks	has improved balance and performance cognition
Masiero et al. (2019) Clinical study Abano Terme, Italy	14- experimental group Parkinson's	thermal water (34-35°C) 45 min, 2/week, 4 weeks	physiotherapy, diet, health education and cognitive-behavioral therapy	Parkinson's disease assessment (UPDRS), Hoehn and Yahr Scale, balance assessment (Tinetti), lift-and-go test (TUG), quality of life (PDQ8), frozen gait (FOGQ)	4 weeks	improving to everyone scales clinical examined after balneotherapy and physical therapy
Uivarosan et al. (2019) Clinical study Baile Felix, Romania	22- experimental group stroke	thermal water (36-37°C) 14 days hydrokinetotherapy, physiotherapy, massage, psychotherapy, occupational therapy, electrotherapy, cryotherapy	robotic therapy (Lokomat) Cerebrolysine	shortcoming motor (Barthel), spasticity (Ashworth) quality quality of life (SS-QOL), self-care (ADL), independence functional (FIM)	6 months 12 months	all indicators analyzed showed improvements to association treatment neurotrophic with training lokomat and with balneotherapy
	18- experimental group		robotic therapy (Lokomat)			
	30- control group					
Dogaru et al. (2016) Clinical study Baile Tusnad, Romania	17-experimental group Parkinson's	mineral water 15 min/day, 16 days	aerotherapy 30 min/day physical therapy massage	Webster scale, balance assessment (Tinetti), walking test, Webster autonomy scale, quality of life	3 weeks	significant improvement in the quality of walking and balance, an increase in independence and quality of life, including through the social interrelationships created during rehabilitation treatment at the Băile Tusnad balneary resort.

The effect of balneotherapy on gynecological pathologies

The therapeutic indications for balneocology aim at chronic pelvic pain syndrome of extragenital origin, climacterium, psychosomatic disorders (premenstrual syndrome, vaginism, disappension), neurovegetative syndrome (dystonia), infertility (cervical hypersecretion, luteal insufficiency), postoperative care, convalescence, chronic interstitial cystitis, chronic vulvovaginitis, chronic pelvic congestive syndrome (fibromioma, functional ovarian cysts), endometriosis, chronic pelvic pain, vulvodinia, vulvar Craurosis and urogenital atrophy.

In countries rich in thermal water, with tradition (Italy, Germany, Turkey, France, Japan and Hungary), the balneology is commonly used in the treatment of gynecological diseases (Zámbó et al., 2008).

In Romania, mineral waters with therapeutic properties aimed at gynecological disorders, recognized at European level since 1850, are at the Sovata resort. In addition, other resorts such as Amara, Buziaș, Bizușa, Covasna, Moneasa, Nicolina, Geoagiu Băi have thermal waters with therapeutic indications in gynecological conditions (www.tbrcm.ro/tratament.php).

The complex purpose of gynecological balneophysiotherapy is the improvement of pelvic microcirculation, thus allowing the lysis of the scar tissues, the relaxation of the contracted muscles in the small basin and from the level of the pelvic-perineal floor as well as the biphasic stimulates Hormezeia (Zámbó et al. 2008; Cheleschi et al. 2020).

In previous studies on balneary and its use in clinical gynecology, there is not much research in this regard, while recommendations refer to the treatment of chronic pain, infertility forms and functional disorders. There was only one clinical study that evaluated the effectiveness of the thermal water in gynecological conditions. Zámbó, et al. (2008) conducted a clinical study that administered balneotherapy and physiotherapy to the experimental group (thermal water with a temperature of 38.8°C, 20 min/day) and only physiotherapy to the control group, and the results demonstrated an improvement in the intensity of pelvic pain and psychological state in the experimental group.

The balneary potential based on ***thermomineral waters*** and ***the bioclimate*** are two interconnected segments that together contribute to the development of balneotherapy and balneary tourism.

5.2. The assessment of bioclimatic potential of Bihor County

Human bioclimatology is defined as the study of the direct or indirect influence of the atmosphere, through climate, on humans, both in health and in pathology (Besancenot, 1997). The analysis of bioclimatic indices is useful in highlighting the areas and periods of comfort or bioclimatic risk to which the population of a given place is exposed at a given time (Grigore et al., 2020). Bioclimatic comfort is mainly based on the complex relationships between air temperature, humidity and wind speed, influencing human well-being and individualized subjective factors (Ionac et al., 2012).

It is considered that temperature, precipitation, humidity and wind play the most important role, especially due to their increase in extreme values, in terms of frequency, intensity and persistence (Banc et al., 2020).

Romania, with a temperate continental climate, presents a great diversity of climate subtypes induced by several important influences. Thus, the central and western regions are characterized by wetter conditions generated by moist oceanic air masses coming from the North Atlantic which, in general, lead to milder and wetter specific bioclimatic conditions in the west of the country (Banc et al., 2020).

5.2.1. Overview of research on bioclimatic indices relevant to balneary tourism

The beginning of bioclimatology as a science is related to the development of the calculation formula for the Thom comfort index (1959), the Terjung index (1966) and the Humidex index (Masterton and Richardson, 1979). Lebedeva et al. (2018) conducted a comparison of the bioclimatic potential in two global regions at the end of the 20th and beginning of the 21st centuries.

Relevant studies on the analysis of bioclimatic indices have been conducted by researchers from various geographical schools such as: Besancenot (1997); Kebiche (1996); Zaninović and Matzarakis (2007) who in their study compare the biometeorological conditions on the Adriatic coast and inland Croatia; Blazejczyk et al. (2015); Błażejczyk and Twardosz (2010) studied the changes in bioclimatic conditions in Poland; Besancenot (1970, 1974, 1985) analyzed the first data on bioclimatic stress in France, etc.

The most important works of bioclimatic analysis in Romania are due to the research activity supported by authors such as: Teodoreanu et al., 1984; Berlescu, 1998; Ionac, 1998, 2000; Teodoreanu, 2002, 2004; Ionac et al., 2008, 2010; Teodoreanu, 2015a in which bioclimatic indices are analyzed in detail.

Research in the field of bioclimatology is extensive and in continuous development. Other works that reflect the issues of bioclimatology and balneoclimatic tourism are: *Introduction to Human Biometeorology* (Croitoru et al., 2012); *Balneoclimatic Tourism in Romania* which advocates for balneoclimatic tourism, carried out in resorts with balneoclimatic resources (Teodoreanu and Gaceu, 2013); *Notions of balneophysiotherapy and balneoclimatology - a selection of restitutions* (Rădulescu et al., 2014); *The bioclimatic regionalization of Moldova west of the Prut River* was carried out by Bistricean et al. (2017) etc.

In the study C*limatic favorability of the Romanian territory for balneary -type tourist activities in the summer season*, the summer climatic favorability was evaluated at the level of the main balneary resorts in Romania, as well as its evolutionary aspects during the period 1961 - 2013. (Sfîcă et al., 2018); *Human bioclimatology* (Munteanu and Dogaru, 2020).

Another study was carried out by Mihăilă et al. (2024) in which they aimed at the bioclimatic evaluation of sustainable tourist activities in western Romania.

For bioclimatic analysis, the equivalent effective temperature indices, the thermo-hygrometric index and the wind chill and its equivalent temperature are the most used, relevant and expressive both because they are applicable throughout the year and because they efficiently and expressively express the intervals of comfort, discomfort or bioclimatic risk to which the inhabitants of a certain area are exposed, depending on the thermal values, as a primary factor influencing the physiological mechanisms of human thermoregulation.

The methodology used in this chapter is based on the results obtained from the processing and interpretation of climatic parameters (temperature, humidity, pressure and wind) and bioclimatic, following the calculation of the average values of the analyzed intervals. The climate data come from seven meteorological stations in Bihor County (Săcueni, Oradea, Holod, Borod, Stâna de Vale, Ștei, Dumbrăvița de Codru), as well as from two stations positioned in the administrative-territorial proximity of Bihor County (Vlădeasa and Chișineu Criș), with a long series of observations over 60 years (1961 - 2020). This was divided into two intervals 1961 - 1990 and 1991 - 2020. The meteorological stations studied come from the network of the National Meteorological Agency of Romania, in order to analyze the variation of the values of the bioclimatic indices between the two intervals.

The spatial distribution of bioclimatic indices was calculated and mapped using GIS software (ArcMap, Saga and Qgis) for the time intervals 1961 - 1990 and 1991 - 2020. The annual average values of the analyzed bioclimatic indices were interpolated using the ordinary kriging method, in order to identify the bioclimatic particularities and their variation, regarding the bioclimatic classification of localities with immediate potential for balneary development in the Bihor County area.

To argue the importance of the analyzed indices, we detail more recent studies that used bioclimatic indices included in our study, for different areas of Romania.

The equivalent effective temperature index is applied for the summer season and is more suitable for areas with coastal and plain climates. Being less suitable for hilly and mountainous areas where thermal values are lower and do not fall within the applicability threshold of this index.

Bistricean et al. (2017) conducted a study on the bioclimatic regionalization of Moldova, for the period 1961 - 2013, in which they also included the equivalent effective temperature index that was calculated for the months of June-August. From the spatial analysis, four areas with different bioclimatic characteristics were identified. An area characterized by torrid bioclimatic conditions, identified in the Lower Siret Plain, with average daily temperatures that often exceed 30°C; an area with a hot bioclimate extended in the south of the region between 100 and 200 m; an area characterized by high temperatures with average daytime values exceeding 26°C; warm bioclimatic conditions characteristic of altitudes located between 200 and 300 m, in the southern part of the Moldavian Plain, the Prut Valley and the Bârlad Plateau. Bioclimatic comfort was identified in the rest of the study area, which included over two-thirds of the analyzed territory.

Bistricean (2018) included in his study the analysis of the effective equivalent temperature index in the area of Moldova, for the period 1961 - 2013 in which, due to the limitation of applicability, the climatic data allowed the calculation of this index in a single month, falling within the bioclimatic particularity of cooling discomfort.

Mihăilă et al. (2016) analyzed the effective equivalent temperature index in the area of the Suceava Plateau for the period 1961 - 2013, in which the calculation of the index had a limited applicability and was not relevant because it generated uncertain results, even for the three summer months for which the index was applicable.

Also, the analysis of the effective equivalent temperature index was carried out by Dincă et al. (2013) through which they analyzed the mountain tourist area Câmpulung Moldovenesc - Vatra Dornei, for the period 1961 - 1998, in order to identify possible changes in the bioclimatic characteristics of comfort and discomfort. Thus, it resulted that the values of the effective-equivalent temperature index have no influence on the potential of outdoor tourism, because their variability range is quite constant, having no statistical significance in the studied period. In the study by Teodoreanu and Mihăilă (2012) the effective equivalent temperature index was analyzed for the stations of the Suceava Plateau, in the period 1960 - 2008, in which they conclude that the variation of the effective equivalent temperature index outlined by daily average values is not a relevant way of capitalizing on this bioclimatic index for the studied area.

The thermo-hygrometric index allows the outline of the main types of bioclimatic characteristics and offers a synthetic and representative image not only of the degree of their spatial

extension, but also of their level of intensity, with applicability in strategies for evaluating the climate-tourism potential of the analyzed regions (Ionac and Ciulache, 2009).

Several studies have analyzed the thermo-hygrometric index on the territory of Romania, which reflects both the level and the extension of bioclimatic areas due to cold or heat, widely used by the National Meteorological Administration of Romania (Ionac et al., 2012).

Roșu (2024) analyzed the variation of the thermo-hygrometric index in the tourist resorts of Moldova, for the period 1961 - 2020, taking into account the different influences of the relief and other geographical factors in these resorts, through which he identified the periods of the year that offer bioclimatic comfort, examining the annual, seasonal, monthly regime for each resort. This study resulted, on the one hand, in the trend of increasing the values of the thermo-hygrometric index, which led to the appearance of periods of thermal discomfort, and on the other hand, indicated an improvement in bioclimatic comfort with the temporal extension both towards the end of spring (May) and towards the beginning of autumn (September).

Banc (2024) analyzed the thermo-hygrometric index in order to identify general bioclimatic particularities, as well as to highlight regional differences in bioclimatic conditions in Romania, taking into account climatic parameters from ten large cities (Botoșani, Bucharest, Cluj-Napoca, Constanța, Craiova, Galați, Iași, Oradea, Sibiu, Timișoara), in the period 1961 - 2016. The results of the study found general trends of increasing bioclimatic discomfort due to heating in Oradea, Botoșani and Galați, with stationary trends for the suffocating thermal stress class. Also, a decrease in discomfort due to cooling was identified for all the cities analyzed, except Craiova. This analysis resulted in the temporal extension of the bioclimatic characteristic of comfort and discomfort due to heating, indicating a similar pattern for most indices and their classes of thermal conditions**.**

Roșu et al. (2022) evaluated the bioclimatic potential of the submontane region between Sucevița and Slănic Moldova based on the thermo-hygrometric index, for which they used monthly data from the period 1961 - 2013 from which, although the annual values of the index resulted with low relevance for bioclimatic analyses, the evolution of the index during the 53 years analyzed highlighted some interesting aspects generated by the role of the geographical location and the tendency of increasing thermal values. Thus, the bioclimatic comfort with the maximum temporal weight was noted, in the summer months, followed by the spring and autumn months.

Grigore et al. (2020) analyzes the thermo-hygrometric index for the area of the South Dobrogea Plateau, between 1981 and 2010. According to the values of the thermo-hygrometric index, bioclimatic particularities of cooling discomfort were identified, characterized by values between -20°C and 15°C; bioclimatic comfort with values between 15°C and 20°C, as well as bioclimatic discomfort by heating with values between 20°C and 30°C. Through the relevance of

the thermo-hygrometric index values, information was obtained indicating visible differences in comfort depending on the area and the existence of a favorable bioclimate for the eastern part of the studied plateau.

Trif (2010) in his doctoral thesis entitled Study of the bioclimatic conditions of the Crișeni and Silvano-Someșeni Hills and their influence on the human body presented the characteristics of the climatic elements in the Silvano-Someșeni Hills and their influence on the human body, as well as the analysis of several bioclimatic indices, including the thermo-hygrometric index, concluding the moderate nature of the climate and the complexity of the relationship between climate and the human body.

Bistricean (2018) in his study analyzes several bioclimatic indices, including the thermo-hygrometric index, for the region of Moldova, in the period 1961 - 2013, based on which he concluded that bioclimatic discomfort due to cooling in the studied territory manifests itself for seven months per year. And from the analysis of the annual averages of the thermo-hygrometric index, for the period 1961 - 2013, it resulted that the entire region of Moldova falls under the bioclimatic type of discomfort due to cooling. However, the annual averages of the thermo-hygrometric index do not have bioclimatic or touristic relevance.

Vlăduț (2016) analyzes the thermo-hygrometric index from six meteorological stations in the Oltenia Plain area, from 1971 to 2010, through which he evaluates thermal comfort to identify whether the results obtained highlight the same state of comfort or discomfort throughout the year, taking into account previous studies. Thus, it resulted that the existence of thermal comfort in only two months – May and September, on the entire Oltenia Plain. Dobrinescu et al. (2015) indicated an upward trend for certain indices (thermo-hygrometric and the temperature equivalent to the wind chill power). According to the results obtained, some common characteristics were found, but also notable differences. Thus, the thermo-hygrometric index indicates bioclimatic discomfort through cooling throughout all winter months, while bioclimatic discomfort through heating is characteristic of July and August, and only partially until June (in the south of the plain, along the Danube).

Grigore (2013) took into account the analysis of the thermo-hygrometric index, which provides a synthetic and suggestive image of the bioclimatic particularities in the South Dobrogea Plateau, from the time interval 1971 - 2000. Thus, for the analyzed area, the predominance of bioclimatic discomfort through cooling processes from October to April resulted. Bioclimatic comfort became dominant in May, June and September, especially in the western and central parts of the analyzed territory, and bioclimatic discomfort through heating was identified in July and August.

The wind chill index and the equivalent wind chill temperature are used for the cold season, in which wind is the most important climatic element that conditions human bioclimatic comfort and, consequently, variations in wind speed can create extremely uncomfortable bioclimatic conditions, either due to general air circulation conditions or due to periodic or non-periodic local wind, generating sensations of discomfort due to the supercooling power of the moving air (Ionac and Grigore, 2012).

Several studies have been conducted based on the wind chill index and the equivalent wind chill temperature in the Romanian area.

For example, Roșu, (2024) analyzed the wind cooling power index in tourist resorts in Moldova for the period 1961 - 2022, segmented into two periods 1961 - 1990 and 1991 - 2022. The annual values of the index highlighted a decreasing trend in all resorts in the study area. This fact is correlated with the increasing trend of measured thermal values. Thus, bioclimatic discomfort due to cooling was identified in the winter months and partially in spring and autumn. In the period 1992 - 2022, a temporal extension of bioclimatic comfort from May to September was identified, compared to the period 1961 - 1990 in which there is even a series of years in which bioclimatic comfort is absent 1962 - 1965, 1967 - 1969 or extends over only one or two months.

Bistricean (2018) calculated the wind cooling power index in the Moldova area, in the period 1961 - 2013, through which the bioclimatic particularities of the territory were identified, regarding the monthly characterization of the values of this index, with the maximum threshold of the index values of 1200W/m2 in the mountain floor, in the months of January and February. These index values placed the area in the bioclimatic characteristic of cooling discomfort, with a type of time characterized by hypocaloric stress, in which the effects of the body's cooling power are very intense. Bioclimatic comfort was identified from March to August. In September, the cool weather type was identified, and from October, bioclimatic discomfort through cooling was identified, because in December, hypocaloric stress was accentuated. From the analysis of the multiannual average values of the wind chill temperature in the studied area, values ranging from 8°C in the south of the region to -12.8°C on Ceahlău Toaca resulted. From the monthly spatial distribution of the wind chill temperature, the bioclimatic peculiarity of cooling discomfort was identified throughout the area of Moldova.

Another study that addresses the wind chill index and wind chill temperature was developed by Teodoreanu and Mihăilă (2012) who analyzed for the Suceava Plateau area, in the interval 1961 - 2006, the temporal and spatial variation of this index and identified the annual and daily periods in which the critical thresholds of these indicators are exceeded. Thus, the bioclimatic comfort feature was identified from May to October for the plateau stations, the rest of the months fell within the bioclimatic feature of cooling discomfort. An analysis revealed some differences

between the meteorological stations in the Suceava Plateau, with cooling discomfort accentuated in the winter months in the northern and central plateau, and the identification in the far south, at Roman, of periods of heating discomfort in July. The spatial analysis showed that the smallest distribution of monthly mean values of wind chill temperature was encountered in February, resulting in pronounced cooling discomfort, with index values ranging between -10 and -18°C, in the southern half of the plateau. Cooling discomfort was also identified in April, October and November. Bioclimatic comfort was identified with a small difference between the south and north of the plateau, with maximum values in July. The interdiurnal variation of the index value over the course of a year showed that although there were average values, from one day to the next variations of up to 5 - 6°C of equivalent temperature can occur, especially in winter and early spring, indicating discomfort. From the analysis of the variation of hourly values for each month of the year, the difference between night and day did not exceed a few degrees, being more pronounced in the warmer months, it resulted that comfort being specific to the whole day only in the months of June-September.

Vlăduț (2016) conducted another study that aimed at the wind chill temperature index, which was analyzed with climate data from six meteorological stations in the Oltenia Plain area, from 1971 to 2010. By analyzing the results, bioclimatic comfort characteristics were identified in the April-October interval, except for the northern sector, where the first and last months presented a slight discomfort due to cooling. Comfort was identified in the April-October interval, except for the northern sector where January and December presented a slight discomfort.

Ionac and Grigore (2012) analyzed the wind chill index in Southern Dobrogea, for the interval 1971 - 2000, during the cold season (November - March) and were based on the analysis of the spatial and temporal distribution through which they identified the bioclimatic risk areas. From the analysis of the wind chill index values, the bioclimatic peculiarity of pronounced cooling discomfort was highlighted in February and March, over more than half of the central inner part and the entire eastern strip of the Black Sea coast, with a pronounced maintenance from November to January, especially in the western part. From the spatial analysis, it was found that the equivalent wind temperature values depend directly on the wind chill values, but indirectly on the wind speed, and increased as the wind chill became weaker, since the wind speed decreases as the wind chill increases. From the spatial analysis, it was found that the equivalent wind temperature values depend directly on the wind chill values. The equivalent temperature values increased as the cooling power became weaker, which indicated that the wind speed decreases when the cooling power increases.

A significant study that addressed the wind cooling index over the entire area of Romania was conducted by Ionac and Ciulache (2006) for the period 1961 - 1990, taking into account the

cold season (November - March), with the aim of obtaining a synthetic and suggestive image of the intensity and extension of the bioclimatic risk areas due to supercooling in Romania. The level of bioclimatic risk due to cold, expressed with the help of this index, varies greatly from one region to another and from one month to another. Thus, the mountainous region and the northern center of the Moldavian Plateau were subjected to frequent Scandinavian-Baltic advections, as well as the Dobrogea Plateau, which was affected by the cumulative influence of cold air and the intensification of the wind by the action of the East European Anticyclone, causing a significant decrease in thermal values in November. In December, bioclimatic discomfort due to increased cooling was identified throughout the country, being influenced by the cold air coming from the East-European Anticyclone, except in the Getic Subcarpathians, the Mureș corridor and the western part of Transylvania where the index values were recorded below the risk limit. In January, bioclimatic stress increased throughout the eastern half of the country and on the highest peaks. In February, this particularity continues, except for the sheltered areas of the Getic Subcarpathians where the index values decreased, identifying milder bioclimatic conditions. At the beginning of spring (March), the only type of cold climate extended inside the Carpathian arc and continued in the central-western part of the Romanian Plain, except for a few valleys where low thermal values persisted.

A recent study (Haidu et al., 2024) included in the analysis the same bioclimatic indices, as well as a part (Oradea, Bihor County, Romania) of the area of interest. By comparative analysis of the regime of some climatic elements and bioclimatic indices specific to the two reference periods, it was proven that a small change in the descriptive statistical characteristics between the two normal periods has a significant impact on the bioclimatic indices.

Through the results obtained from the analysis of these indices indicating significant temperature changes, compared to a similar period to that considered for this study, temperature and wind appear to be the triggering factors of the changes identified for these bioclimatic indices.

The values of the indices calculated in our study are in accordance with the bioclimatic particularities reproduced or validated in the studies of several authors in the national specialized literature (Paucă, 1988; Berlescu, 1998; Ciulache et al., 1998; Ionac et al., 2004a, 2004b, 2006, 2007b, 2007a, 2009, 2010; Ioanc et al., 2008; Gaceu et al., 2009; Teodoreanu et al., 2009, 2012, 2013; Trif, 2010; Vlăduţ, 2011; Gaceu, 2012; Ionac and Mihoc, et al., 2012; Ionac and Tăbleţ, et al., 2012; Dincă et al., 2013; Grigore, 2013; Mihăilă, 2014; Dobrinescu et al., 2015; Mihăilă et al., 2015, 2016, 2019, 2020, 2024; Teodoreanu, 2015a, 2015b; Vlăduț, 2015, 2016; Croitoru et al., 2016; Maftei et al., 2017; Mihăilă and Bistricean, 2018; Mihăilă, et al., 2018; P. Ichim et al., 2020; Roșu et al., 2022; Roșu, 2024 etc), as well as in studies from the international specialized literature (Besancenot, 1970, 1974, 1985, 1986, 1993, 1997b, 2001a, 2001b; Kyle, 1992; Auliciems et al.,

1998; Alcoforado, 2001; Besancenot et al., 2004; Gulyás, 2005; Schitzer, 2006; Boubaker, 2007; Gulyás et al., 2007; Vincent et al., 2007; Błażejczyk et al., 2010; Rivas-Martínez et al., 2011; Boko et al., 2014; Cannistraro et al., 2014; Cetin, 2015; Mekis et al., 2015; Lebedeva et al., 2018; Sirangelo et al., 2020; Asghari et al., 2022; Glogowska et al., 2022 etc.).

5.2.2. Bioclimatic characteristics of Bihor County

The bioclimatic analysis of a region is one of the components included in the inventory of balneary resources, with applicability in determining the region's tourist potential, the impact of environmental conditions on human health, and socio-economic activities (Głogowski et al., 2022). The relationship between climatic elements and the human body is best reflected through bioclimatic characterization (Teodoreanu and Bunescu, 2009).

Identifying the bioclimatic characteristics of Bihor County, based on multiannual monthly average values of bioclimatic indices, enabled the bioclimatic classification of localities with immediate balneary potential.

This study provides a detailed presentation of the bioclimatic characteristics recorded at the Săcueni meteorological station, as this locality is insufficiently documented in the specialized literature, despite the fact that it has exploited hydromineral resources. The importance of detailing this area is also underlined by its proximity to other localities that already exploit hydromineral resources (such as Marghita, Sânnicolau de Munte, Chișlaz, Tămășeu or Valea lui Mihai) or that possess immediate potential for balneal exploitation (Ciocaia, Cherechiu, Cheșereu, Ciocaia, Mihai Bravu, Roșiori, Sântimreu, Valea lui Mihai) (Ciurba et al., 2023; Haidu et al., 2023; Linc et al., 2023).

Therefore, detailing the bioclimatic characteristics at the Săcueni meteorological station contribute to a better understanding of the regional balneoclimatic potential and supports the justification for future initiatives aimed at the therapeutic exploitation of the area.

5.2.2.1 Effective equivalent temperature index (TEE) (°C)

The equivalent temperature represent the internal temperature of a given air volume, under constant pressure conditions, that would be reached if the latent heat from the water vapor it contains were released.

This index is applicable for air temperatures between + 20°C and + 45°C (Table 29) and for atmospheric pressure values between 800 and 1100 hPa. At temperatures above 45°C, where humidity and atmospheric pressure vary, the effective-equivalent temperature index (TEE) indicates only extreme values associated with intense heat conditions (Mihăilă et al., 2016).

The mathematical formula for calculatingg the effective-equivalent temperature index was developed by Hougton Yaglou (1947), confirmed by Landsberg (1964), and cited by Grigore et al., 2016):

$$\mathbf{TEE = Tusc + w \cdot (r - 2.326 \cdot Tusc) / (cp + w^* \cdot cw)}$$

where: TEE = effective-equivalent temperature; Tusc = air temperature (measured with a dry bulb thermometer) (°C); r = latent heat released by the vaporization of water (cal·g-1), having a value of 585 cal·g-1; w = real ratio of the mixture, i.e. the ratio between the amount of water vapor and the amount of dry air (g/Kg-1); cp = specific heat of air at constant pressure (cal °C·g-1), having a value of 0.24 cal·°C·g-1; cw = specific heat of water (cal·°C·g-1), having a value of 1 cal·°C·g-1.

To obtain real values and for correct use, the real mixing ratio (w) is expressed using the following mathematical formula:

$$\mathbf{E = 6.112 \times 10.07.5 \times Tusc / (237.7 + T\ usc) \rightarrow W = E / P \rightarrow w = UR \times W / 100}$$

where: E = saturated vapor pressure (hPa); W = saturation mixture ratio, i.e. the ratio between the amount of water vapor that could saturate a given parcel of air and the amount of dry air (g/Kg-1); P = air pressure measured at sea level (hPa); UR = relative air humidity (%); w = actual mixture ratio.

Table 29. The thresholds of the effective equivalent temperature index (°C), weather types and bioclimatic particularity.

Index TEE (^{0C})	Weather Type	Bioclimate type: comfort/discomfort
TEE ≤ 27	Cold	Bioclimatic discomfort due to cooling
27 < TEE ≤ 34	Cool	
34 < TEE ≤ 47	Comfortable	Bioclimatic comfort
47 < TEE ≤ 51	Warm	Bioclimatic discomfort due to heating
TEE > 51	Sweltering	

(source: Kyle, 1994, cited by Ionac and Ciulache, 2008)

To calculate the values of the effective equivalent temperature index (TEE), the required variables - mean air temperature (°C), relative humidity (%) and atmospheric pressure (hPa) – were derived from data recorded at the Săcueni meteorological station (Table 30). The temperature values according to the applicability limits of this index are highlighted, along with the effective equivalent temperature index values obtained from the periods 1961 - 1990 and 1991 – 2020, in order to observe the variation of the analyzed bioclimatic indices over time.

Table 30. Multiannual monthly values of the effective equivalent temperature index at the Săcueni meteorological station in the intervals 1961-1990 and 1991-2020.

Variables/ Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
T med (1961-1990)	-2,3	0,5	5,3	11,1	16,2	19,0	20,6	19,9	16,1	10,7	5,2	0,3	10,22
T med (1991-2020)	-0,3	1,3	6,0	11,9	16,9	20,5	22,0	21,8	16,4	11,3	6,1	0,9	11,23
UR med (1961-1990)	85	82	75	69	69	70	69	72	74	77	83	87	76
UR med (1991-2020)	84	80	71	66	68	69	68	68	72	77	82	86	74
P med (1961-1990)	1006	1004	1003	999	1001	1001	1001	1002	1004	1006	1005	1005	1003
P med (1991-2020)	1006	1005	1003	1000	1001	1001	1000	1002	1003	1005	1005	1006	1003
TEE (°C) (1961-1990)							55,39						55,39
TEE (°C) (1991-2020)						55,24	59,33	58,17					57,58

Following the analysis of the variables used to determine the effective equivalent average temperature index (TEE), its calculation was performed, according to the index's applicability limits, for the month of June during the period 1961 - 1990. In contrast, for the period 1991 – 2020, the index was calculated for the months of June, July and August.

The comparative analysis revealed a bioclimatic characteristic of thermal discomfort due to heating with an increase of 2.2 units in the TEE during 1991 - 2020 compared to 1961 - 1990.

To support this comparison, multiannual monthly average values of the effective equivalent temperature index were compiled for all analyzed meteorological across both intervals (Table 31).

Table 31. Multiannual monthly values of the effective equivalent temperature index at the meteorologicalstations analyzed in the intervals 1961 - 1990 and 1991 - 2020.

TEE °C	**Altitude (m)**	**(1961 - 1990)**		**(1991 - 2020)**		
		VII	VIII	VI	VII	VIII
Chișineu Criș	96	56,35	55,77	55,24	59,33	58,17
Săcueni	125	55,39		56,26	59,97	59,46
Oradea	136	56,19	56,14	54,91	58,81	58,40
Holod	163					
Ștei	275				57,94	57,52
Borod	333					
Dumbrăvița de Codru	432			56,61	56,62	
Stâna de Vale	1108					
Vlădeasa	1800					

The comparative analysis of the average values of the effective equivalent temperature index from meteorological stations analyzed during the two study intervals, revealed both higher values and a temporal extensions of the index in the interval 1991 - 2020, compared to the interval 1961 - 1990.

Thus, the bioclimatic particularity of discomfort due to heating was identified at three meteorological stations in the plain area (at Chișineu Criș, Oradea and Săcueni) for two months (July and August), in the interval 1961 – 1990. In contrast, during 1991 - 2020, the same bioclimatic discomfort due to heating was identified across a longer period (June, July and August) at meteorological stations in the

hill area (at Chișineu Criș, Oradea Săcueni) and also extended to meteorological stations located in the hilly and depression area (at Ștei and Dumbrăvița de Codru).

In the altitudinal development, bioclimatic discomfort due to heating was identified up to an altitude of 136 m, in Oradea in the interval 1961 - 1990, while in the interval 1991 - 2020 it reached elevations of up to 432 m in Dumbrăvița de Codru.

In the territorial distribution of the annual values of the effectively equivalent temperature index in Bihor County, for the two analyzed intervals, the trend of variation of the bioclimatic particularity was identified, so that discomfort due to heating, with a suffocating weather type, was also identified at the Dumbrăvița de Codru and Ștei meteorological stations in the interval 1991 - 2020 compared to the interval 1961 - 1990 in which this index could not be calculated at these meteorological stations, due to the limits of applicability (Figure 62).

From the identification of localities with immediate balneary potential, as well as localities that capitalize on the hydromineral resource depending on the bioclimatic particularity, it resulted that in the period 1961 - 1990, five localities were classified as heating discomfort, with suffocating weather type (Cheșereu, Cherechiu, Săcueni, Ciocaia, Sântandrei, Oradea), and in the period 1991 - 2020 the number of localities classified as having the same bioclimatic particularity and weather type increased to nine (Cheșereu, Cherechiu, Săcueni, Ciocaia, Sântandrei, Ștei, Borș, Roșiori, Oradea).

Regarding the bioclimatic discomfort with hot weather type in the period 1961 - 1990, only one locality was identified (Borș), and in the period 1991 - 2020, four localities were identified (Mihai Bravu, Valea lui Mihai, Băile Felix, Băile 1 Mai). In the bioclimatic comfort particularity in the period 1961 - 1990, six localities were identified (Valea lui Mihai, Marghita, Mihai Bravu, Roșiori, Băile Felix, Băile 1 Mai). In the bioclimatic discomfort particularity through cooling with cool weather type in the period 1961 - 1990, three localities were included (Salonta, Ciumeghiu, Ghiorac), and in the period 1991 - 2020, the number of localities decreased to only one (Balc). The bioclimatic discomfort with a cold weather type in the period 1961 - 1990 included seven localities (Balc, Aleșd, Ceica, Tinca, Răbăgani, Beiuș, Ștei), compared to the period 1991 - 2020 which included four localities (Aleșd, Ceica, Tinca, Răbăgani).

These results highlight shifts in the regional bioclimatic profile, largely determined by a gradual increase in the annual average of the effective equivalent temperature index, suggesting a progressive warming trend over time, despite the stability of the cool-type bioclimate, specific for the temperate climate with oceanic influences in the region of the Western Plain and Hills.

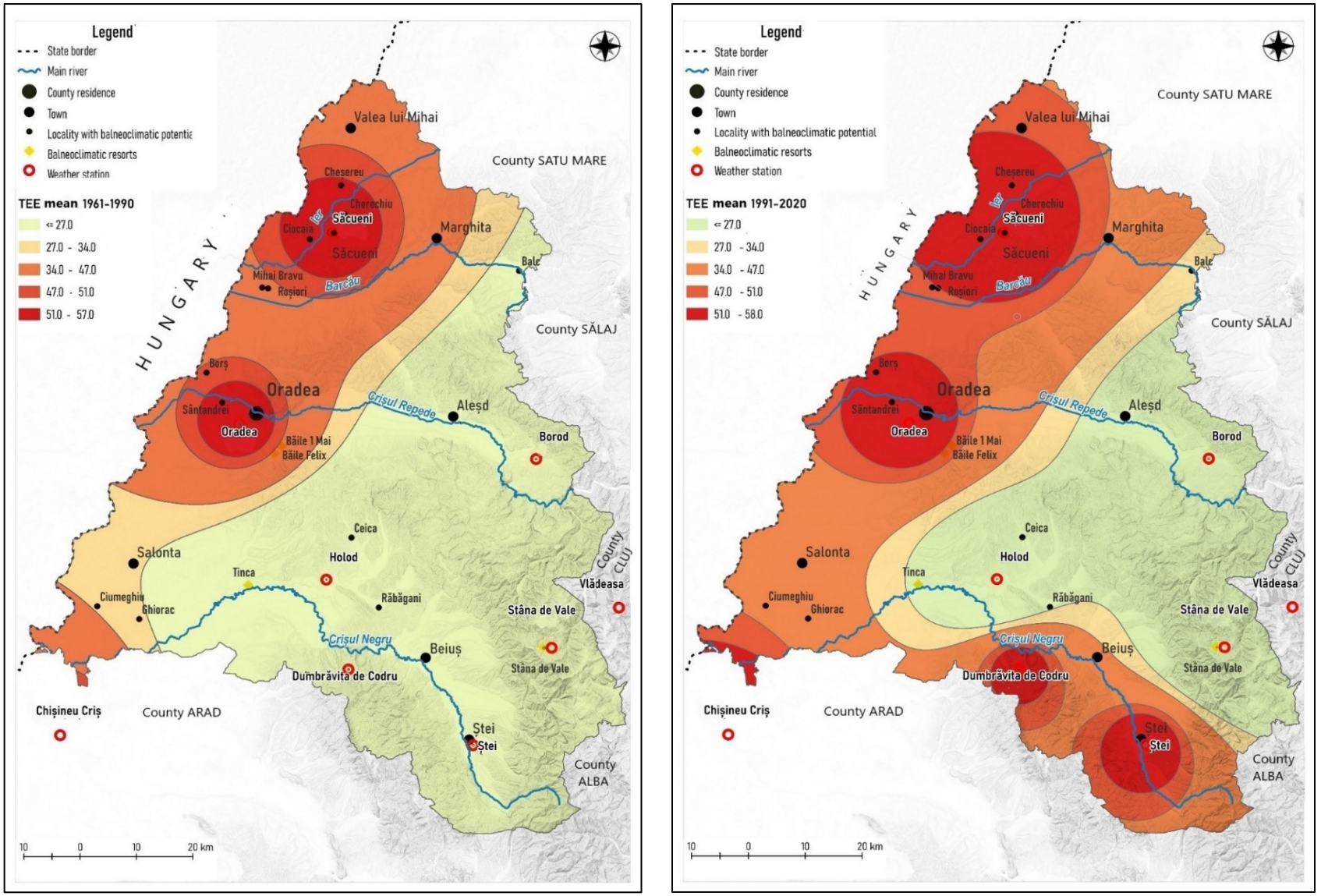


Figure 62. Spatial distribution of the effective equivalent temperature index in Bihor County for the intervals 1961 - 1990 and 1991 - 2020.

The comparative analysis of the share of bioclimatic particularities identified according to the number of localities with immediate balneary potential in Bihor County (Figure 63) was carried out in order to identify the extension of the types of bioclimates in which these localities are included, in the two intervals.

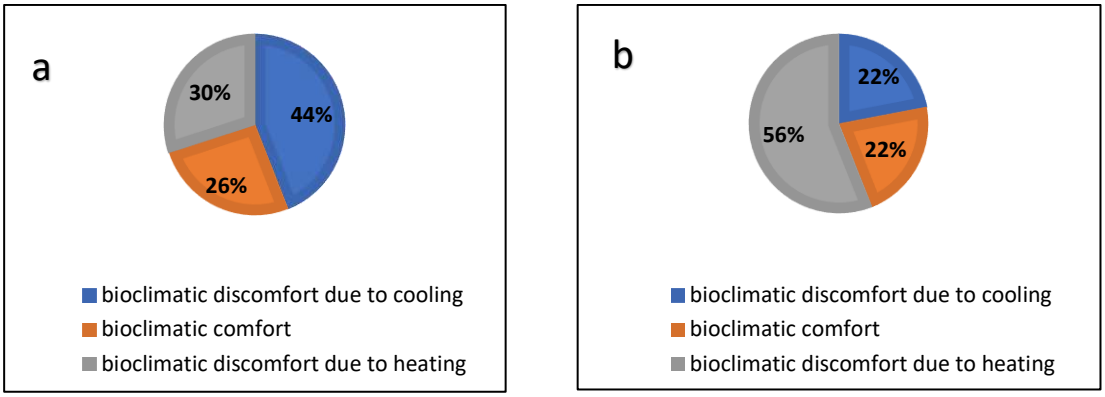


Figure 63. Bioclimatic particularity in Bihor County (a) 1991 – 2020 and (b) 1991 – 2020.

In localities with immediate potential for balneary development in Bihor County, an involution was identified for bioclimatic discomfort through cooling, which decreased from 44% in the period 1961 - 1990 to 22% in the period 1991 - 2020, followed by discomfort through heating, which increased, with an almost double share, from 30% in the period 1961 - 1990, to 56% in the period 1991 - 2020. Thus, the bioclimatic particularity of comfort had a slightly decreasing share from 26% in the period (1961 - 1990) to 22% in the period (1991 - 2020).

5.2.2.2. Thermo-hygrometric index (THI) (°C)

The thermo-hygrometric index (THI), by the US National Weather Service in 1959, is used to highlight the combined effects of temperature and humidity on heat stress levels under various climatic conditions, (Asghari et al., 2022).

The mathematical calculation of the index is based on the formula:

THI (°C) = T usc - (0.55 - 0.0055 *UR) * (T usc - 14.5) (Kyle, 1992)

where: THI = thermo-hygrometric index**; T usc** = air temperature (°C) measured with a dry bulb; **UR** = relative air humidity (%).

The threshold values of the thermo-hygrometric index corresponding to the types of weather and types of bioclimates are highlighted in Table 32.

Table 32. Threshold values of the thermo-hygrometric index (°C), types of weather and bioclimatic particularity.

Index THI	Weather Type	**Bioclimatic peculiarity: comfort or discomfort**

– 20 < THI ≤ – 10	Excessively Cold	Bioclimatic discomfort due to cooling
– 10 < THI ≤ – 1.8	Very Cold	
– 1.8 < THI ≤ 13	Cold	
13 < THI ≤ 15	Cool	
15 < THI ≤ 20	Comfortable	Bioclimatic comfort
20 < THI ≤ 26.5	Warm	Bioclimatic discomfort due to heating
26.5 < THI ≤ 30	Very Hot	
THI > 30	Heatwave	

Source: Kyle,1994, citat de Ionac și Ciulache, 2008

For the analysis of this index, multiannual monthly average values of air temperature (°C) and relative air humidity (%) from the meteorological stations included in the study were used, for the intervals 1961 - 1990 and 1991 - 2020, in order to identify bioclimatic particularities and conduct a comparative analysis of the thermo-hygrometric index values (Tablel 33).

Tablel 33. Variables and multiannual monthly average values of the thermo-hygrometric index at the Săcueni meteorological station.

Variables / Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
T mean (1961-1990)	-2,3	0,5	5,3	11,1	16,2	19,0	20,6	19,9	16,1	10,7	5,2	0,3	10,2
T mean (1991-2020)	-0,3	1,3	6,0	11,9	16,9	20,5	22,0	21,8	16,4	11,3	6,1	0,9	11,2
UR mean (1961-1990)	85	82	75	69	69	70	69	72	74	77	83	87	76
UR mean (1991-2020)	84	80	71	66	68	69	68	68	72	77	82	86	74
THI (°C) (1961-1990)	-0,91	1,91	6,63	11,66	15,87	18,29	19,56	19,03	15,89	11,17	6,06	1,31	10,5
THI (°C) (1991-2020)	0,9	2,8	7,3	12,4	16,5	19,5	20,7	20,5	16,1	11,7	6,9	2,0	11,4
Difference THI (1991-2020)-(1961-990)	1,8	0,9	0,7	0,7	0,6	1,2	1,1	1,5	0,2	0,5	0,8	0,7	0,9

The analysis of thermo-hygrometric index revealed a bioclimatic particularity of discomfort due to cooling, with the same temporal extent in both intervals, but higher intensity during the 1991 – 2020 period.

The bioclimatic comfort characteristic was observed from May to September in the 1961 – 1990 interval, whereas in the 1991 - 2020 interval, it was limited to the months of May, June and September. Unlike the 1961 – 1990 interval, bioclimatic discomfort due to heating was identified in the months of July and August during the 1991 – 2020 period.

The comparative analysis of the multiannual monthly values of the thermo-hygrometric index in Săcueni revealed higher values for the 1991 – 2020 period, for each annual period, with differences ranging from 1.8°C in January to 0.2°C in September. From the comparative analysis of the annual average, it resulted that the value of the thermo-hygrometric index was 0.9 °C higher in the 1991 – 2020 period , compared to 1961 - 1990.

The thermo-hygrometric index values for both intervals were graphically represented to illustrate the monthly amplitudes at the Săcueni meteorological station (Figure 64).

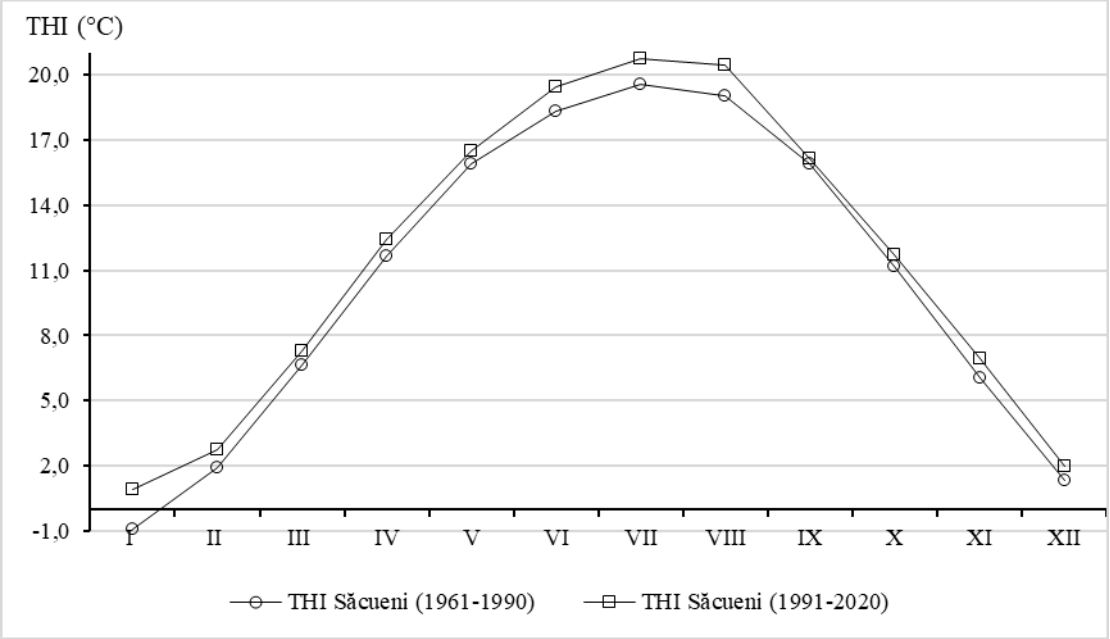


Figure 64. Multiannual variation of the monthly average values of the thermo-hygrometric index at the Săcueni meteorological station for the intervals 1961 – 1990 and 1991 – 2020.

The graphic representation shows that the multiannual average values of the thermo-hygrometric indexduring the 1991 – 2020 period are higher than those from 1961 - 1990, due to increased air temperature, especially during the summer months.

The thermo-hygrometric index values were compiled for all the meteorological stations analyzed, in order to identify the bioclimatic characteristics of the study area for the 1961 – 1990 period (Table 34).

Table 34. Monthly and annual average values of the thermo-hygrometric index at the meteorological stations analyzed in the period 1961 - 1990.

THI - mean C°	**(1961 - 1990)**												
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**Anual**
Chișineu Criș	-1,1	1,6	6,3	11,3	15,7	18,3	19,7	19,2	15,8	10,8	5,8	1,2	10,4
Săcueni	-0,9	1,9	6,6	11,7	15,9	18,3	19,6	19,0	15,9	11,2	6,1	1,3	10,5
Oradea	-0,7	1,5	6,4	11,3	15,5	18,3	19,7	19,4	16,0	11,3	6,3	1,7	10,6
Holod	-0,3	2,5	6,9	11,0	15,6	17,8	19,2	18,8	15,2	10,7	5,8	1,8	10,4
Ștei	-0,2	2,2	6,2	10,7	14,7	17,2	18,5	18,2	15,0	10,7	6,3	1,7	10,1
Borod	-0,6	1,7	6,4	10,1	14,5	16,6	17,9	17,5	14,4	10,0	5,2	1,6	9,6
Dumbrăvița de Codru	1,8	4,8	10,4	14,3	16,1	18,9	18,6	15,3	11,4	5,1	2,1	0,1	9,9
Stâna de Vale	-5,0	-3,9	-0,4	3,6	8,8	11,5	13,0	12,5	9,3	5,2	0,2	-2,6	4,4
Vlădeasa	-5,9	-5,9	-3,4	0,7	5,2	7,7	9,5	9,6	6,9	4,0	-1,1	-4,4	1,9

From the analysis of the multiannual monthly values of the thermo-hygrometric index in the studied area, a bioclimatic comfort peculiarity was identified, characterized by values ranging from 15°C at Ștei to 19.7°C at Oradea. The bioclimatic comfort was observed from May to September at the Chișineu Criș, Săcueni, Oradea, Holod meteorological stations.

These bioclimatic characteristics were influenced by the landforms where the meteorological stations are positioned. Thus, during the 1961-1990 interval, bioclimatic comfort was identified both in the plain areas - characterized by higher temperatures and lower humidity (at Chișineu Criș, Săcueni, Oradea, Holod) - and in the hills and depressions (at Ștei, Borod, Dumbrăvița de Codru), from May to September.

Additionally, the bioclimatic peculiarity of discomfort due to cooling was identified throughout the entire annual period, characterized by values ranging from -5.9°C in January at Vlădeasa to 13°C in June at Stâna de Vale. This is attributed to the location of these meteorological stations in the mountainous area, which exibit specific climatic characteristics.

The analysis of the annual averages of the thermo-hygrometric index values for the 1961 – 1990 period, shows that the entire area exhibited bioclimatic discomfort due to cooling, with values ranging from 1.9°C at Vlădeasa to 10.6°C at Oradea.

The values of thermo-hygrometric index for the 1961 – 1990 period were graphically represented in order to identify their amplitudes recorded at the meteorological stations studied (Figure 65)

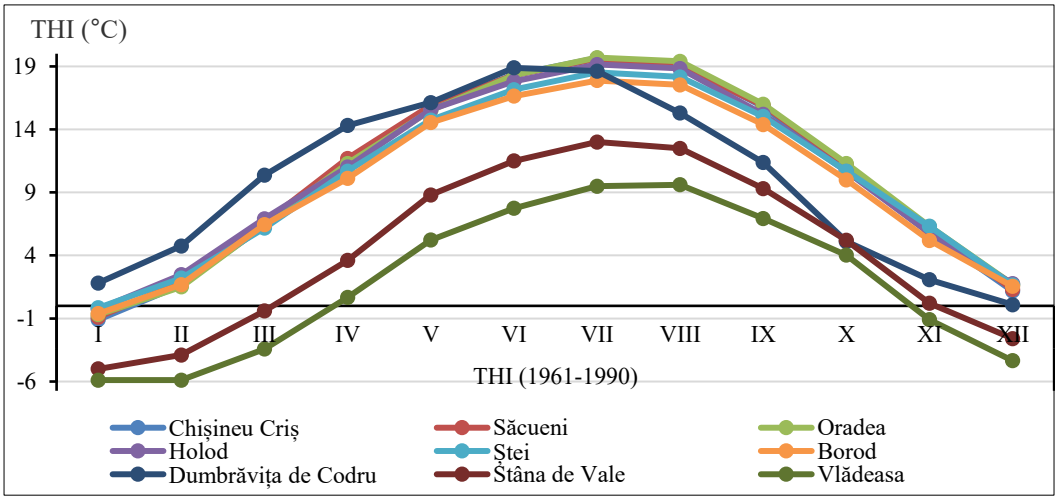


Figure 65. Multiannual variation of the monthly mean values of the thermo-hygrometric index for the meteorological stations analyzed during the period 1961 – 1990.

The analysis of thermo-hygrometric index variation across the studied meteorological stations, highlights the significant influence of the meteorological stations positioning along different hypsometric levels, as well as other local geographical factors. thermo-hygrometricThe index values are higher throughout the year at the meteorological stations located in lowland (plain) areas and decrease with increasing altitude, reflecting the spicific climatic characteristics of mountainous area, such as lower temperatures and higher wind intensity.

Thermo-hygrometric index values from each meteorological station were compiled and analyzed for the 1991 – 2020 period, in order to identify bioclimatic particularities (Table 35).

Table 35. Monthly and annual average values of the thermo-hygrometric index at the meteorological stations analyzed in the period 1991-2020.

THI - mean C°	(1991 - 2020)												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Anual
Chișineu Criș	0,9	2,8	7,3	12,4	16,5	19,5	20,7	20,5	16,1	11,7	6,9	2,0	11,4
Săcueni	0,5	2,2	6,9	12,2	16,5	19,6	20,9	20,6	16,2	11,3	6,5	1,9	11,3
Oradea	0,8	2,5	7,1	12,2	16,3	19,4	20,7	20,6	16,3	11,6	6,9	2,0	11,4
Holod	0,6	2,3	6,6	11,9	16,1	19,4	21,0	21,0	16,1	11,2	6,2	1,5	11,2
Ștei	1,3	3,0	6,9	11,6	15,4	18,5	19,8	19,7	15,4	11,2	7,1	2,5	11,0
Borod	0,3	1,7	5,5	10,7	15,0	18,3	19,8	19,7	15,0	10,5	6,1	1,6	10,3
Dumbrăvița de Codru	2,6	6,5	11,5	15,3	18,2	19,7	19,9	15,7	11,7	7,3	2,2	1,3	11,0
Stâna de Vale	-3,8	-2,7	0,2	4,5	9,6	13,1	14,3	13,8	9,5	5,6	1,7	-2,7	5,3
Vlădeasa	-5,1	-5,1	-3,2	1,8	6,2	9,6	11,2	11,7	7,3	4,2	0,5	-3,7	3,0

The analysis of multiannual monthly average values resulted in the identification of bioclimatic characteristics of discomfort due to cooling throughout the annual period, characterized by values ranging from -5.9°C in January at Vlădeasa and 14.3°C in June at Stâna de Vale.

During the 1991-2020interval, a bioclimatic particularity of discomfort due to heating was identified in July and August at the meteorological stations located in the plain area (Chișineu Criș, Săcueni, Oradea and Holod), , with values ranging from 20.5°C at Chișineu Criș and 21.0°C at Holod.

From the analysis of the annual averages of the thermo-hygrometric index values for the 1991 - 2020 period from the meteorological stations analyzed, it was found that the entire area falls within the bioclimatic particularity of cooling discomfort, characterized by values ranging from 3.0 °C, at Vlădeasa to11.4 °C, at Chișineu Criș.

A graphical representation of the multiannual variation of the thermo-hygrometric index was created to identify the monthly amplitudes at each meteorological station during the 1991 - 2020 period (Figure 66).

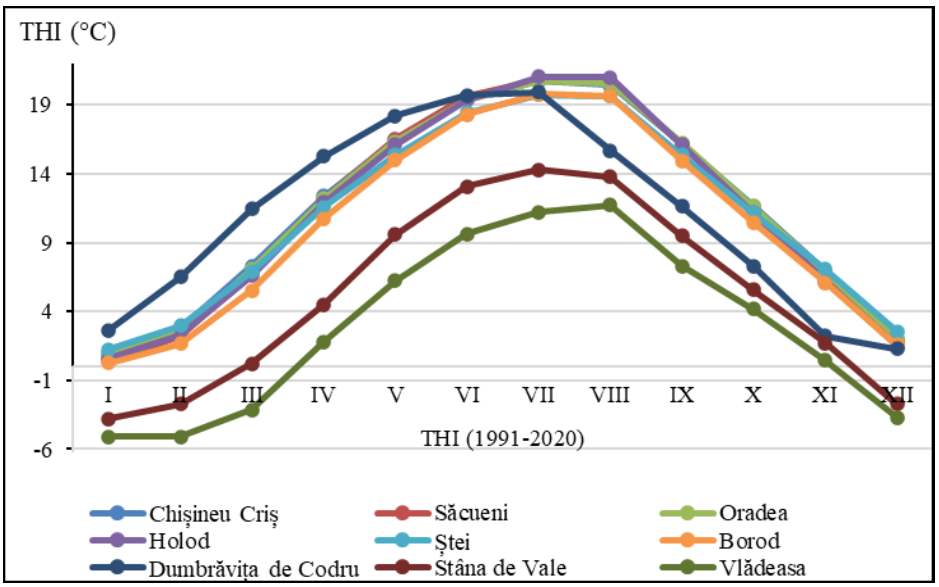


Figure 66. Multiannual variation of monthly mean values of the thermo-hygrometric index for the meteorological stations studied between 1991 and 2020.

The analysis of the variation of the multiannual monthly values of the thermo-hygrometric index for the analyzed meteorological stations revealed a significant influence of the positioning of the stations on different hypsometric steps of the relief. Thus, at the meteorological stations positioned in the plain area, the values of the thermo-hygrometric index were positive for each annual period, unlike the meteorological stations positioned in the mountainous area where the values of this index were negative in the months of December, January, February and March. The amplitude of the index values is accentuated in the summer months at all meteorological stations, due to the high thermal values in this season.

The multiannual monthly averages for each interval, as well as the annual average of the thermohygrometric index values (Table 36), were centralized in order to perform a comparative analysis of the values between the two intervals.

Table 36. Multiannual monthly average values of the thermo-hygrometric index in the intervals 1961 - 1990 and 1991 - 2020.

THI (°C)	**Comparison 1961 - 199 cu 1991 - 2020**												
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**Anual**
Monthly mean (1961-1990)	-1,4	0,7	5,1	9,4	13,6	16,1	17,3	16,6	13,3	8,8	4,1	0,3	8,6
Monthly mean (1991-2020)	-0,2	1,5	5,4	10,3	14,4	17,4	18,7	18,1	13,7	9,4	4,9	0,7	9,5
Difference THI (1961-1990 vs 1991-2020)	1,2	0,7	0,4	0,9	0,9	1,4	1,4	1,5	0,4	0,6	0,8	0,5	0,9
Percentage difference %	86	114	6	10	6	8	8	9	3	7	20	133	10

The comparative analysis of the multiannual monthly average values showed that the temporal extension of the bioclimatic particularities was equal in both intervals in the months of

June-August, but with higher values in the 1991 – 2020 interval, ranging from 0.4 units in March to 1.5 units in August.

From the comparative analysis of the multiannual annual average of the thermo-hygrometric index values, it was found that during the 1991 – 2020 period, the value of the thermo-hygrometric index is higher by 0.9 units compared to the annual average values from the 1961 – 1990 period. Regarding the characteristic of the bioclimate in the analysis of the annual averages of the two intervals, bioclimatic discomfort due to cooling was identified, with higher values in the 1991 – 2020 period.

The monthly average values of the thermo-hygrometric index recorded a generalized increase in the 1991–2020 period compared to the 1961–1990 interval. The largest percentage increases are observed in the winter months, especially in December (133%), February (114%) and January (85.7%), which indicates a decrease in the severity of the cold season. In the summer months, the values increase moderately (between 5% and 9%), but constantly, indicating an increase in bioclimatic discomfort.

A graphical representation of the trend of the thermo-hygrometric index values was made, in order to identify whether there are differences in the thermo-hygrometric index values in the two intervals (Figure 67).

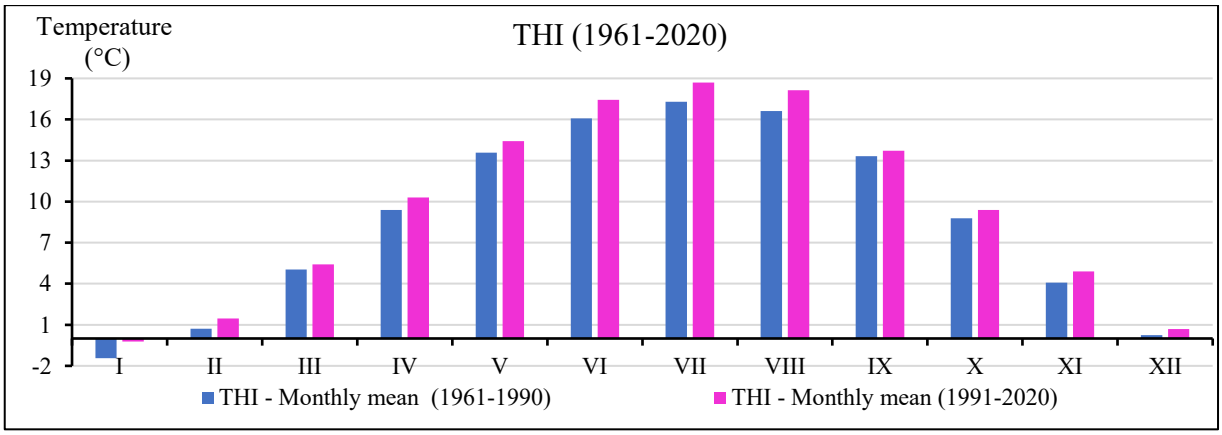


Figure 67. Multiannual monthly variation of thermo-hygrometric index values in Bihor County in the 1961 - 1990 and 1991 – 2020 intervals.

From the graphic analysis (Figure 67) it resulted that the evolution of the thermo-hygrometric index values is higher due to the thermal values of the area which have been higher in recent years, respectively in the 1991 – 2020 period.

From the territorial distribution of the thermo-hygrometric index in Bihor County, for the two analyzed intervals, increased values were found in the 1991 – 2020 period compared to the 1961 – 1990 interval, through the territorial extension of the bioclimatic discomfort due to heating, in the entire analyzed

area. Thus, from the comparative analysis of the two analyzed intervals, it is observed that the minimum values of the index increased from below 2 units (1.9 at Vlădeasa) in the interval 1961 - 1990, to the minimum value in the interval 1991 - 2020, below 3 units (also at the Vlădeasa meteorological station). The maximum values of the thermo-hygrometric index increased from 10 - 11 units (11.6 in Oradea) in the period 1961 - 1990 to 11 - 12 units in the period 1991 - 2020, (11.4 units in Săcueni). The index values increased in the plain areas in the west of the county up to the border with the Western Hills (Figure 68).

According to the threshold values, the annual average of the thermo-hygrometric index was identified the bioclimatic peculiarity of discomfort through cooling, with a cold weather type in the entire area of Bihor County.

The analyzed data resulted in slight temporal-territorial changes in the thermo-hygrometric index, highlighting a generalized increase in the monthly average values in the period 1991–2020 compared to 1961–1990. The most significant increases were recorded in the summer months, especially in July and August, indicating an increase in thermal discomfort. At the territorial level, the values differ from one meteorological station to another, being influenced by their altitudinal positioning.

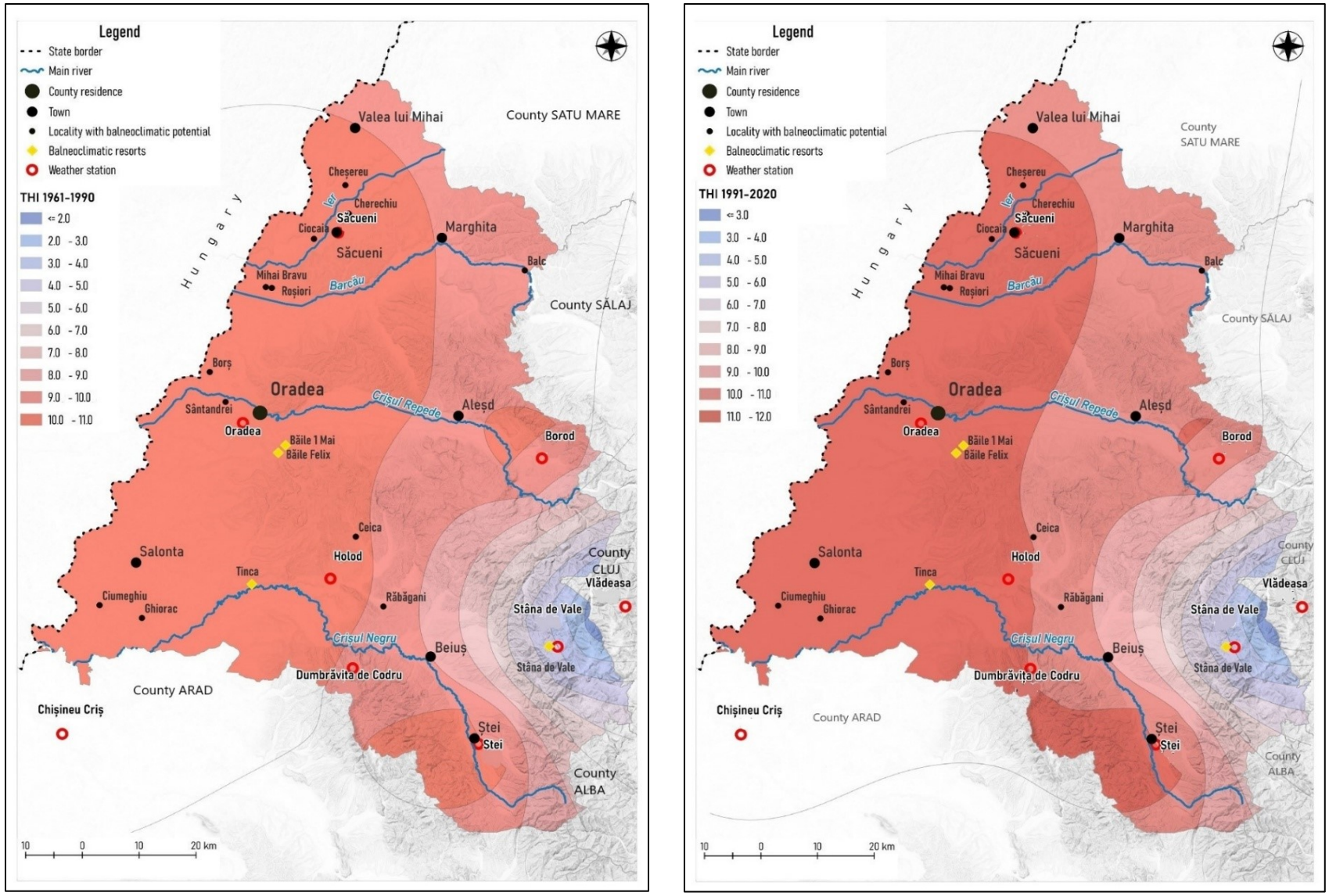


Figure 68. Territorial distribution of the thermo-hygrometric index in Bihor County in the intervals 1961 - 1990 and 1991 - 2020.

5.2.2.3. Wind Cooling Index (WCI) (W/m^2)

The Wind Chill Index (WCI) is expressed in W/m^2 and was developed by Paul Siple and Charles Passel, following an experiment in Antarctica in 1941. It mainly reflects the combined influence of air temperature and wind speed on the thermal balance of the human body, so that the cooling process directly depends on the wind speed (Bistricean, 2018).

This index is a meteorological indicator that measures the heat loss of the human body through the combined effect of air temperature (°C) and wind speed (m/s). It provides an objective measure of the perception of cold felt by the skin in windy conditions. When the air temperature is low and the wind speed is high, the human body is prone to increased cooling discomfort. When the air temperature is high, the wind increases thermal comfort (Teodoreanu, 2015b). This index provides a simple and practical means for assessing the thermal effects of wind on the human body outdoors. The temperature perceived by the human body can vary depending on the wind speed (Shitzer, 2006).

The value of the index expresses the intensity of heat loss (W) suffered by the unit of body surface (m2) in unit of time (s), by combining several physical processes such as radiation, conduction, convection and evaporation (Bistricean, 2018; Ionac and Ciulache, 2007).

There are several formulas for this index in the specialized literature. One of these formulas is that of Siple and Passel in 1945, which uses an empirical equation that takes into account the combined effect of air temperature measured with a dry bulb and wind speed in m/s. (Bistricean, 2018; Siple and Passel, 1945).

$$\mathbf{WCI = (12{,}1452 + 11{,}6222\sqrt{v1} - 1{,}16222v1) \times 33 - Tusc}$$

were:

WCI = Wind Chill Index (W/m^2);

Tusc - dry bulb temperature (°C);

v - wind speed (m/s).

The wind chill index is complemented by another one called the wind chill equivalent temperature (WCET). This is the temperature that the air reaches at certain values of wind speed (Teodoreanu and Mihăilă, 2012).

This index can be calculated for all months of the year and indicates the state of bioclimatic comfort or discomfort determined by the influence of temperature (°C) and wind speed (m/s) on the human body (Table 37).

Table 37. Wind chill power (W/m^2), equivalent temperature to wind chill power, weather type and bioclimatic conditions.

Wind cooling power WCI (W/m^2)	Wind chill equivalent temperature – WCET (°C)	Weather Type	Bioclimatic conditions
200-400	Tpr > +10	Comfort	Bioclimatic comfort
400-600	+10 ≥ Tpr >-1	Cool	Bioclimatic discomfort due to cooling
600-800	-1 ≥ Tpr > -10	Very Cool	
800-1000	-10 ≥ Tpr >-18	Cold	
1000-1200	-18 ≥ Tpr >-29	Very Cold	
1200-1400	-29 ≥ Tpr >-50	Hypocaloric Stress	
> 1400	Tpr ≤-50	Risk of Instant Frostbite	

(source: Ionac et al., 2012; Bistricean, 2018)

For the analysis of this index, average monthly data of air temperature and wind speed were used. The calculated values for the Săcueni meteorological station are presented in detail. The analysis of these variables produced valuesfor the two intervals, 1961 - 1990 and 1991 - 2020, which were then compared to identify the bioclimatic particularities (Table 38).

Table 38. Wind chill index values at the Săcueni meteorological station for the periods 1961 - 1990 and 1991 - 2020.

WCI (W/m^2) / Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
T mean (1961-1990)	-2,3	0,5	5,3	11,1	16,2	19,0	20,6	19,9	16,1	10,7	5,2	0,3	10,2
T mean (1991-2020)	-0,3	1,3	6,0	11,9	16,9	20,5	22,0	21,8	16,4	11,3	6,1	0,9	11,2
WS mean (1961-1990)	2,6	2,9	3,1	3,0	2,6	2,2	1,9	1,6	1,9	2,1	2,9	2,8	2,5
WS mean (1991-2020)	2,2	2,4	2,9	2,5	2,2	1,9	1,7	1,5	1,7	2,0	2,1	2,2	2,1
WCI (1961-1990)	918	945	954	940	905	863	838	807	837	867	936	934	895
WCI (1991-2020)	886	900	934	898	871	838	814	785	818	853	873	881	863
WCI difference (1991-2020) - (1961-1990)	**32**	**45**	**20**	**42**	**34**	**25**	**24**	**22**	**19**	**14**	**63**	**53**	**33**
Percentage difference %	3,6	5	2,1	4,7	3,9	3	**3**	2,8	2,3	1,6	7,2	6	3,7

The comparative analysis of the multiannual monthly average values of the wind chill index at the Săcueni meteorological stationshowed that values were lower in each month of the year during the 1991 – 2020 period compared to 1961-1990, with differences ranging from 63 units (November) to 14 units (October). The annual average valuesalso indicated a decrease of 33 units in the 1991 – 2020 periodrelative to 1961 - 1990. Accordingly, the wind chill index values reflect bioclimatic discomfort due to cooling across the study area for both intervals, with lower values ranging from 807 W/m^2 to 954 W/m^2 during 1961-1990 and from 785 W/m^2 to 934 W/m^2 during 1991-2020.

Analysis of the percentage differences in the monthly average wind chill index values between the two intervalsreveals a slight increase during the winter months (November: 7.2%, December 6%,

February 5%). Variations in the summer months, are smaller (below 3%), indicating a relative stability in thermal discomfort during this season.

The multiannual monthly average values of the wind chill index at the Săcueni meteorological station were graphically represented (Figure 69), in order to identify their variation and differentiate the monthly amplitudes between the studied intervals.

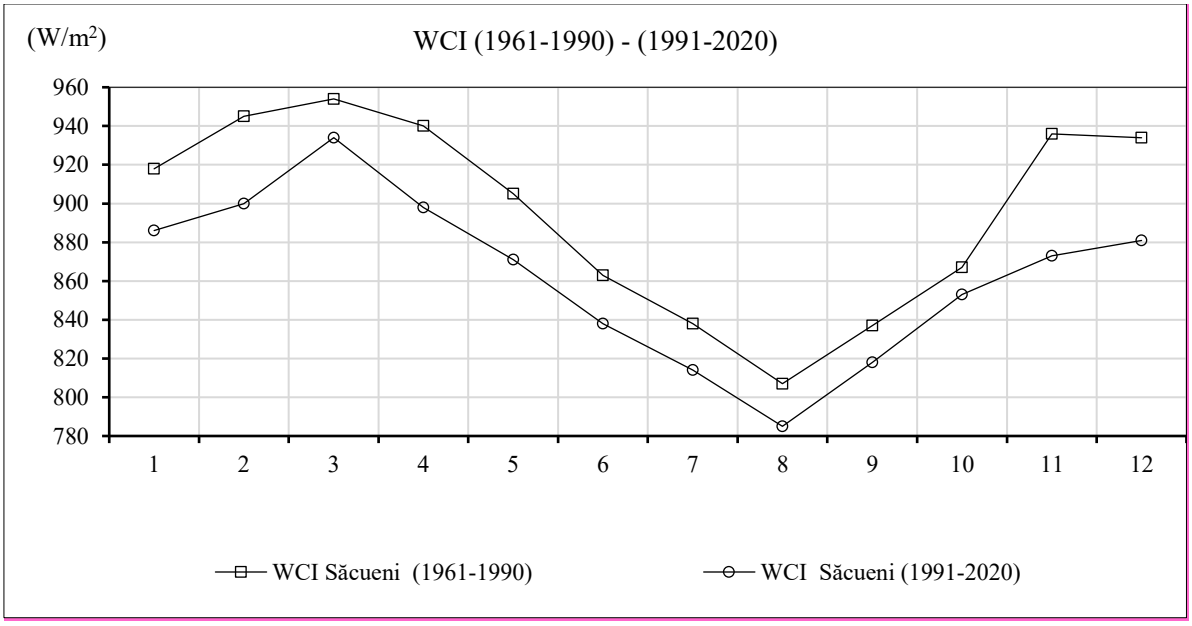


Figure 69. Multiannual variation of wind chill index values at the Săcueni meteorological station for the intervals 1961 - 1990 and 1991 – 2020.

The graphical representation of wind chill index values, reveals a downward variation in each month during the 1991 – 2020 period, compared to 1961-1990. The minimum amplitude was recorded in August for both intervals, while the maximum amplitude was recorded in spring and autumn, respectively in the months of March and November for the 1961 – 1990 period, and in March and December for 1991 - 2020. These variations indicate an improvement in bioclimatic conditions, during the more recent period, characterized by lower wind speed and higher –air temperatures.

The multiannual and annual monthly average values obtained at the meteorological stations studied for the 1961 - 1990 period were compiled (Table 39), in order to identify the bioclimatic characteristics in which each meteorological station studied for this period falls.

Table 39. Multiannual monthly average values of wind cooling power at the analyzed meteorological stations for the period 1961 – 1990.

WCI (W/m²) (1961-1990)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Anual
Chișineu Criș	898	919	922	931	900	873	852	827	828	845	889	908	883
Săcueni	918	945	954	940	905	863	838	807	837	867	936	934	895
Oradea	959	984	991	986	948	924	914	899	911	874	979	970	945
Holod	855	887	908	912	888	874	865	847	837	854	863	851	870
Ștei	877	876	865	872	846	825	814	810	819	859	885	867	851
Borod	809	832	871	887	817	812	808	785	806	828	832	839	827
Dumbrăvița de Codru	880	863	892	854	818	808	815	843	819	871	879	862	850
Stâna de Vale	701	718	714	710	666	664	640	640	666	690	714	698	685
Vlădeasa	1229	1221	1200	1179	1136	1115	1113	1084	1130	1148	1211	1227	1166

From the analysis of the multiannual monthly values of the wind chill index for each meteorological station analyzed in the 1961 - 1990, it results that in the entire studied area the bioclimatic peculiarity of cooling discomfort was identified, characterized by values ranging between 640 W/m^2 at Stâna de Vale and 1229 W/m^2 at Vlădeasa. These values were influenced by the highaltitude positioning of the Vlădeasa meteorological station, and the low values of the wind chill index obtained at Stâna de Vale are due to the fact that the meteorological station is located in a depressional area, surrounded by forests, buildings and slopes. At Stâna de Vale the lowest wind speeds are recorded (between 3.1 m/s in February and October and 1.8m/s in August) (Gaceu, 2005). All these factors contributed to the low values of the wind chill index at Stâna de Vale.

From the analysis of the annual average values of the wind chill index for each meteorological station included in the study, from 1961 to 1990, it results that the lowest value of 685 (W/m²) was recorded at Stâna de Vale, and the highest value, of 1166 W/m², was recorded at Vlădeasa. The multiannual average values of the wind chill index highlight a long period with bioclimatic discomfort due to cooling for all stations in the study area. The multiannual monthly average values of the wind chill index for the 1961 to 1990 period were graphically represented (Figure 70), in order to identify the variation of the monthly amplitudes for each meteorological station analyzed.

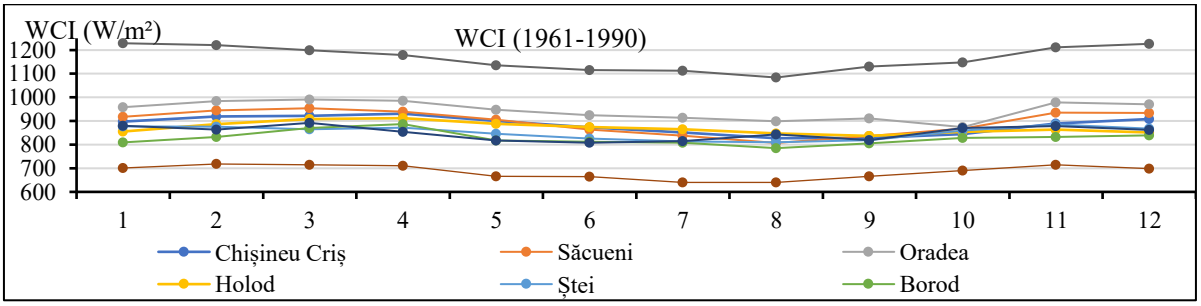


Figure 70. Multiannual variation of monthly mean values of the wind chill index for meteorological stations analyzed in the period 1961 – 1990.

Thus, the variation of the amplitudes of the multiannual monthly values for each meteorological station analyzed was slightly lower during the summer months, being influenced by the increased temperature values and low wind speed. The exception is the meteorological station in Oradea where the lowest value of the wind chill index was recorded in October. The monthly average values of the wind chill index obtained at each meteorological station were different, being influenced by their altitude and positioning.

The multiannual and annual monthly average values of the wind chill index were also centralized for the 1991 – 2020 interval, in order to identify the bioclimatic particularities for this period (Table 40).

Table 40. Multiannual monthly average values of the wind chill index at the meteorological stations analyzed between 1991 and 2020.

Wind chill med (W/m²) (1991-2020)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Anual
Chișineu Criș	914	927	940	919	907	865	850	822	840	862	885	910	887
Săcueni	886	900	934	898	871	838	814	785	818	853	873	881	863
Oradea	965	973	985	954	936	914	898	880	902	927	941	951	936
Holod	855	882	932	906	885	859	841	831	840	856	858	853	867
Ștei	886	892	897	879	864	860	852	838	858	879	895	891	874
Borod	784	814	851	826	804	781	762	753	771	786	796	792	793
Dumbrăvița de Codru	835	846	821	809	775	769	764	799	815	835	821	821	809
Stâna de Vale	656	672	687	670	665	645	637	622	641	659	665	658	656
Vlădeasa	1185	1182	1180	1125	1088	1057	1056	1030	1083	1111	1141	1169	1117

From the analysis of the multiannual monthly average values of wind chill, the bioclimatic characteristic of cooling discomfort was identified for all months analyzed at each meteorological station.

A particular case was identified at Stâna de Vale, where lower wind chill index values were recordeddespite its location in a mountainous region, compared to meteorological stations positioned in the plain or hill range. This situation is due to the the meteorological station positions within a depressional area, well enclosed by slopes rising 200-400m higher, which contribute to the decrease in wind speed and implicitly the wind chill index values.

From the analysis of the multiannual average values of the wind chill index from 1991 to 2020 for the analyzed meteorological stations, it results that the minimum value of 818 W/m² was recorded in July, while the maximum value of 914 W/m² occured in March.

The multiannual monthly average values of the wind chill index from 1991 to 2020 were graphically represented, in order to identify the trend of the monthly amplitude values for each analyzed meteorological station (Figure 71).

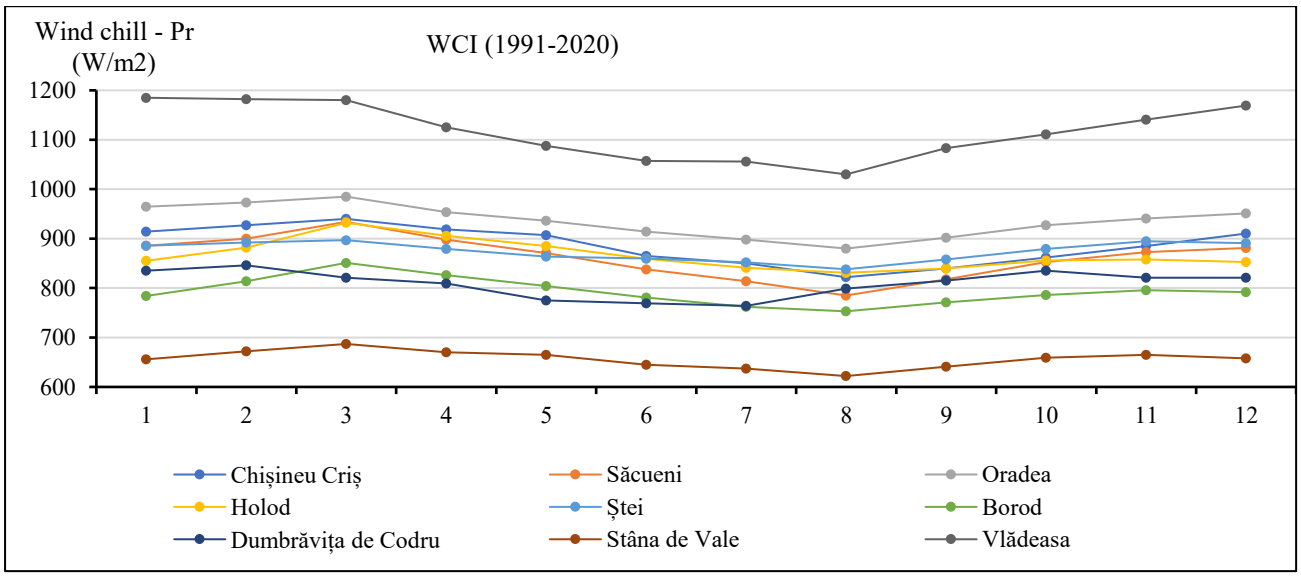


Figure 71. Multiannual monthly average values of the wind chill index for the meteorological stations analyzed in the period 1991 - 2020.

Regarding the multiannual monthly average values of the wind chill index over the 12 months, it was found that they are relatively constant throughout the year, with slight decreases in the summer months. The values recorded at each meteorological station vary, being influenced by geographical and anthropogenic factors.

There is a downward trend in the amplitude in the summer months, with the maximum in August, specific to each meteorological station analyzed, depending on their altitude and geographical positioning. These particularities played an essential role in identifying the monthly amplitude of the wind chill index values.

In order to carry out the comparative analysis of the wind chill index values, from the meteorological stations in the studied area, the multiannual monthly averages were centralized in the two intervals and the differences between them were identified (Table 41).

Table 41. Monthly average values of wind chill values at the studied meteorological stations for the intervals 1961 - 1990 and 1991 - 2020.

WCI (W/m²) / Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Anual
WCI Monthly mean (1961-1990)	903	916	924	919	880	862	851	838	850	871	910	906	886
WCI Monthly mean (1991-2020)	885	899	914	887	866	843	830	818	841	863	875	881	867
Difference (1961-1990) - (1991-2020)	18	17	10	32	14	19	21	20	9	8	35	25	19
Percentage Difference %	3,6	5	2,1	4,7	3,9	3	2,9	2,8	2,3	1,6	7,2	6	3,7

From the analysis of the multiannual and annual monthly average values of the wind chill index, it results that both intervals fall within the bioclimatic particularity of cooling discomfort, with lower values in each month from 1991 to 2020. Thus, by calculating the difference in the index values between the two intervals, lower wind chill index values occured in the 1991 to 2020 interval, ranging from eight units (October) to 35 units (September).

From the analysis of the percentage differences in the wind chill index for all the meteorological stations analyzed, an increasing trend in the monthly average values was found in the 1991–2020 period, compared to 1961–1990. The largest increases were recorded in November with a percentage of 7.2% and in December with 6%, indicating a decrease in the intensity of the wind cooling power for the 1991-2020 interval. In the rest of the annual period, the percentage differences are moderate (between 1.6% and 5%). This indicates a decrease in the bioclimatic discomfort induced by the wind, especially in the cold months, being determined by the increase in thermal values. The values of the wind cooling power index were graphically represented, in order to identify the variation of the monthly amplitudes between the two analyzed intervals (Figure 72).

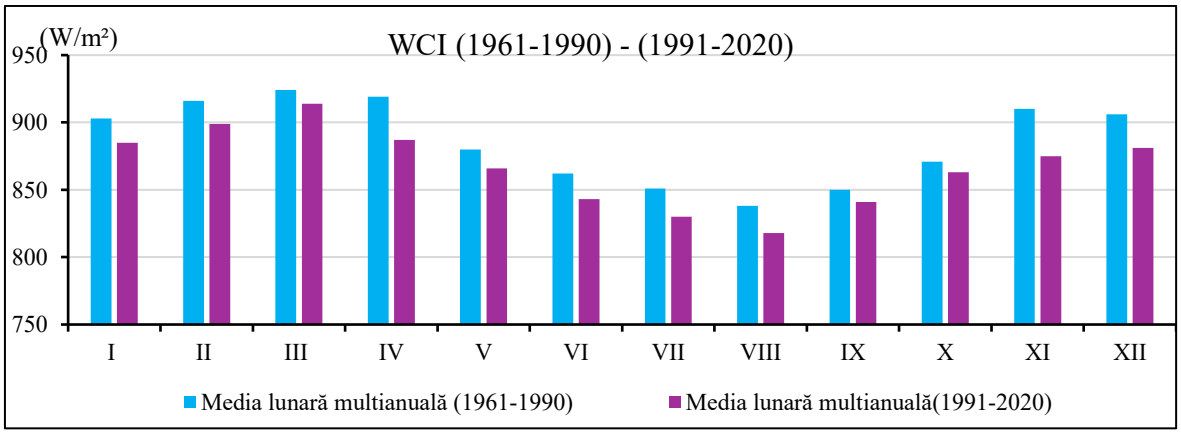


Figure 72. Variation of the monthly average of the wind chill index in the intervals 1961 - 1990 and 1991 - 2020.

Regarding the analysis of the evolution of the wind chill index values over the 12 months, significant variations are observed, highlighting a clear seasonality in both analyzed intervals, with lower values in each month from 1991–2020. Thus, a downward evolution of the values is observed, correlated with the increase in average temperatures and the decrease in wind speed.

The spatial distribution of the annual average values of the wind cooling power index for the two intervals (Figure 73) showed that the bioclimatic discomfort due to cooling was reduced throughout the analyzed area, due to the increased thermal values and lower wind speed in the interval 1991 - 2020. The maximum values were between 1000 and 1200 in the interval 1961 - 1990 (at

Vlădeasa 1800) and 900 - 1000 W/m² (also at Vlădeasa 1117 W/m², in the interval 1990 - 2020, and the minimum values were below 700 W/m² in both intervals, but with a lower difference in the interval 1991 - 2020, at Stâna de Vale of 656 W/m², compared to the interval 1961 - 1990 also at Stâna de Vale with 685 W/m².

The prevalence of bioclimatic discomfort through cooling throughout the year is observed in both the 1991 – 2020 and 1961 – 1990 periods as an effect of the moderating action of the wind on the thermal regime, against the background of temperate-oceanic influences in the western regions of the country.

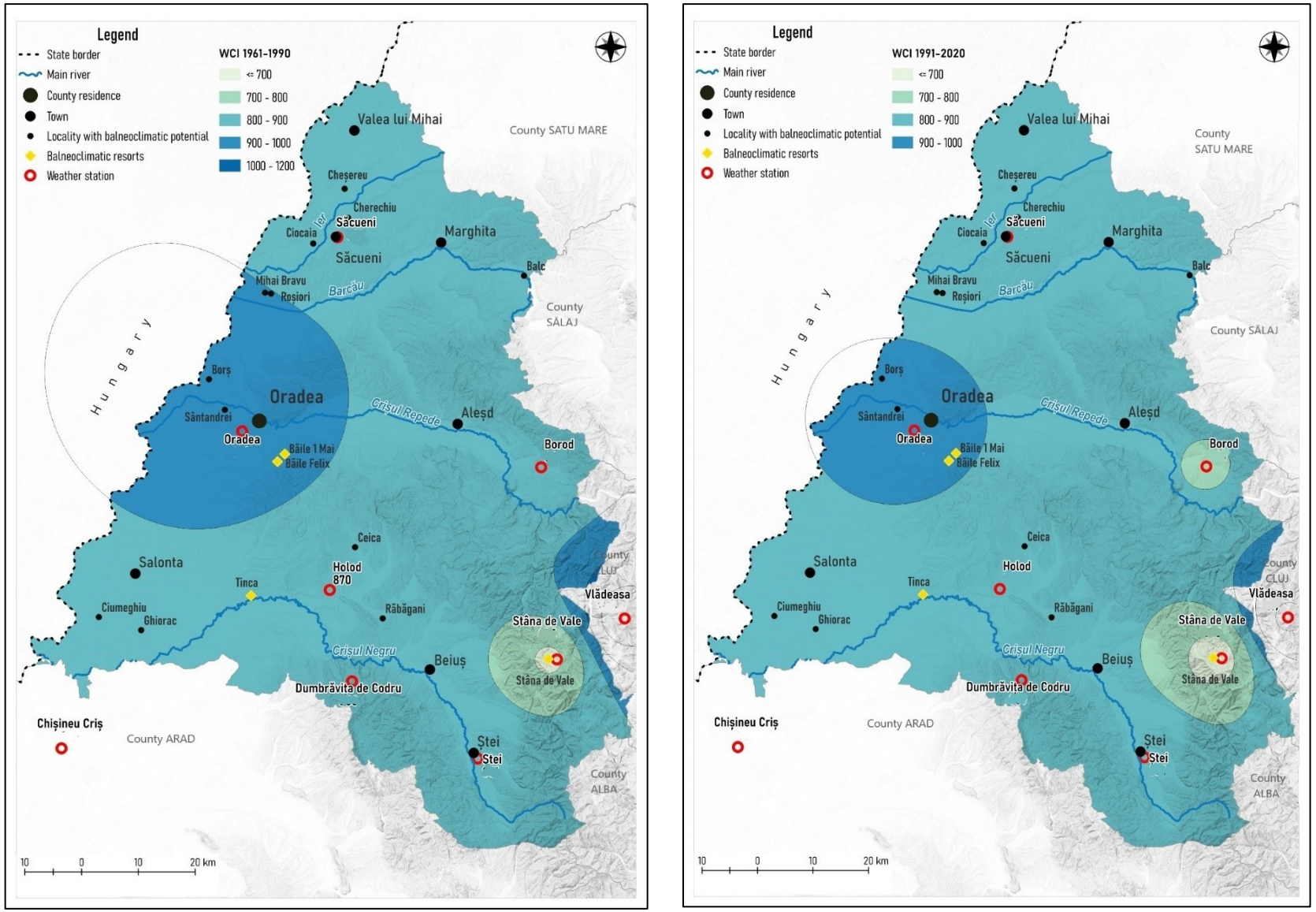


Figure 73. Territorial distribution of the wind chill index in Bihor County in the intervals 1961 - 1990 and 1991 - 2020.

5.2.2.4. Wind chill equivalent temperature (WCET) (°C)

The main elements taken into account in calculating this index were the air temperature, especially below about 10°C, and the wind speed, usually above about 6 km/h.

The wind chill equivalent temperature (called WCET in this study), generally represents the temperature (°C) that the air would have if its cooling power were taken into account. It is calculated according to the formula:

$$\mathbf{WCET = (33 + (Tusc - 33) \times (0.474 + 0.454\sqrt{v1} - 0.0454v1))} \text{ (Ionac et al., 2012)}$$

where: **WCET** = wind chill equivalent temperature; **T usc** = air temperature measured with the dry bulb (°C); **v** = wind speed (m/s).

The calculated value represents the cooling effect of the wind on the skin, indicating the equivalent temperature on a colder day with the speed of calm air that causes the same body heat loss. The main practical use of the wind chill temperature index and similar indices is to inform the public when thermal conditions reach a critical threshold (Saue, 2016).

Based on the above formula, the equivalent wind chill temperature for the intervals 1961-1990 and 1991-2020 was calculated for the Săcueni meteorological station, in order to identify bioclimatic particularities, as well as their temporal variation (Tablel 42).

Tablel 42. Variables, multiannual monthly average values of the wind chill equivalent temperature index at Săcueni station in the period 1961 - 1990 and 1991 - 2020.

WCET (°C) / Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
T mean (1961-1990)	-2,3	0,5	5,3	11,1	16,2	19,0	20,6	19,9	16,1	10,7	5,2	0,3	10,2
T mean (1991-2020)	-0,3	1,3	6,0	11,9	16,9	20,5	22,0	21,8	16,4	11,3	6,1	0,9	11,2
WS mean (1961-1990)	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6	2,6
WS mean (1991-2020)	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2
WCET (1961-1990)	-5,2	-3,3	1,6	8,3	14,6	18,4	20,4	20,2	16,0	9,8	2,0	-3,2	8,3
WCET (1991-2020)	-1,9	-0,8	2,9	10,3	16,1	20,3	22,1	22,3	16,6	10,8	5,0	-0,5	10,3
Difference WCET (1961-1990)- (1991-2020)	**3,3**	**2,5**	**1,3**	**2**	**1,5**	**1,9**	**1,7**	**2,1**	**0,6**	**1**	**3**	**2,7**	**2**
Percentage difference %	63	76	81	24	10	10	8	10	4	10	150	84	24

The resulting values were analyzed comparatively, resulting in values that highlight comfort for 1961 - 1990, from May to September, and for the 1991 – 2020 period, it was recorded from April to October.

The bioclimatic conditions of cooling discomfort were identified in the period 1961 - 1990 from January to April and from October to December. With cool weather type from March to April

and October-November, as well as very cool weather type in January, February and December. Also, the shorter period of bioclimatic discomfort by cooling was evident in the period 1991 - 2020, with very cool weather type recorded in a single month (January), as well as cool weather type recorded in February - March and November - December.

Bioclimatic discomfort due to cooling was characterized by higher values in each month of the year, during the 1991 - 2020, which were between 0.6 units (in September) and 3.3 units (in January).

From the analysis of the multiannual annual averages of the two intervals, it resulted that in the 1961 – 1990 period, bioclimatic discomfort due to cooling was identified, with a value of 8.3 units, and during 1991 - 2020, a bioclimatic comfort condition was identified with a value of 10.3. Thus, the difference between the two multiannual average values is two units higher in the period 1991 - 2020.

The analysis of the percentage differences in the wind chill equivalent temperature for the two intervals, 1961-1990 and 1991-2020, revealed an increase in the volumes, with the maximum recorded in November of 150%, a moderate increase in the summer months (between 8% and 10%) and the minimum in September of 4%. This indicates a significant decrease in the wind chill equivalent temperature in the cold season, due to the increase in thermal values.

The monthly variations at the Săcueni meteorological station were graphically represented, in order to identify the monthly amplitudes of the wind chill equivalent temperature index values, in the two intervals (Figure 74).

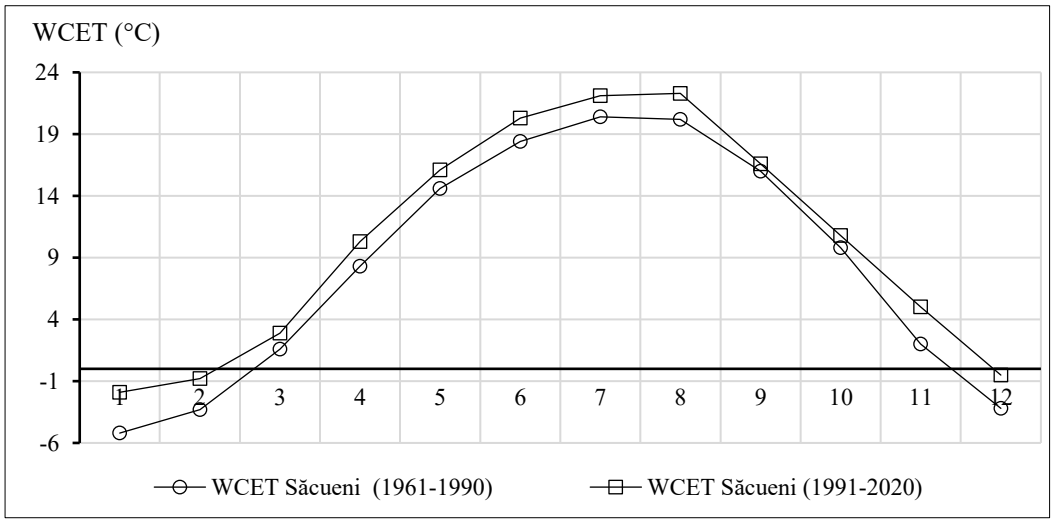


Figure 74. Monthly variation of multiannual average values of the equivalent temperature of the wind chill in Săcueni in the intervals 1960 - 1990 and 1991 - 2020.

Figure 74 shows that the multiannual monthly average values of the wind chill equivalent temperature index varied significantly, indicating seasonality, in both intervals, with higher values in the –more recent interval, by a percentage of 24.1% compared to the previous interval (1961-1990), highlighting a continuous increase in the index values in correlation with the warming period of the last 30 years illustrated by the values of the other bioclimatic indices calculated above.

The multiannual monthly average values of the wind chill equivalent temperature index at the meteorological stations analyzed in the interval 1961 - 1990 were centralized, in order to identify the bioclimatic characteristics in this interval (Table 43).

Table 43. Multiannual monthly values of the wind chill equivalent temperature index at the meteorological stations analyzed in the period 1961 - 1990.

WCET (°C) (1961-1990)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Chișineu Criș	-4,3	-2,3	2,5	8,2	14,5	18,2	20,2	20	16	10,1	3,4	-2,1	8,7
Săcueni	-5,2	-3,3	1,6	8,3	14,6	18,4	20,4	20,2	16	9,8	2	-3,2	8,3
Oradea	-6,6	-4,8	0,5	7	13,5	17,5	19,7	19,3	14,8	8,7	1,6	-3,6	7,3
Holod	-1,8	-0,4	3,6	8,3	14,5	17,5	19,3	19,1	15,1	9,7	4,2	0,6	9,1
Ștei	-2,8	-0,4	4,1	9,0	14,4	17,6	19,3	19,0	15,3	9,6	3,9	-0,3	9,1
Borod	-0,3	0,9	3,8	7,7	14,8	17,4	19	18,8	14,9	9,5	4,3	0,5	9,3
Dumbrăvița de Codru	-1,1	2,4	7,9	13,8	16,6	20,1	19,7	15,2	11,1	2,8	-0,6	-1,9	8,8
Stâna de Vale	1,1	1	4,2	7,5	13,4	15,7	17,5	17,1	13,9	9,7	4,8	3,2	9,1
Vlădeasa	-25,7	-24,7	-20,3	-13,6	-5,5	-1,1	1,3	2,2	-2,9	-8,1	-17,5	-23,1	-11,6

From the analysis of the multiannual monthly values of the wind chill equivalent temperature index in the period 1961 - 1990, the bioclimatic comfort peculiarity was identified, manifested from May to September, for Chișineu Criș, Săcueni, Oradea, Holod, Ștei, Borod, Dumbrăvița de Codru and Stâna de Vale. With a few exceptions such as in Chișineu Criș where the bioclimatic comfort period was also identified in October, and in Dumbrăvița de Codru bioclimatic comfort was also identified in April. The bioclimatic comfort identified in this interval was characterized by values ranging between 10.1°C (in September in Chișineu Criș) and 20.4°C (in July, in Săcueni).

The bioclimatic discomfort due to cooling was identified for the entire period of the year in Vlădeasa, from October to April. This is due to the high altitude, low temperature values and high wind speed, specific to the mountainous area.

The bioclimatic comfort was identified at the meteorological stations located in each landform: in the plain (La Chișineu Criș, Săcueni, Oradea, Holod); in the hills and plateaus (Ștei, Borod, Dumbrăvița de Codru) as well as in the mountains (at Stâna de Vale), with a temporal extension of five months (from May to September, with few exceptions). At Chișineu Criș it extends to six months (until October), and at Dumbrăvița de Codru it begins in April.

From the analysis of the multiannual annual average values of the wind chill equivalent temperature index for all the meteorological stations analyzed, the bioclimatic particularity of discomfort due to cooling was identified, characterized by values between -11.6 °C (at Vlădeasa) and 9.3°C (at Borod).

From the graphic representation of the multiannual monthly average values of the wind chill equivalent temperature index, the differentiated variation of the monthly amplitudes for each meteorological station can be observed (Figure 75).

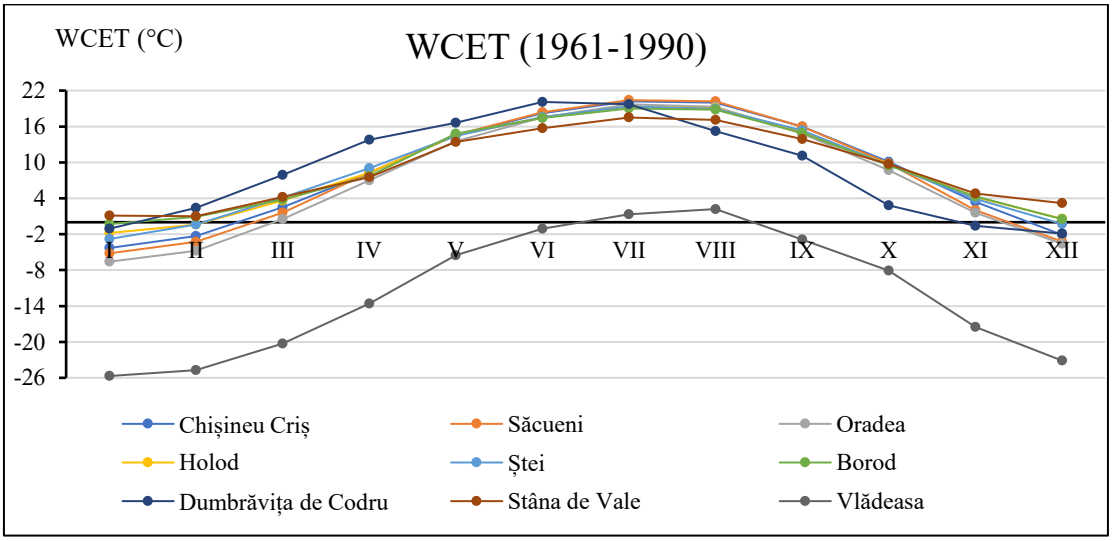


Figure 75. Monthly variation of the multiannual average values of the equivalent temperature index of wind chill at the analyzed stations in the period 1961 - 1990.

From the analysis of the graphic representation in Figure 75, the values of the equivalent temperature index to the cooling power of the wind in the interval 1961 - 1990 show that the variation of the amplitudes of the values is higher in the summer months and lower in the winter months, depending on the altitude and the positioning of the meteorological station.

At the Stâna de Vale meteorological station, the values of the equivalent temperature index to the cooling power of the wind are increased although it is positioned in a mountainous area. These increased values were influenced by the conditions of the location of the meteorological station, which determined the increase in thermal values and the decrease in wind speed, thus determining values similar to the meteorological stations positioned in the plain area (Chișineu Criș, Oradea, Holod, Săcueni, Ștei, Borod), or those in the hill area (Dumbrăvița de Codru) where the thermal values are specific to the plain climate. The lowest amplitude of the wind chill equivalent temperature index

values for the entire annual period was identified in Vlădeasa, due to its location at an altitude of 1800 m.

The multiannual monthly average values of the wind chill equivalent temperature index for the period 1991 - 2020 were centralized, in order to identify bioclimatic particularities in this period (Table 44).

Table 44. Multiannual monthly average values of the wind chill equivalent temperature index in the period 1991-2020.

WCET (°C)	1991-2020												
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Anual
Chișineu Criș	-3,1	-2,1	2,5	9,6	15,4	20	21,8	21,9	16,2	10,2	4,4	-1,4	9,6
Săcueni	-1,9	-0,8	2,9	10,3	16,1	20,3	22,1	22,3	16,6	10,8	5	-0,5	10,3
Oradea	-5	-3,7	1	8,6	14,6	19,1	21,2	21,2	15,1	8,9	2,8	-3	8,4
Holod	-0,4	0,1	2,9	9,7	15,2	19,4	21,5	21,4	16	10,5	5,3	0,8	10,2
Ștei	-1,7	-0,4	3,6	9,8	14,8	18,6	20,3	20,4	14,9	9,6	4,4	-0,4	9,5
Borod	1,7	1,7	4,3	10,5	15,6	19,5	21,4	21,2	16,3	11,4	6,7	2,6	11,1
Dumbrăvița de Codru	-1,3	1,5	7,5	12	15,9	17,7	18,5	13,4	8,8	3,9	-0,5	-1,6	8,0
Stâna de Vale	3,9	3,8	5,3	9,5	13,9	17,4	18,6	18,5	14,7	11	7,7	4,7	10,8
Vlădeasa	-22,2	-22	-19	-10,2	-2,6	3	5,1	6,4	-0,9	-6,4	-12,7	-19,6	-8,4

From the analysis of the multiannual average monthly values of the temperature index equivalent to the wind chill, in the entire area, the bioclimatic comfort peculiarity for this interval resulted, identified mainly from May to October in Chișineu Criș, Holod, Stâna de Vale and from April to October in Săcueni and Borod. The decrease in the bioclimatic comfort period was identified in Dumbrăvița de Codru where it was identified from April to August, with values ranging between 10.2°C (in Chișineu Criș) and 22.3°C (in Săcueni).

The annual average of the multiannual average values of the wind chill equivalent temperature resulted in the bioclimatic comfort feature in Săcueni, Holod, Borod and Stâna de Vale, characterized by wind chill equivalent temperature index values between 10.2°C (at Holod) and 11.1°C (at Borod), as well as the bioclimatic discomfort feature in Chișineu Criș, Oradea, Ștei, Dumbrăvița de Codru and Vlădeasa, with values between -8.4 (at Vlădeasa) and 9.6 (at Chișineu Criș).

The only exception in which bioclimatic comfort was not identified for any month of the year during this interval was recorded in Vlădeasa. This is due to the mountainous altitude in which the meteorological station is located, where the climatic characteristics are specific to the mountainous area.

A graphical representation of the values of the wind chill equivalent temperature index for the period 1991 - 1920 was made, in order to identify the differentiated variation of the amplitudes of the monthly values of this interval (Figure 76).

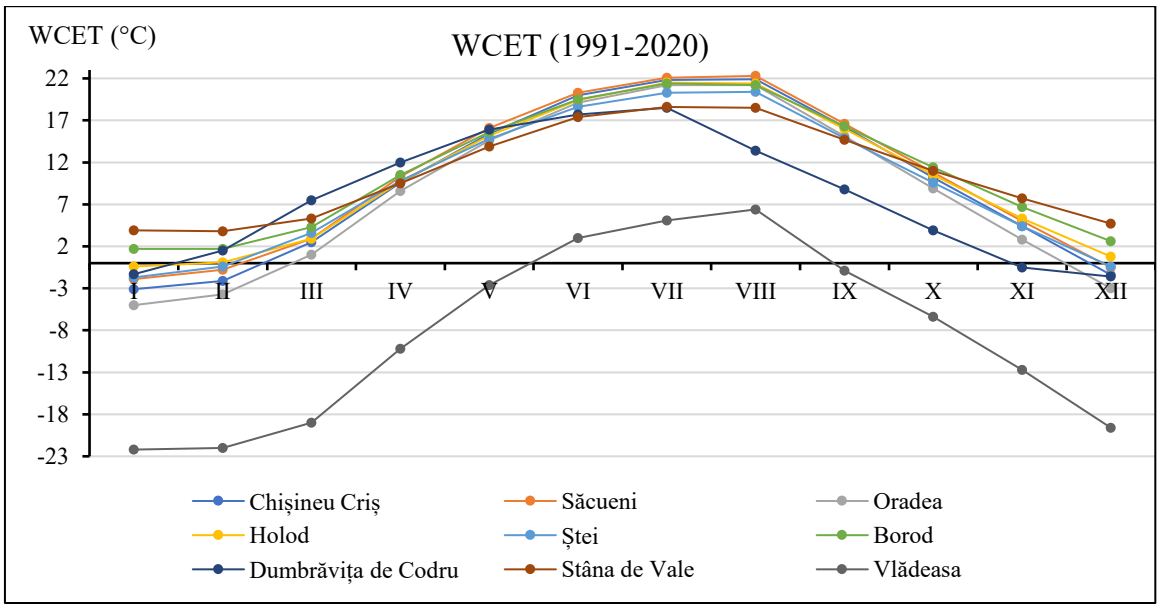


Figure 76. Monthly variation of multiannual average values of the equivalent wind chill temperature index in the period 1991 - 2020.

From the graphic representation of the values of the wind chill equivalent temperature index, it resulted that the maximum monthly amplitude was recorded in August for all the meteorological stations analyzed, with different amplitudes depending on the altitude, except for the one from Dumbrăvița de Codru, where the maximum value was identified in July. The difference in values for the entire annual period between Vlădeasa and the other analyzed stations can be observed, due to its positioning in the mountainous area, at an altitude of 1800 m. The higher we climb in altitude, the higher the wind speed and the lower the thermal values.

The average of the multiannual and annual monthly average values of the wind chill equivalent temperature index in the two intervals was calculated and centralized, in order to carry out their comparative analysis (Table 45).

Table 45. Average of multiannual monthly mean values of the wind chill equivalent temperature index for the periods 1961 - 1990 and 1991 - 2020.

WCET (°C) / Monts	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Monthly mean (1961-1990)	-5,2	-3,5	0,9	6,2	12,3	15,7	17,4	16,8	12,7	6,9	0,7	-3,3	6,5
Monthly mean (1991-2020)	-3,3	-2,4	1,2	7,8	13,2	17,2	18,9	18,5	13,1	7,8	2,6	-2,0	7,7
Difference WCET (1961-1990) - (1991-2020)	1,9	1,1	0,3	1,6	0,9	1,5	1,5	1,7	0,4	0,9	1,9	1,3	1,2
percentage difference %	36,5	31,4	33,3	25,8	7,3	9,6	8,6	10,1	3,1	13,0	271,4	39,4	18,5

The comparative analysis of the average of the multiannual monthly mean values of the wind chill equivalent temperature index showed that over the entire annual period, index values are higher during the 1991 – 2020 period, with the difference between 0.3 units (in March) and 1.9 units (in January and November). The analysis of the annual average of the multiannual monthly mean values showed a higher difference in the wind chill equivalent temperature values by 1.2 units in the period 1991 - 2020.

In terms of percentage change, the maximum increase between the two intervals was recorded in November (271.4%), while the minimum was observed in September (3.1%).The annual average percentage increase of 18.5% confirms a general trend toward a reduction in wind chill intensity during the 1991–2020 period compared to 1961–1990.

The multiannual monthly average values of the wind chill equivalent temperature index were graphically represented, in order to analyze the variation of bioclimatic particularities in Bihor County (Figure 77).

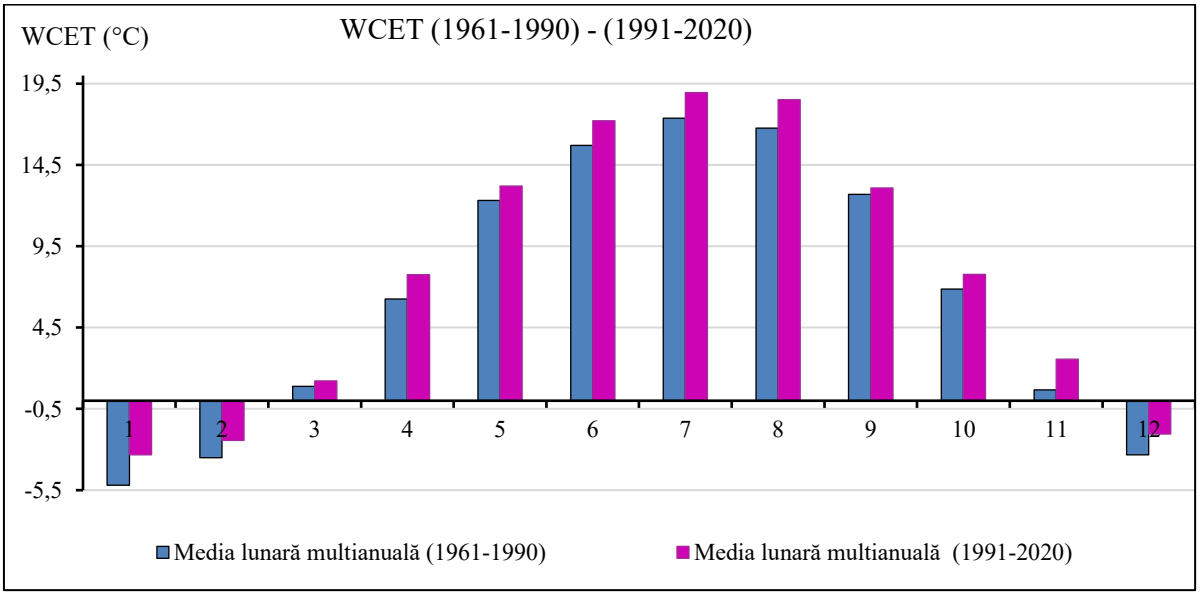


Figure 77. Monthly variation of multiannual average values of the equivalent wind chill temperature index for the periods 1961 - 1990 and 1991 - 2020.

Graphic analysis illustrate that the variation of the average values of the wind chill equivalent temperature index was higher during 1991 - 2020, compared to the 1961 – 1991 period, for the entire annual period. The upward variation of the wind chill equivalent temperature index values was correlated with the increased thermal values and the decreased wind speed in the 1991 – 2020 period, compared to the 1961 – 1990 interval.

From the territorial distribution of the multiannual average values of the wind chill equivalent temperature, it was found that the bioclimatic particularities identified in Bihor County were represented by the territorial extension of the bioclimatic comfort regions, through the increase in the bioclimatic index values, determined by the increase in temperature values. The values of the temperature index equivalent to the wind cooling power in the period 1991 - 2020 exceeded the reference threshold of (10°C), thus falling within the bioclimatic comfort characteristic (in Săcueni, Holod, Borod, Stâna de Vale) (Figure 78).

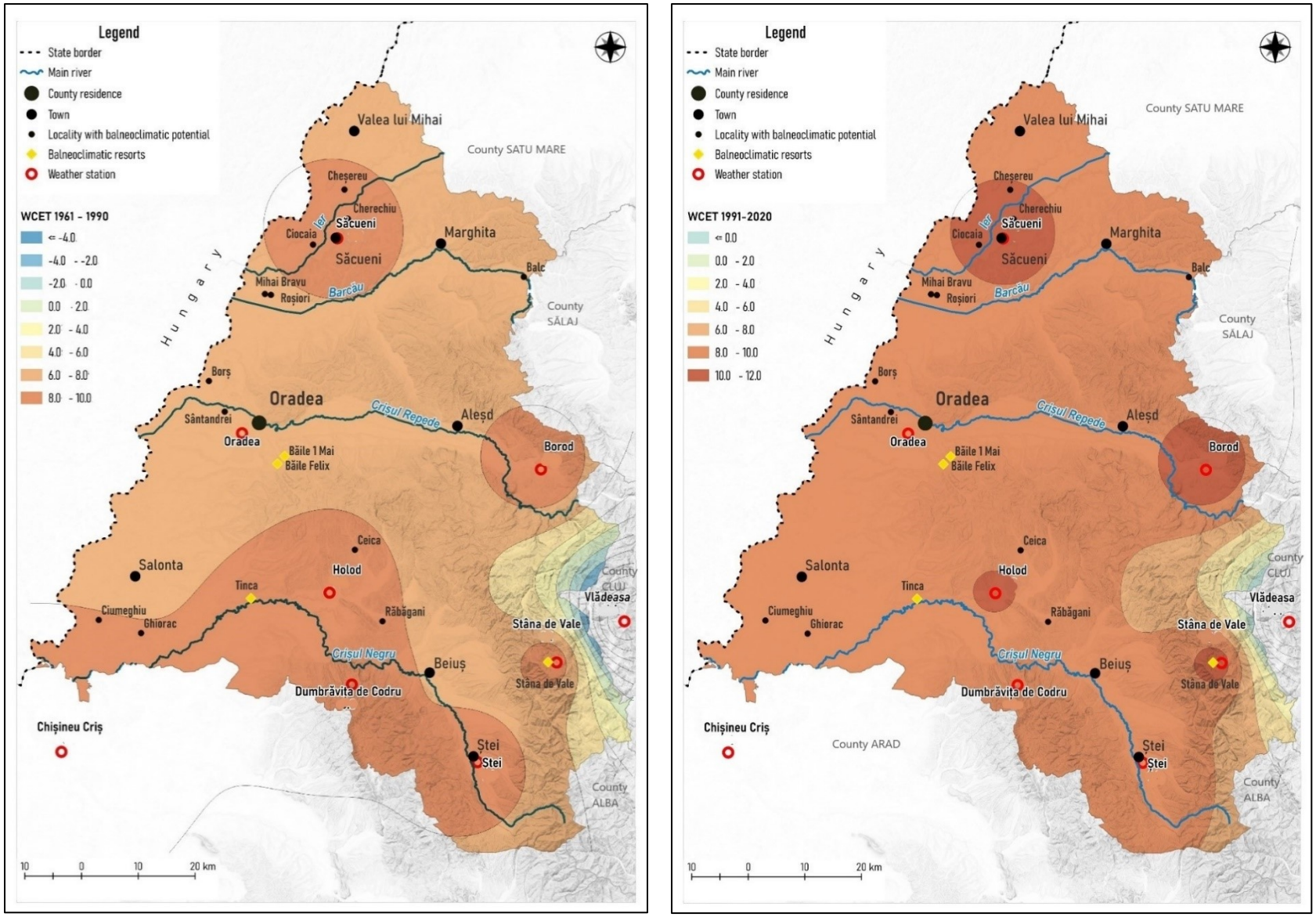


Figure 78. Territorial distribution of wind chill equivalent temperature index values in the intervals 1961 - 1990 and 1991 - 2020.

5.2.2.5. The trend variation of reference bioclimatic indices

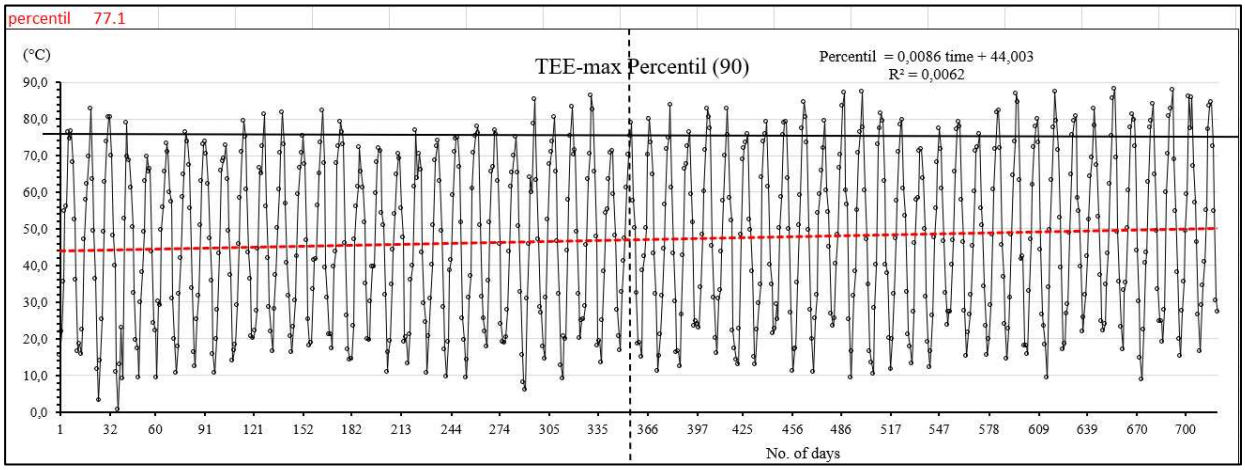
Regarding the annual and interannual variation of the values of the relevant bioclimatic indices (equivalent effective temperature, thermo-hygrometric index, and wind chill index with its equivalent temperature) taken into account for the two periods 1991 - 2020 and 1961 - 1990, an analysis of their evolution trend was also required, by referring to their extreme limits of manifestation (minimum or maximum values) from the entire interval 1961 - 2020, for an assessment of the degree of ensuring optimal bioclimatic conditions for the comfort and health of the population in the area. In this regard, for each of the bioclimatic indices analyzed, the number of exceedances of the 90p percentile for the maximum values and, respectively, the number of non-exceedances of the 10p percentile for the minimum values of the selected indices was calculated using the percentile method; the results obtained are consistent with all the conclusions drawn from the sequential analyses carried out over the 30-year climatological normal periods taken into account.

The trend variation in the frequency of occurrence of extreme values of the reference bioclimatic indices, expressed by the representative percentile method, calculated for the maximum and minimum values of variation of the bioclimatic indices of interest (respectively the 90p percentile for the maximum values and the 10p percentile for the minimum ones), clearly indicates, on the one hand, that the number of exceedances of the maximum values (90p max) from the period 1991 - 2020 is increasing and, on the other hand, that the frequency of occurrence of minimum values (the number of minimum values that do not exceed the 10p min percentile) is decreasing compared to that from the period 1961 - 1990, which reflects the same process of increase in thermal values, which becomes more pronounced. Therefore, the period 1991 - 2020 is distinguished by a thermal superiority over the period 1961 - 1990, both by increasing the frequency of exceeding the maximum thermal values, and by the corresponding reduction of not exceeding the minimum thermal values, thus revealing the fact that air temperature is and will remain the dominant factor of influence of the local bioclimate, whose extreme characteristics must be taken into account, with varying degrees of assurance, in tourism development strategies and recreation/leisure activities in the Bihor County area.

In order to understand the calculation approach of the frequency of occurrence of maximum and minimum extreme values, the graphs for the equivalent effective temperature index for the 90p percentile (Figure 79) and the 10p percentile (Figure 80) from the Săcueni meteorological station are exemplified in detail.

The percentile value was obtained by a calculation formula that included the monthly temporal variables for a period of 60 years and the equivalent effective temperature index value.

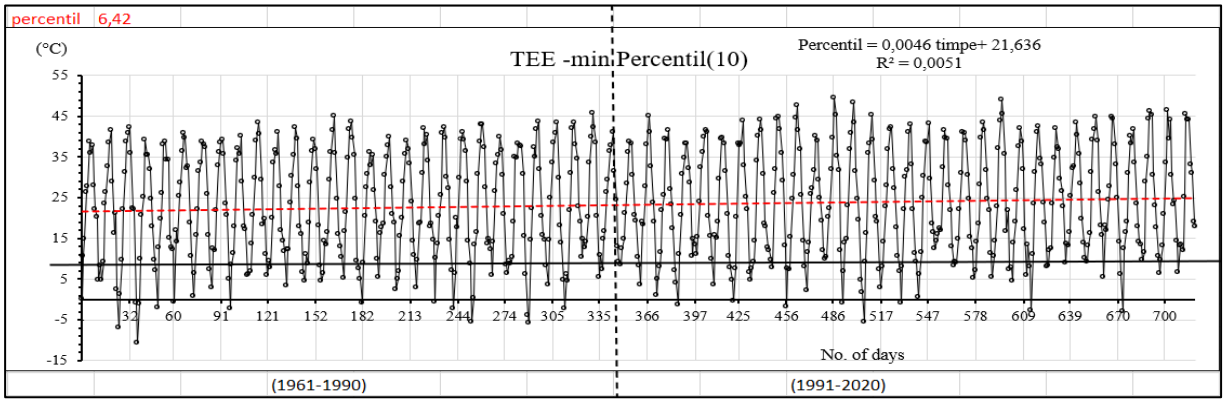
By referring to this value, the maximum and minimum extreme values of the indices were established.



Note: ------ Linear trend; ——— Percentil value

Figure 79. Number of exceedances of the 90th percentile for maximum values of the equivalent effective temperature index at the Săcueni meteorological station in the period 1961 - 1990 and 1991 - 2020.

At the Săcueni meteorological station, the obtained value of the 90p percentile was 77.1, and the number of exceedances of the maximum equivalent effective temperature index values, reported to the percentile value, was 19 in the period 1961 - 1990 and 55 exceedances in the period 1991 - 2020.



Note: ------ Linear trend; ——— Percentile value

Figure 80. Number of non-exceedances of the 10th percentile for the minimum values of the equivalent effective temperature index at the Săcueni meteorological station in the period 1961 - 1990 and 1991 - 2020.

The percentile value (10p) is 6.42, and the number of non-exceedances reported to this value is 46 in the period 1961 - 1990 and 37 non-exceedances in the period 1991 - 2020 for the

minimum values of the equivalent effective temperature index at the Săcueni meteorological station.

The value evolution of the reference bioclimatic indices representing the representative percentile 90p and 10p for the Săcueni meteorological station, which determined the number of exceedances and non-exceedances, are shown in Table 46.

Table 46. Number of cases in which the monthly maximum values exceed the 90p percentile and of cases in which the monthly minimum values do not exceed the 10p percentile of the effective equivalent temperature, thermo-hygrometric, wind chill and wind chill equivalent temperature indices at the Săcueni meteorological station in the period 1961 - 1990 and 1991 - 2020.

	Percentil (90); (1961-2020)			Percentil (10); (1961-2020)	
SĂCUENI	No. of exceedances (1961-1990)	No. of exceedances (1991-2020)	SĂCUENI	No. of non-exceedances (1961-1990)	No. of non-exceedances (1991-2020)
TEE (°C) max Percentil (90) = 77,1	19	55	TEE (°C) min Percentil (10) = 6,42	46	37
THI (°C) max Percentil (90) = 25,2	11	26	THI (°C) min Percentil (10) = -1,8	28	22
WCET (°C) max Percentil (90) = 27,6	14	37	WCET (°C) min Percentil (10) = -6,1	27	15
WCI (W/m²) max Percentil (90) = 967	52	15	WCI (W/m²) min Percenti (10) = 785	29	34

For the maximum effective equivalent temperature index (90p), a higher difference in exceedances of 36 units was highlighted in the period 1991 - 2020, and the number of non-exceedances (10p) was 9 units less in the period 1961 - 1990. For the maximum thermo-hygrometric index (90p), 15 more exceedances were recorded in the period 1991 - 2020, and the number of non-exceedances (10p) was 6 units less in the period 1990 - 2020. For the maximum wind chill equivalent temperature index (90p), the number of exceedances was 23 units more in the period 1991 - 2020, and for the number of non-exceedances the difference was 5 units less in the period 1991 - 2020. The wind chill power had a difference of 37 units more in the interval 1961 - 1990 for the percentile (90), and for the percentile (10) were recorded 22 units more in the interval 1991 - 2020.

The effective equivalent temperature index for the analyzed meteorological stations regarding the trend of the evolution of the frequency of production of maximum and minimum extreme values at all analyzed meteorological stations is presented in Table 47.

Table 47. The number of cases in which the monthly average values exceed the 90p percentile and the number of cases not exceeding the 10p percentile corresponding to the monthly maximum and minimum values of the effective equivalent temperature index for the intervals 1961 - 1990 and 1991 - 2020.

Weather Stations	**Chișineu Criș**	**Săcueni**	**Oradea**	**Holod**	**Ștei**	**Borod**	**Dumbrăvița de Codru**	**Stâna de Vale**	**Vlădeasa**
Variables / Altitude	**96**	**125**	**136**	**163**	**275**	**333**	**432**	**1108**	**1800**
Average Temperature (1961-2020)	10,6	10,7	10,7	10,7	10,1	9,6	10,3	4,4	1,5
Relative Humidity (1961-2020)	78	75	76	81	78	79	72	88	86
Pressure (1961-2020)	1005	1003	1000	998	983	979	948	890	813
TEE-min Percentil (10)	6.2	6,42	6.49	7.4	6.42	5.3	7.6	-1.8	-1,7
No. of non-exceedances (1961-1990)	45	46	41	27	23	34	14	16	26
No. of non-exceedances (1991-2020)	33	37	35	25	16	31	9	9	26
Difference (1961-1990) - (1991-2020)	12	9	6	2	7	3	5	7	0
TEE-max Percentil (90)	80.46	77,1	78.05	81.6	78.3	77.4	71.22	69.0	49.2
No. of exceedances (1961-1990)	20	19	22	12	28	21	16	14	5
No. of exceedances (1991-2020)	50	55	48	38	59	46	34	38	27
Difference (1991-2020) – (1961-1990)	30	36	26	26	31	25	18	24	22

In the area covered by the study, the largest difference in the number of non-exceedances was 12 units less in the period 1991-2020, at the Chișineu Criș meteorological station, and the smallest number of non-exceedances was recorded at Vlădeasa (0 units). For the percentile (90p), the difference in exceedances with the largest number was recorded at the Săcueni meteorological station with 30 units more in the period 1991-2020, and the smallest difference was recorded at Dumbrăvița de Codru, with 18 units more in the period 1991-2020. The number of non-exceedances of the minimum values in the analyzed area was graphically represented, in order to analyze the trend in the evolution of the frequency of occurrence of extreme values of the effective equivalent temperature index (Figure 81).

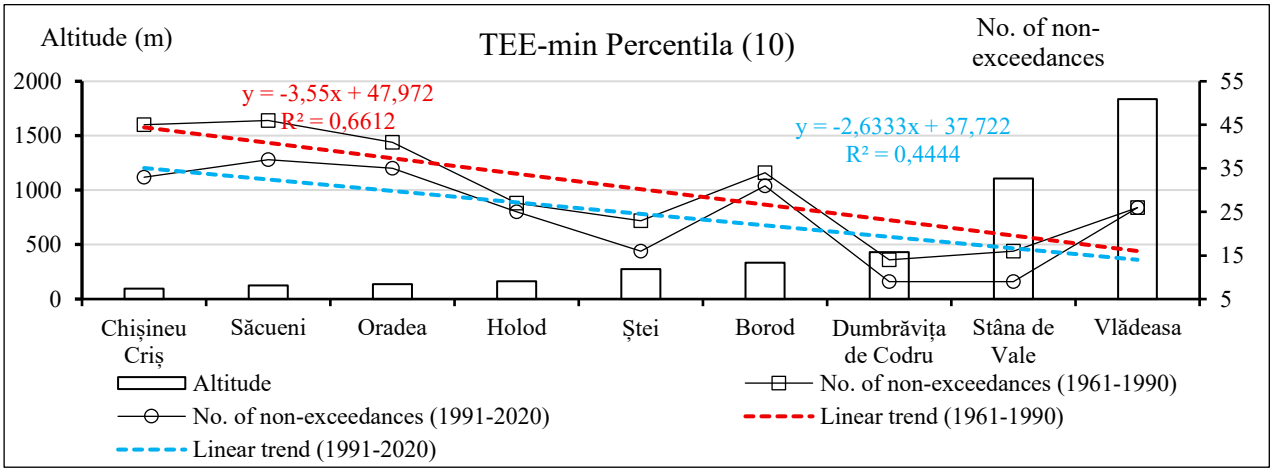


Figure 81. Variation in the number of non-exceedances of the minimum extreme values for the effective equivalent temperature index by the 10p percentile at the meteorological stations analyzed in the intervals 1961 - 1990 and 1991 - 2020.

The number of non-exceedings of the minimum extreme values had a downward trend in the period 1991 - 2020 for all meteorological stations analyzed, except for the Vlădeasa station where the number of non-exceedings was the same in both intervals (26).

The graphical representation of the number of exceedings of the maximum extreme values of the effective equivalent temperature index for the purpose of analyzing the trend in the frequency of occurrence of extreme values is shown in Figure 82.

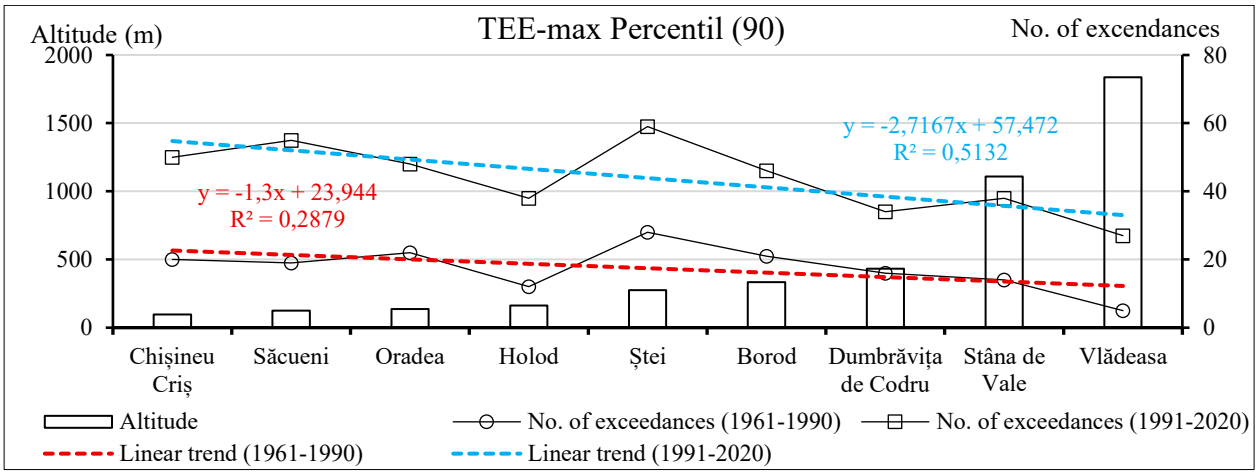


Figure 82. Variation in the number of exceedances of the maximum extreme values of the effective equivalent temperature index by the 90p percentile for the meteorological stations analyzed in the intervals 1961 - 1900 and 1991 - 2020.

The number of maximum extreme value exceedances had an upward, continuous and almost equal evolution for all meteorological stations analyzed, from 20 units in the interval 1961 - 1990 to over 50 units in the interval 1991 - 2020.

The increase in the amplitudes between the extreme values of the effective equivalent temperature could indicate a possible trend of bioclimatic extremization, expressed not only by the increase in the amplitude of extreme variation of bioclimatic characteristics, especially air temperature, by the substantial attenuation, up to the disappearance, of the intervals with bioclimatic comfort conditions or those that require the least possible intervention of human thermoregulation mechanisms.

The maximum and minimum values of the thermo-hygrometric index calculated by the 90p and 10p percentile method for the meteorological stations analyzed in order to highlight the evolution of the frequency of production of critical values are presented in Table 48.

Table 48. The number of cases in which monthly values exceed the 90p percentile and the number of cases not exceeding the 10p percentile corresponding to the monthly maximum and minimum values of the

thermo-hygrometric index, at the meteorological stations analyzed in the intervals 1961 - 1990 and 1991 - 2020.

Weather stations	Chișineu Criș	Săcueni	Oradea	Holod	Ștei	Borod	Dumbrăvița de Codru	Stâna de Vale	Vlădeasa
Variables / Altitude	**96**	**125**	**136**	**163**	**275**	**333**	**432**	**1108**	**1800**
Mean temperature (1961-2020)	10,6	10,7	10,7	10,7	10,1	9,6	10,3	4,4	1,5
Relative humidity (1961-2020)	78	75	76	81	78	79	72	88	86
THI-min Percentil (10)	-2,2	-1,8	-1,81	-1,9	-1,9	-2,6	-1,4	-7,9	-8,1
No. of non-exceedances (1961-1990)	40	28	40	33	21	32	25	28	28
No. of non-exceedances (1991-2020)	25	22	29	25	19	26	15	21	19
Difference of no. of non-exceedances	15	6	11	8	2	6	10	7	9
THI-max- Percentil (90)	25,9	25,2	25.7	25,8	24,8	24,5	23,5	20,4	13,8
No. of exceedances (1961-1990)	25	11	18	16	21	15	12	8	15
No. of exceedances (1991-2020)	53	26	37	45	40	40	29	30	50
Difference of no. of exceedances	28	15	19	29	19	25	17	22	35

The number of cases of non-exceedances in which the minimum values were higher in the interval 1961 - 1990 compared to the interval 1991 - 2020, with the largest difference recorded in Chișineu Criș of 15 units, and the smallest difference was recorded in Ștei (of two units), in the interval 1991 - 2020, compared to 1991-2020. The number of exceedances of the maximum values were higher in the interval 1991 - 2020, with the largest difference recorded in Vlădeasa, of 35 units, and the smallest difference was 15 units, in Săcueni.

The graphic representation regarding the amplitude of the minimum value variation of the thermo-hygrometric index for the percentile (10p) is shown in Figure 83.

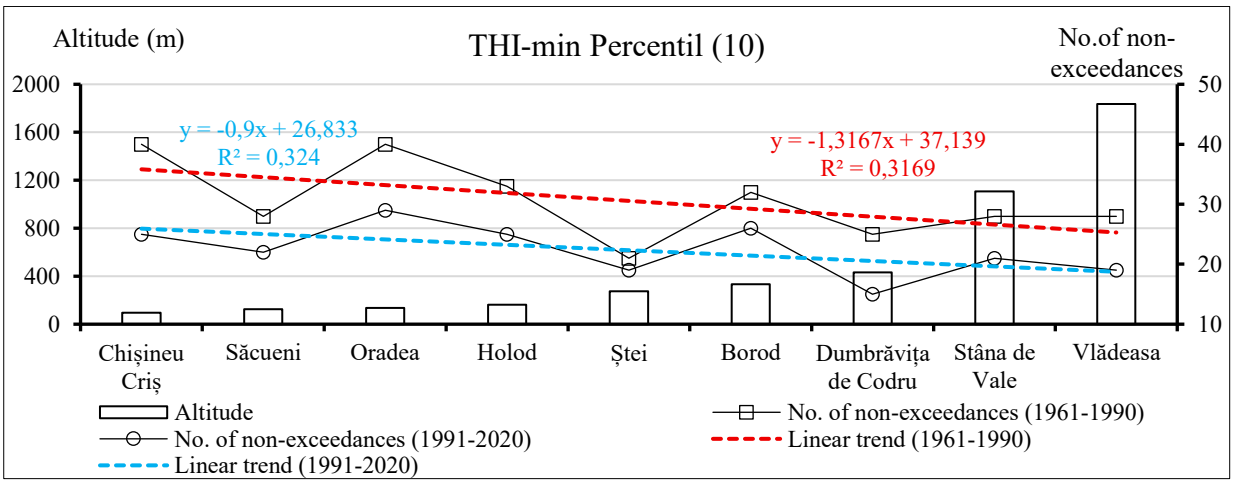


Figure 83. Variation in the number of non-exceedings of the minimum extreme values of the thermo-hygrometric index obtained by the 10p percentile for the meteorological stations analyzed in the intervals 1961 - 1990 and 1991 - 2020.

The number of non-exceedings of the minimum values of the thermo-hygrometric index had a downward evolution, from under 30 non-exceedings in the interval 1961 - 1990, to under 20 non-exceedings in the interval 1991 - 2020, with the lowest difference between the intervals in Ștei.

The graphic representation of the number of exceedings of the maximum values of the thermo-hygrometric index, by percentile (90p), for the purpose of analyzing the trend of variation of the frequency of occurrence of maximum extreme values, is shown in Figure 84.

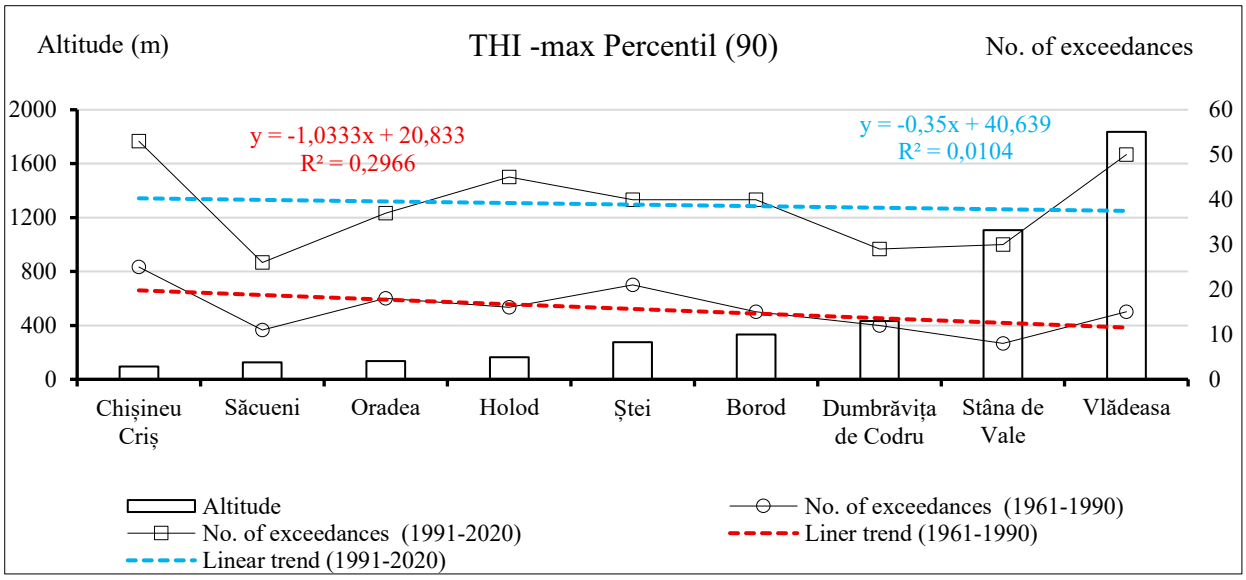


Figure 84. Variation in the number of cases of exceeding the maximum extreme values for the thermo-hygrometric index obtained by the 90p percentile at the meteorological stations analyzed in the periods 1961 - 1990 and 1991 - 2020.

The amplitude of the number of exceedances of the maximum extreme values of the thermo-hygrometric index were continuous and higher in the period 1991 - 2020, for all meteorological stations analyzed, from the maximum number of over 20 units in the period 1961 - 1990, to over 50 units in the period 1991 - 2020.

The maximum and minimum extreme values of the wind chill index calculated by the percentile method (90p) and (10p) for the meteorological stations analyzed in order to highlight the trend of variation in the frequency of occurrence of extreme values are presented in Table 49.

Table 49. The number of cases in which monthly values exceed the 90p percentile and the number of cases of non-exceedance by the 10p percentile corresponding to the monthly maximum and minimum extreme values of the wind chill index for the period 1961 - 2020.

Weather stations	**Chișineu Criș**	**Săcueni**	**Oradea**	**Holod**	**Ștei**	**Borod**	**Dumbrăvița de Codru**	**Stâna de Vale**	**Vlădeasa**
Variables / Altitude	**96**	**125**	**136**	**163**	**275**	**333**	**432**	**1108**	**1800**
Mean temperature (1961-2020)	10,6	10,7	10,7	10,7	10,1	9,6	10,3	4,4	1,5
Wind speed (1961-2020)	2,3	2,3	3,0	2,1	2,1	1,5	1,6	0,6	7,1
WCI (W/m²) min Percentile (10)	804	785	872	808	929	718	733	608	1018
No. of non-exceedances (1961-1990)	28	31	36	29	61	12	10	25	14
No. of non-exceedances (1991-2020)	20	28	22	18	48	22	27	20	30
Difference (1961-1990) - (1991-2020)	8	3	14	11	13	-10	-17	5	-16
WCI (W/m²) max Percentile (90)	957	967	1003	930	920	878	885	716	1238
No. of exceedances (1961-1990)	36	40	36	32	25	37	36	41	47
No. of exceedances (1991-2020)	29	15	22	25	21	14	9	8	23
Differences (1961-1990) - (1991-2020)	7	25	14	7	4	23	27	33	24

Regarding the number of non-exceedances, it decreased between 1991 and 2020 in most of the meteorological stations analyzed, with some exceptions (Borod, Dumbrăvița de Codru and Vlădeasa).

The increase in the number of non-exceedances in the stations located in the depression and mountain area is due to the altitude and climate specific to this area. Although the Stâna de Vale meteorological station is located in the mountain area, the number of non-exceedances decreased between 1991 and 2020, this is due to the location of the meteorological station in the depression area, being surrounded by buildings, vegetation and slopes 200-400 m higher. The number of exceedances decreased between 1991 and 2020 for all meteorological stations analyzed, with the largest difference between intervals recorded at Stâna de Vale (33 units), and the smallest difference was recorded at Ștei (four units).

It is found that the number of maximum extreme values of the wind chill index is more numerous between 1961 and 1991, and the decrease in their number between 1991 and 2020 determined a corresponding reduction in the intensity of heat loss suffered by the human body, contributing to the intensification of thermal stress, especially against the background of increasing thermal values. The bioclimatic contribution of the wind to maintaining a state of "comfort" will decrease substantially, and the thermal regime of the air will become the major factor influencing the bioclimatic profile of the analyzed region.

The number of non-exceeding of the minimum percentile values (10p) was graphically represented, in order to analyze the trend of evolution of the frequency of occurrence of the minimum extreme values of the wind chill index in Figure 85.

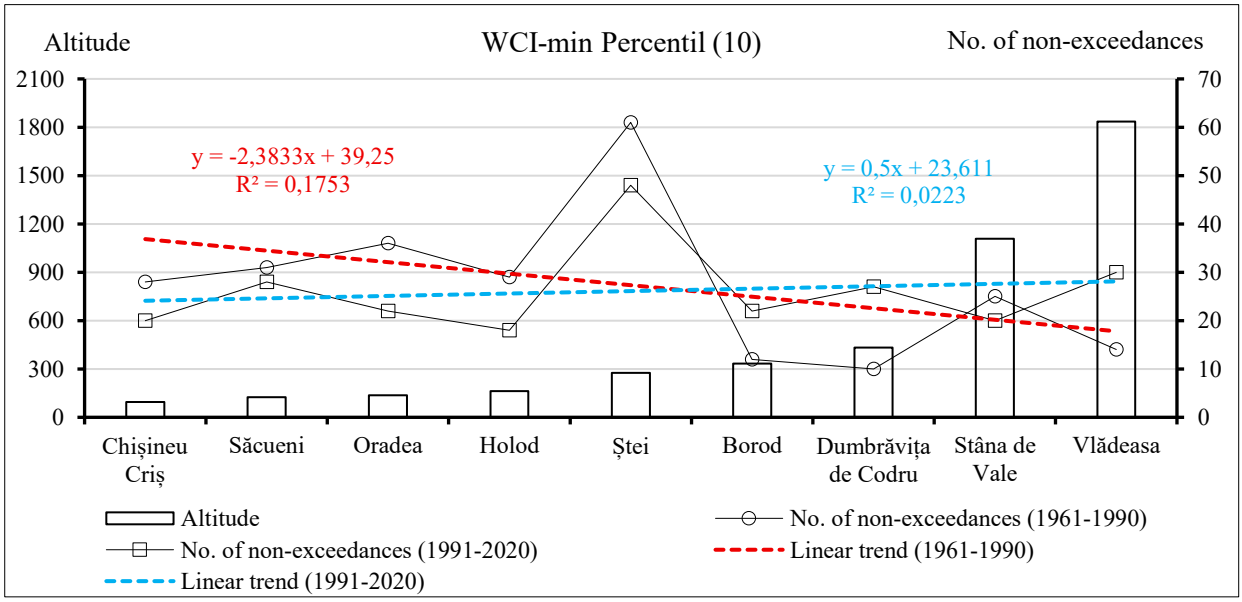


Figure 85. Variation of cases in which the minimum extreme values of the wind chill index do not exceed the 10p percentile at the meteorological stations analyzed in the periods 1961 - 1990 and 1991 - 2020.

For the most part, the evolution of non-exceedances was downward for meteorological stations located in the plain and hilly areas (Chișineu Criș, Săcueni, Oradea, Holod and Ștei), and for meteorological stations located in the depression and mountainous areas the evolution was upward (Borod, Dumbrăvița de Codru and Vlădeasa), with the exception of the meteorological station at Stâna de Vale, where the evolution of the number of non-exceedances was downward. The number of non-exceedances of the minimum extreme values had a downward evolution for all stations except Borod, Dumbrăvița de Codru and Vlădeasa where the number of non-exceedances increased in the period 1991-2020.

The graphical representation of the number of exceedances of the maximum extreme values of the wind chill index, by percentile (90p), for the purpose of analyzing the trend of evolution of their frequency of occurrence is shown in Figure 86.

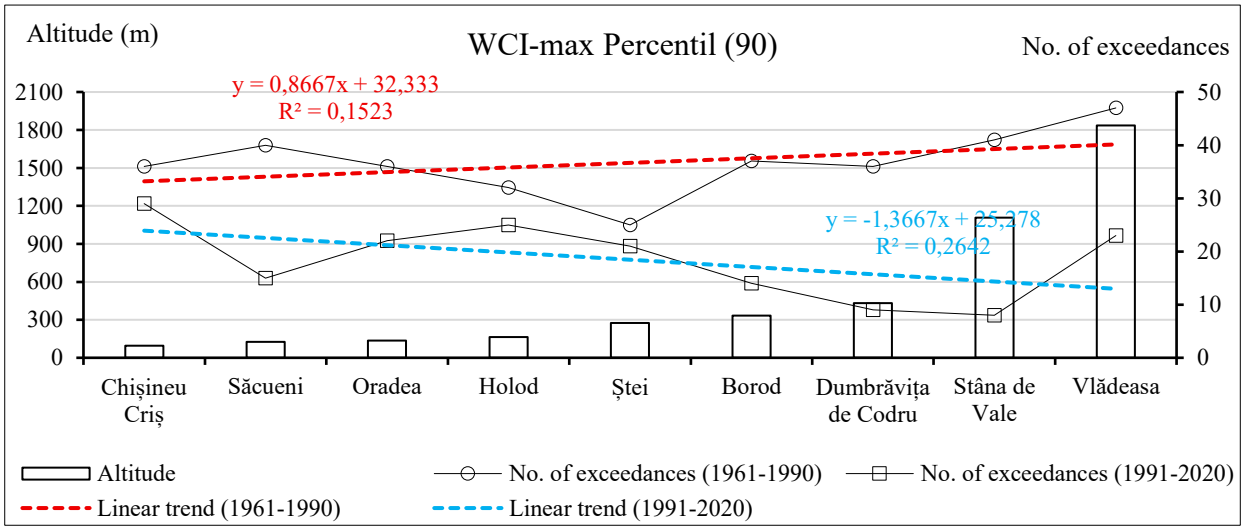


Figure 86. Variation in the number of cases in which the maximum extreme values of the wind chill index obtained by the 90p percentiles were exceeded at the meteorological stations analyzed in the intervals 1961 - 1990 and 1991 - 2020.

The upward trend of the maximum extreme values was observed at all stations, but the amplitudes between the intervals were different, with the smallest difference at Ștei and the largest at Stâna de Vale.

The number of exceedances and non-exceedances of the maximum and minimum values of the wind chill equivalent temperature index for the meteorological stations analyzed in the intervals 1961 - 1990 and 1991 - 2020 are presented in Table 50.

Table 50. The number of cases in which the maximum extreme values of the wind chill equivalent temperature index exceed the 90p percentile and the number of cases of non-exceeding minimum values do not exceed the 10p percentile at the meteorological stations analyzed in the intervals 1961 - 1990 and 1991 - 2020.

Weather stations	**Chișineu Criș**	**Săcueni**	**Oradea**	**Holod**	**Ștei**	**Borod**	**Dumbrăvița de Codru**	**Stâna de Vale**	**Vlădeasa**
Variables / Altitude	**96**	**125**	**136**	**163**	**275**	**333**	**432**	**1108**	**1800**
Mean temperature (1961-2020)	10,6	10,7	10,7	10,7	10,1	9,6	10,3	4,4	1,5
Wind speed (1961-2020)	2,3	2,3	3,0	2,1	2,1	1,5	1,6	88	7,1
WCET (˚C) min-Percentil (10)	-6,3	-6,1	-8.51	-8.51	-5,0	-2,5	-2,2	-0,8	-27,5
No. non-exceeds (1961-1990)	36	27	38	38	34	34	25	35	44
No. non-exceeds (1991-2020)	29	15	29	29	27	16	10	13	19
Difference (1961-1990) - (1991-2020)	7	12	9	9	7	18	15	22	25
WCET (˚C) max-Percentile (90)	28,1	27,6	27.6	27,4	26,6	26,6	26,1	23,7	9,1
No. exceedances (1961-1990)	19	14	21	18	19	30	14	10	14
No. exceedances (1991-2020)	53	37	47	41	48	39	28	40	37
Difference (1991-2020) - (19961-990)	34	23	26	23	29	9	14	30	23

The difference in the number of cases of the minimum percentile values (10p) of the index was recorded in Vlădeasa with 25 fewer non-exceedances in the period 1991 - 2020, and the lowest number of non-exceedances was recorded in Ștei and Chișineu Criș with seven units less in the period 1991 - 2020. The number of cases of maximum values by the percentile (90p) with the largest difference between the intervals was recorded in Stâna de Vale with 30 units more in the period 1991 - 2020, and the smallest difference was recorded in Borod, with nine units more in the period 1991 - 2020.

The number of non-exceedances of the minimum percentile values (10p) was graphically represented, in order to analyze the trend in the evolution of the frequency of occurrence of the minimum extreme values of the temperature index equivalent to the cooling power of wind in Figure 87.

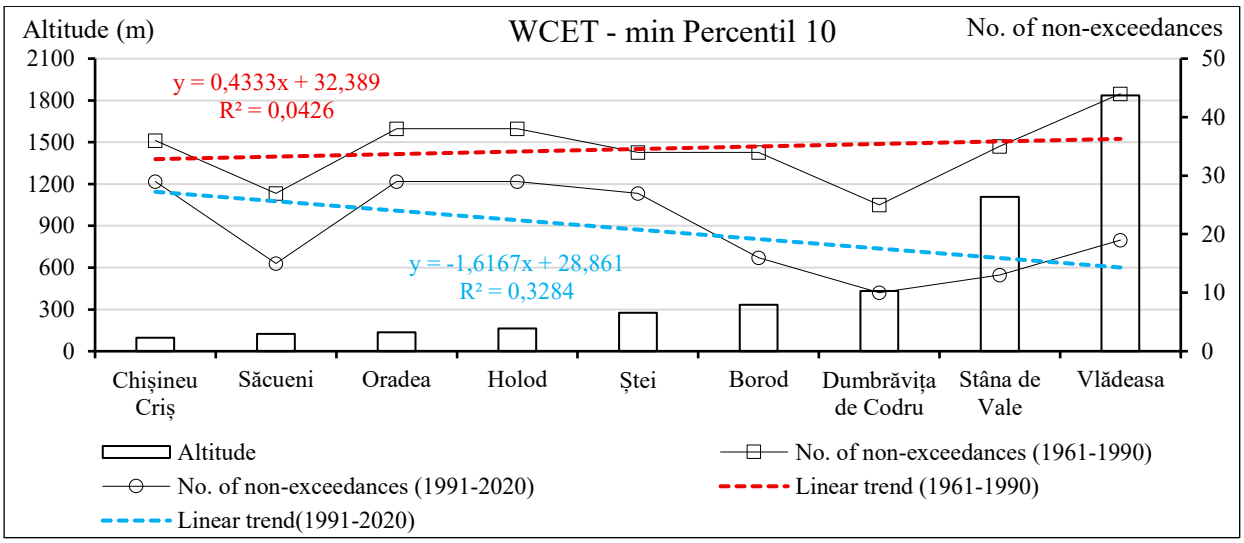


Figure 87. Variation in the number of cases in which the minimum extreme values obtained by the 10p percentile for the equivalent wind chill temperature were not exceeded at the meteorological stations analyzed in the intervals 1961 - 1990 and 1991 - 2020.

The downward trend in the number of non-exceedances was noted in the interval 1991 - 2020 where it was significantly lower with a maximum of 30 non-exceedances, compared to the interval 1961 - 1990, where the maximum number of non-exceedances exceeded 40 units.

The graphical representation of the number of exceedances of the maximum percentile values (90p) of the wind chill equivalent temperature index, for the purpose of analyzing the trend in the frequency of occurrence of extreme values, is shown in Figure 88.

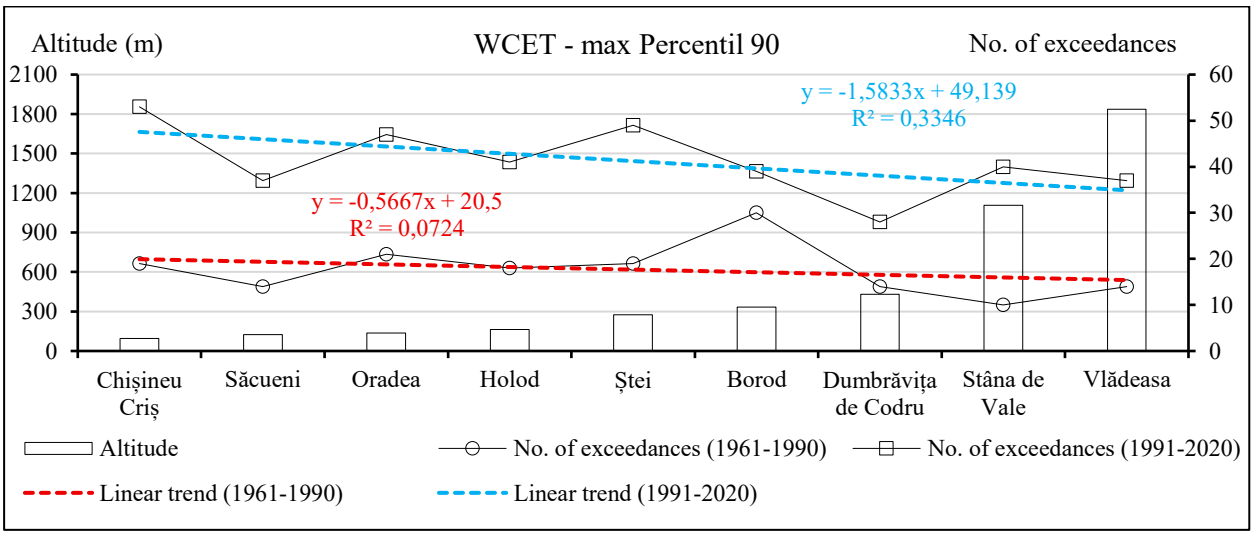


Figure 88. Variation in the number of cases in which the minimum extreme values of the wind chill equivalent temperature index were exceeded calculated by the 90p percentiles at the meteorological stations analyzed in the intervals 1961-1990 and 1991-2020.

The upward trend in the evolution of the maximum extreme values of the wind chill equivalent temperature index was recorded at all meteorological stations, but with different amplitudes. The lowest amplitude was recorded at the Borod meteorological station, and the highest amplitude was recorded at the Chișineu Criș and Vlădeasa meteorological stations.

By comparing the two intervals, the maximum extreme values of the wind chill equivalent temperature index, an upward evolution is observed in the interval 1991-2020, compared to the interval 1961-1990.

Balneoclimatic resources represent an important pillar in the socio-economic development of Bihor County, having a significant impact through sustainability on several aspects that combine economic benefits with the quality of life of the community.

6. The assessment of socio-economic potential of balneary resources in Bihor County

The balneoclimatic and socio-economic potential are interconnected, as the exploitation of balneal resources can have a significant impact on local economic and social development.

The socio-economic potential is an important indicator, which characterizes a certain territory through its economic specificity, but also its development opportunities (Baburin et al., 2018).

Exploring the development potential of balneology and balneal tourism can become one of the engines of regional development, with an effect on the local economy. Today, balneotherapy has become a medical specialty involved in the process of improving public health, for prophylactic and therapeutic purposes, but also a branch of tourism with economic (Moţica, 2018) and social value (Torres-Pruñonosa et al., 2022).

Regarding the identification of sustainable development prospects for balneology and balneary tourism in Bihor County, the main peculiarity is the similarity of geothermal water dependent on the connection between aquifers, regardless of their age (Haidu et al., 2023).

6.1. The current state of socio-economic research

The international literature is full of studies on the socio-economic potential of balneary tourism, as found in the works of authors Michalkó, Rátz (2010) who presented the balneary destinations in Hungary that play a unique role in the history of Hungarian tourism. Eusébio et al. (2013) reported on the importance of developing social health tourism programs for seniors. Other authors such as Wray, Weiler (2013) presented the identification of resources, factors and processes that can be used to develop and improve balneary tourism as a tool for competitive advantage and sustainability of regional tourist destinations.

Kazandzhieva (2014) reported that balneary tourism is positioned at a profitable intersection between the growing leisure tourism industry and the massive tourism economy in the world. Authors such as Csapó et al., 2017; Printz-Markó et al. (2017) discuss the thermal waters of Hungary and the competition that the balneary sector has in neighboring countries. Other authors (Kurek et al., 2020) investigated to what extent geothermal energy resources used for local tourist facilities are a factor of local development, in resorts in Poland.

Andreu et al. (2021) presented the use of various strategies and policies of diversification and seasonal adjustment in the face of the challenges of achieving economic, social and environmental sustainability, the fact that balneary destinations should consider the relaxation tourism market as a post-pandemic and long-term opportunity in Spain. Quintela (2023) conducted

a comparative study on balneary tourism and its role in sustainable development in two destinations in Europe.

In the specialized literature on the socio-economic potential of balneary tourism in Romania, there are researches that reveal the paradigm of balneary tourism in the communist and post-communist period, actors and regulations, etc. by authors such as: Măhăra et al. (1999) who focused on analyzing the potential of each geographical element in the Crișul Repede river basin in order to organize and use the space for tourism purposes; Petre (2006) who presented in his doctoral thesis entitled *Strategies for the development of spa tourism in Romania in the perspective of European* integration historical landmarks of the use of balneary treatment internationally, but also in Romania and considerations on the importance of tourism in the general strategy of economic development, as well as a strategy for the development of balneary tourism in Romania.

Cornea (2007) investigated the relationship of the administrative factor with the political system in different regimes, as well as the influence of the state structure on the structure of the administrative sector and their role; Turtureanu (2011) reported that the development of balneary tourism in Romania is important to be both a goal and a means to achieve general socio-economic development, taking into account the circumstances of the national development policy and integration into the European structure; Rădulescu (2011) targets the natural potential of balneary resorts in Romania, emphasizing the need for standards in relation to European requirements in the development directions of Romanian balneary tourism.

Other authors such as Erdeli et al., 2011; Teleki et al., 2012 conclude that it is important for tourism actors to be involved in opening up the balneary heritage to new socio-economic dimensions.

Authors such as Soare, Zugravu (2014) have synthesized the developments and challenges of the development of balneary tourism as well as the need to define, organize and promote this sector. Aluculesei (2016) in his doctoral thesis entitled *Innovative ways of capitalizing on natural spa resources in Romania through tourist services* specifies that he approaches balneary tourism as a possible solution for improving the health of the elderly, mainly and for prevention in the case of the young segment of the population, with applicability in Romania. Marin et al. (2019) presented in their studies the role, importance and perspective of balneary tourism in Romania.

Other research on the socio-economic tourism potential reported to the Bihor County area can

be found in the works of authors Josan and Sabău (2004) who analyze and present in advance the emergence of undesirable phenomena and processes with a harmful character on the environment and society. Ilies, Josan (2009) draw attention to the wrong understanding and implementation of practical aspects regarding the role of the natural and anthropogenic framework in the integrated

tourism development of the territory. Morar (2013) presented the tourism resources of the natural and anthropogenic framework of the disadvantaged mining areas, the positive or negative effects of tourism in these areas, the financing programs for investments carried out by the local administrations of the disadvantaged areas, proposals, solutions and recommendations for the development of tourism.

Ilies et al. (2015) reported that ways of raising awareness among locals regarding local natural values and ways of protecting and promoting them would be necessary, emphasizing the need for a pronounced sociological involvement in the study of various tourism processes and phenomena that could fundamentally contribute to the creation and implementation of a realistic local tourism development strategy. Herman and Tatar (2015) mentioned that through the relational analysis of the natural and anthropogenic environment, an attempt was made to capture the errors and development trends of the Băile Felix - Băile 1 Mai tourism system in, thus showing an identifying perspective on its evolution.

Other specialized studies related to Bihor county can be found in authors such as Carțiș (2017) in the doctoral thesis *Geographical study of the development of Bihor county as a tourist destination* and Handaric (2018) in *Research on the development of thermomineral tourism in the west taking the Western model*, who emphasized that the development of tourism in Romania is important to be an objective and a means of socio-economic development within the framework of the national development policy and integration into European structures.

Other authors, such as Herman et al. (2018) highlighted the role and importance of tourism in the sustainable development of the local economy of the tourist system Băile Felix and Băile 1 Mai. Ciurba et al. (2023) highlighted the therapeutic and recreational valorization of the balneary resource in rural localities in Bihor County that were not included in the state balneary tourism management plan before the 1989 Revolution nor in the network of the relevant ministry after the revolution. The same authors (2023) reported the importance of involving the administrative factor in the valorization of the balneary resource (thermal water) as well as their role in the local socio-economic development of the lesser-known localities of Bihor County. Marușca (2024) referred to the impact of its balneary tourism on the environment, analyzing the tourist potential and the natural therapeutic factors that contribute to its development.

6.2. Personal contributions regarding the socio-economic potential of balneary resources in Bihor County

The modern socio-economic situation and the need for constant adjustment of the processes taking place in a region require the development and formation of conceptual and methodological tools for complex analysis of the level of development potential of a region.

In Romania, the forms of administration of balneary and tourism structures have been influenced, over time, by the existing political regimes. The „balneary phenomenon" is based on the important aspects that contribute to the sustainability of the exploitation of geothermal resources. Their administrative system influenced the impact of the change of ownership as a result of the transition from socialism to capitalism.

The entire activity of capitalization after 1989 was linked to administrative changes and political goals focused on a rapid exploitation of thermal baths. Initially, the functionality of thermal baths during the privatization period 2000 - 2003 led to many failures. Since no investments were made in their arrangement or functional maintenance, they were abandoned or closed down. Then, gradually, some entrepreneurs found a way to capitalize on the balneary potential using permissive and encouraging legislation, although the state intervened timidly to support the progress of balneary tourism.

The progress of capitalizing on the balneary resource is influenced by several factors such as economic factors (prices, population income, tourist offer), social factors (free time), educational factors (level of education, desire for knowledge), administrative factors (facilities and services), etc.

The socio-economic potential related to the thermomineral resources of Bihor County analyzes the characteristics of the " balneary phenomenon" generated by their forms of administration. The administrative factor was taken into account, because it is directly involved in the sustainability of the balneary resource through the quality, cost and diversity of the services offered, adequate promotion and implementation of financing projects.

For this purpose, field data were collected and bibliographic documentation was carried out. The field study included approaching each location and administrative entity through on-site visits, inventorying the public catering, accommodation, treatment, and recreational infrastructure. Interviews were conducted with the administrative representatives of the balneary source (mayors, private administrators, locals) in 10 locations with lesser-known balneary resources from rural and small urban localities.

Thus, the real situation of the balneary resource was analyzed in terms of the development of accommodation, catering, leisure and treatment infrastructures.

Based on the analysis of the situation in the field, it was found that the evolution of the „balneary phenomenon" is influenced by the involvement of its administrative factor, highlighted by the impact of the change of ownership as a result of the transition from socialism to capitalism.

Cornea (2007) made references to the influence of the existing political regime on state administration, namely the major differences in the way the administrative system is organized and operated that were dictated by the two categories of political regimes (communist and democratic).

In the area of Bihor County, a number of 81 localities have hydromineral resources, of which seven localities have mineral water resources and 75 localities have thermal resources. There is one locality (Tămășeu) in the area of which there are both mineral water resources and thermal water resources. Hydromineral resources are arranged in relief steps from the plain where they predominate, to the hills and mountains where the fewest localities with hydromineral resources are found.

Of the 75 localities with geothermal resources, in 18 localities (Balc, Borș, Ceica, Cherechiu, Chișereu, Ciocaia, Ghiorac (Cighid), Mihai Bravu, Răbăgani, Roșiori, Salonta, Sântandrei, Sântimreu, Stâna de Vale, Valea lui Mihai) there are drillings with immediate potential for balneary valorization of geothermal water.

The evolution of the „balneary phenomenon" was analyzed depending on the form of administration, the level of interest, alternative ways of valorization of thermal water and risks of unsustainability.

6.2.1. Forms of administration of locally relevant balneary resources

In Romania, until the 1989 Revolution, balneary resources were managed exclusively by the public form, represented by Agricultural Production Cooperatives or city halls. With the transition from socialism to capitalism, the impact of the change in ownership for some balneary locations meant the transfer of the old administrative units of the balneary sources from state ownership to private administration. These were taken over as management locations (through concession), and their form of administration did not contribute to any investment, only to exploitation. The management did not increase the capital, they only increased salaries and invented expenses, which led to bankruptcy and ruin.

In Romania, the transition period can be divided into two stages, the first stage was dominated by rapid, predominantly destructive privatization that lasted from 1990 to 2000, and the second stage took place from 2001 to 2004 and was characterized by the privatization of large companies that occupied strategic positions in the Romanian economy. The restitution of properties confiscated under communism completes the privatization process, causing major changes in the economy and society alike, with fraud causing serious damage (Zamfir, 2018), which is probably one of the causes of the unsustainability of rural thermal baths.

The administration of balneary resources in rural localities, as well as in small towns of Bihor County, from the 1989 Revolution to the present (2023), has been represented by 61% of private administration and 31% of public administration.

At first, local communities rudimentarily arranged the balneary sources, in the form of simple thermal water baths, after which they were taken over by the Agricultural Production Cooperatives that managed them until the end of the socialist period, in 1989.

After the 1989 Revolution, the country's return to capitalism determined an unclear background for the entire national tourism activity with questionable privatizations. These were accompanied by a lack of clear government policies regarding the Romanian balneary heritage, which meant that some of the balneary towns and localities were left in disrepair.

With privatization, entrepreneurship developed and new sources of internal or external financing appeared (in 2010, Government Decision No. 120 was issued regarding the list of tourism investment programs and projects, sources of financing for technical documentation, as well as the execution works of tourism investment programs and objectives) (www.turism.gov.ro).

Thus, in several of the localities where the administrative factor was involved and concerned with the evolution and development of the balneary resource, through new accommodation structures (three-star hotels, three-star guesthouses, modern wooden cabins, wooden houses, mobile homes) in Sânnicolau de Munte, Săcueni, Sarcău, Mădăras and Livada de Bihor, these became important balneary tourist attractions of the place.

In other localities, the thermal baths were permanently maintained at a functional level (Aleșd, Chișlaz and Tămășeu). A special case was encountered in Răbăgani, where, with the property transfer process, the thermal bath became the property of individuals acquired by court order. They requested the local authorities to demolish it.

Some of the thermal baths remained the property of local town halls and failed to remain functional due to high operating costs, so they remained in disrepair: Mihai Bravu, Valea lui Mihai, Cadea and Ciocaia (Ciurba et al. 2023).

At the level of Bihor County during the period 2020 - 2024, in addition to the four known balneoclimatic resorts (Băile 1 Mai, Băile Felix, Stâna de Vale and Băile Tinca), 13 localities met the criteria for certification as local tourist resorts, following the feasibility study, according to the annexes to Government Decision no. 852/2008. These were Oradea, Marghita, Beiuș, Ștei, Salonta, Mădăras, Bratca, Borș, Vadu Crișului, Săcuieni, Șuncuiuș, Pietroasa - Budureasa, Padiș and Vârtop - Nucet. Of these, eight tourist resorts (Oradea, Beiuș, Ștei, Marghita, Salonta, Mădăras, Borș and Săcueni) have the balneal resource (thermal water). The status of a tourist resort facilitates access to European funding axes, so we can expect a future development of these resorts.

6.2.2. Alternative uses of geothermal water in rural areas and in emerging new tourist resorts of Bihor County

At the rural level, the exploitation of resources until the 1989 Revolution was done locally and for some balneary and recreational purposes (in Mădăras, Sarcău, Chișlaz, Tămășeu, Sânnicolau de Munte and Săcueni). In the 1980s, geothermal water was used in district heating for heating homes (Oradea and Livada de Bihor), and from 1985 to 1989 it was exploited in the fish farming industry, serving the largest thermal water fish breeding station in Europe (Livada de Bihor). Today, in Bihor County, geothermal water is exploited in fish farming only in Sântandrei.

From 1989 to today, new geothermal water drillings have been carried out both in rural localities (Sântandrei) and in urban ones (Oradea, Beiuș, Ștei, Salonta, Aleșd). Also, the areas of geothermal water utilization have multiplied. Thus, the number of localities that use geothermal water in district heating for heating has increased (Oradea, Ștei, Beiuș, Marghita, Livada de Bihor and Săcueni). Because it has proven to be a profitable and renewable source that has contributed to the growth of the economy due to the low cost of using gigacalorie, which has led to increased thermal comfort for the community.

Another niche for geothermal water utilization was in agriculture, serving local tomato greenhouses (Livada de Bihor, Toboliu and Roșiori). In Livada de Bihor, the greenhouses operated from 2006 to 2014, and tomato production resumed in 2022.

Another way to utilize geothermal water is in the dermato-cosmetic industry. Since 2018, the thermal water from Băile Felix has been used as the main ingredient in creams, face masks, lotions and gels, for daily care and anti-aging in dermato-cosmetic products under the name Synergy (www.synergytherm.com). Starting in 2021, thermal water in Beiuș is also used in the skin care industry through Beyus products (www.beyuscosmetics.com).

In addition to these forms of exploitation, after 1990 the wellness and balneary sector with thermal water developed at the Elite Hotel and Nymphaea Aquapark in Oradea, at Laguna Beiuș, but also in the rural localities of Sarcău and Sânnicolau de Munte.

Since the balneary resources were under the supervision of a stable administration, new jobs were created that contributed to the growth of the local economy through tax payments, capital accumulation and, as a result, contributed to the improvement of the quality of life of residents (Ciurba et al., 2022).

6.2.3. Sustainability risk associate with exploiting balneary resources in rural areas

The lack of investment in thermal baths and the rudimentary maintenance to keep them functional led to their falling into disrepair (in Cadea, Mihai Bravu, Valea lui Mihai, Ciocaia and

Balc) or disappearance through demolition (in Răbăgani). This situation began with the privatization after the 1989 Revolution when the thermal baths came under public or private administration. This was due to the lack of prioritization by the administration of local public projects oriented towards tourism, which implies that a recreation base in a rural locality does not have priority over sewage infrastructure, water supply or asphalting of village roads. The sustainability of geothermal water exploitation in rural localities is subject to administrative risks, unpopularity or depopulation of villages.

Administrative risks could be a cause of the unsustainability of geothermal water exploitation by changing the administrative factor, especially to the private one, which may pursue a too fast profit by increasing tariffs without increasing the quality of services. Risks of unpopularity could be a cause, due to the lack of modernization of the infrastructure and thus ultimately became unattractive for tourists who are becoming increasingly informed. The risk of depopulation of villages, determined by the migration of the young population to localities with educational and entertainment potential, reduces the prospects and opportunities for development and could even determine the unsustainability of the exploitation of the rural balneary potential.

6.2.4. Classification of localities according to the present condition of balneary resource exposure

Following the analysis of the development of the „balneary phenomenon" influenced by its administrative factor, the classification of localities according to the current stage of exposure of the balneary resource resulted, as follows:

a) Localities with simple baths that capitalized on thermal water before the 1989 Revolution

In these localities (Cadea, Mihai Bravu, Răbăgani, Balc, Valea lui Mihai and Ciocaia) the balneary resource was identified during the period 1960 - 1970, during which geological prospecting works were carried out in order to identify oil or natural gas deposits. The works highlighted the presence of valuable geothermal resources that were exploited for balneary purposes. Sometimes local communities, through their own initiative and effort, built small rural swimming baths. Even though these were simple thermal baths, their connection to the hydrographic network or the sampling of cooling water required works related to the additions, discharges or delimitation of the dam basins (Donati, 2022). The management of the balneary source in these rural locations was entrusted to the Agricultural Production Cooperatives or the town halls that managed them until the 1989 Revolution (Ciurba et al., 2023). Since 1990, against the backdrop of an unstable political environment, the privatization process began, the thermal

baths have been managed by various management teams, and due to the fact that there was little interest, little experience or insufficient financial support, they fell into disrepair.

b) Localities that exploit the balneary resource.

All localities with balneary resources (Aleșd, Sarcău, Livada de Bihor, Sântandrei, Sânnicolau de Munte, Chișlaz and Tămășeu) exploited since the 1970s were managed by the Agricultural Production Cooperatives until the 1989 Revolution. At that time, these thermal baths were among the few forms of recreation in the rural area.

After 1989, these resources were managed by various forms of public or private administration.

Aleșd is a city that exploits geothermal water through a drilling that was carried out between 1979 and 1981 that supplies two entities (the thermal bath and the day center for the elderly) in which the thermal water is exploited for recreation. The management of the balneary resource belongs to the public administrative sector. The city of Aleșd has a forward-looking plan to exploit the geothermal resource for the purpose of obtaining green energy, for energy efficiency and the rehabilitation and modernization of the Aleșd thermal bath (www.alesd-bihor.ro).

Livada de Bihor is a rural locality that has used geothermal water as a thermal agent since 1980. Since 1985, it has served the largest thermal water fish breeding station in Europe. In 1982, the thermal bath was built and operated until 2007. Then, the thermal water served the tomato greenhouses in the locality until 2014. The reopening of the thermal bath was carried out in 2020 when it was rented to a local private company and improved with an accommodation structure consisting of modern wooden cabins (classified in the three-star category) and a restaurant.

Currently, the administration of the balneary resource is both public and private. In view of the development of the balneary potential, 1500 m2 of land was purchased, in order to expand the thermal bath, with an indoor bath, an outdoor bath and a guesthouse (Thermal Bath Administration, 2023). Sânnicolau de Munte is one of the few rural localities that, with the privatization after 1990, developed the local balneary resource by improving the old thermal baths, building accommodation infrastructure (caravans, wooden houses, up to a small three-star hotel). It also has a restaurant infrastructure for 100 people and a modest recreation area. In addition to the old thermal bath, in the summer of 2022 the Kre spa bath was established in the immediate vicinity. Both thermal bath are under private administration.

Sarcău is a rural locality in Bihor that has had a thermal bath since the 1970s. Four years after the 1989 Revolution, the Adorianis complex became the most modern and complex treatment facility in the rural area, consisting of appropriate equipment, an accommodation structure consisting of two modern three-star guesthouses and a villa, a conference room, a leisure center

and a public catering structure. Since 2003, the administration of the balneary resource in Sarcău has been carried out by a private entity.

Chișlaz is a rural locality with balneary resources that utilizes geothermal water at the local thermal bath. After the 1989 Revolution, the thermal bath was administered by a private company until 2010. Since then and until now, it has been administered by a public entity (city hall).

Tămășeu is a rural locality that has had cold mineral water since 1887, when the Oradea - Valea lui Mihai railway was inaugurated. The hydrothermal resource has been exploited since the 1960s by bottling for sale under the name Lithium, then Tămășeu. Currently, the water from the borehole flows freely. In this locality, thermal water is also exploited in the swimming bath that has been operating since its arrangement by the residents of the time in the 1970s. The administration of the balneary source is carried out by a private agent. As a project to capitalize on the balneary resources, 10 hectares of land were purchased on which an accommodation and treatment base and an aquatic park will be built.

Sântandrei is a rural locality that has been using geothermal water for fish farming since 1993 when the borehole was carried out. The administration of the balneary source is carried out by a private investor. Regarding the development plan, a project is proposed for the establishment of a treatment and recreation center (www.primariasantandrei.ro).

c) New tourist resorts: urban and rural localities of national and local interest with a balneary specific

Bihor County has 16 new tourist and balneary resorts (Vadu Crișului, Oradea - Crișul Repede, Salonta, Beiuș, Ștei, Marghita, Mădăras, Borș, Săcueni, Bratca, Șuncuiuș, Vârtop - Nucet, Pietroasa-Budureasa and Padiș). Eight of these tourist resorts have resources with a balneary factor (Oradea, Beiuș, Ștei, Marghita, Săcueni, Mădăras, Salonta and Borș). These localities were certified as tourist resorts in the period 2020 - 2024 (Table 51).

Table 51. The new tourist resorts with balneary potential in Bihor County.

Locality	Year of certification as a tourist resort	Level of interest	Type of resort
Oradea	2022 2020	national	balneological and balneoclimatic tourist
Marghita	2022	national	tourist
Salonta	2021	local	tourist
Săcueni	2021	local	tourist
Borș	2021	local	tourist
Beiuș	2020	local	tourist
Mădăras	2020	local	tourist
Ștei	2020	local	tourist

Oradea, the capital of Bihor County, acquired the status of a tourist resort of national interest in 2020 (H.G. no. 377, 2020), for the historic center and the Crișul Repede riverbed. Then,

in 2022, it was recognized as a turist and balneoclimatic resort (H.G. no. 898, 2022). In the area of the municipality, thermal water is used for heating, recreation (a sector of the Nymphaea Aquapark complex, the Ioșia swimming bath, the thermal baths of some hotels). The administration of the balneary facilities is both public and private. As a provisional plan for the valorization of the balneary source, it envisages the development of the Ioșia Thermal Garden (www.oradea.ro).

Marghita is the municipality that was certified as a tourist resort of local interest in 2022 (H.G. no. 910, 2022). The thermal water is used for therapeutic purposes at the Dr. Pop Mircea Municipal Hospital, the balneology department and for recreation at the thermal hotel-complex and at the municipal swimming bath. The administration of the balneary source is both public and private. According to the integrated urban development strategy, it has projects for the creation of a balneary tourism complex and the rehabilitation of a geothermal water bath covered for the winter period and an outdoor thermal garden (www.primariamarghita.ro).

Beiuș is the municipality that was certified as a tourist resort of local interest in 2020 (H.G. no. 1073, 2020). The main use of thermal water is in heating, making it the only city in the country where the heating agent is made exclusively based on thermal water, which gave it the name of the green city (www.municipiulbeius.ro) and secondary for leisure (thermal water baths) and in the cosmetics industry (www.beyuscosmetics.com). The administration of the balneary source is public and private. As a development plan, it has a project that provides for the use of the hydrotherapeutic resource by building a complex water park (www.municipiulbeius.ro).

Ștei is an urban locality that obtained the status of a tourist resort of local interest in 2020 (H.G. no. 887, 2020). The city of Ștei has balneary resources that are currently being valorization. The geothermal water drilling was carried out after the 1989 Revolution. The management of the The city of Ștei has balneary resources that are currently being exploited resources belongs to the public administration. In the summer of 2024, the The city of Ștei has balneary resources that are currently being exploited center, the balneophysiology department of the city hospital and the thermal bath were inaugurated, which were restored.

Săcueni is a locality certified as a tourist resort of local interest in 2021 (H.G. no. 343, 2021). The thermal water is exploited for heating (in institutions) and recreation (thermal bath). The administration of the balneary source is both public and private. As a perspective of capitalization, it has a project that provides for the exploitation of thermal water by building a balneary/treatment center (www. sacueni.ro).

Mădăras is a rural locality that was certified as a tourist resort of local interest in 2020 (H.G. no. 1073, 2020). The thermal resource is valorized for recreation at the Mădăras thermal bath. The administration of the balneary source is carried out by a private investor.

Salonta and ***Borș*** have been certified as tourist resorts of local interest. The village of Borș was certified in 2020 (H.G. no 887, 2020) and the municipality of Salonta in 2021 (H.G. no. 343, 2021). These localities have thermal water resources that are currently not valorized. As a preliminary plan for the exploitation of thermal water, projects are foreseen for the establishment of the Borș Thermal Complex, the expansion of the Iris Hotel to include a treatment center, conference room and balneary center (www.primariabors.ro).

A sports and recreation center is under construction in Salonta, which will be equipped with swimming baths and geothermal water baths (Figure 89) (www.arenaconstruct.ro).



Figure 89. Salonta Sports and Recreation Center in December 2024.

d) Localities with untapped balneary resources

In Bihor County, there are 61 localities that have untapped thermal water resources. Some of these form the reserve balneary fund, and in many localities there are only boreholes with thermal water (Adoni, Albești, Biharia, Borș, Balc, Betfia, Căbești, Cadea, Ceica, Cheresig, Cheșereu, Curtuișeni, Chiraleu, Cihei, Ciocaia, Ciuhoi, Cefa, Ciulești, Cordău, Ciumeghiu, Corbești, Coșdeni, Curățele, Cusuiuș, Criștioru de Sus, Diosig, Fegernic, Galoșpetreu, Ghiorac, Girișu de Criș, Hidișel, Husasău de Tinca, Miersig, Mihai Bravu, Niuved, Nojorid, Olosig, Finiș, Oșorhei, Otomani, Palota, Păușa, Răbăgani, Rontău, Roșiori, Salonta, Sălacea, Sălard, Săcădat, Șimian, Sâniob, Sântion, Tășad, Tăuteu, Sântimreu, Tileagd, Toboliu, Tria, Tulca, Valea lui Mihai, Vașcău).

To these are added three mineral water wells (Tămășeu, Sălard, Sântimreu) and three mineral water springs (Tinca, Budureasa, Voivozi in the Pădurea Neagră holiday village)

e) Forms of administration and valorization of the balneary resource in the pre- and post-Revolutionary period

After the development of the balneary springs in the thermal baths during the communist period, some rural localities (Sarcău, Livada de Bihor, Săcueni, Sânnicolau de Munte, Chișlaz, Mihai Bravu, Cadea, Răbăgani, Tămășeu, Mădăras, Ciocaia and Balc) were administered by agricultural production cooperatives. At the level of urban localities (Oradea, Marghita, Aleșd) the

balneary sources were also managed by the public administrative factor, respectively by the city halls. After 1990, both rural and urban balneary resources came to be managed by public and private administrative factors Table 52).

Table 52. Forms of administration and exploitation of the balneary potential in the pre- and post-revolutionary period of December 1989.

Locality with balneary potential	Form of administration in the period 1970 - 1989	Form of valorization until the 1989 Revolution	Form of administration in the interval 1990 - 2023	The form of valorization in the interval 1990 - 2023
Aleșd	public	leisure	public	leisure
Băile Felix	public	treatament, leisure	private public	treatament, leisure, dermato-cosmetic industry, wellness and spa
Băile 1 Mai	public	leisure, treatament	private/public	treatament, leisure, wellness and spa
Băile Tinca	public	treatament	private	treatament
Balc	public	leisure	private	abandoned
Beiuș	drilled in 2003		private/public	heating, leisure, dermato-cosmetic industry
Cadea	public	leisure	public	abandoned
Chișlaz	public	leisure	public	leisure
Ciocaia	public	leisure	public	abandonat
Livada de Bihor	public	leisure, agriculture, heating, pisciculture	public/private	leisure, heating
Mădăras	public	leisure	private	leisure
Marghita	public	leisure	public/private	leisure, treatment, heating
Mihai Bravu	public	leisure, agriculture	private	abandoned
Oradea	public	leisure, heating	private/public	leisure, heating
Răbăgani	public	leisure	private	demolish
Săcueni	public	leisure	private	leisure, heating
Sântandrei	drilled in 1993		private	pisciculture
Sarcău	public	leisure	private	treatment, leisure, wellness and spa
Sânnicolau de Munte	public	leisure	private	leisure, wellness and spa
Ștei	public		public	treatment, leisure, heating
Tămășeu	public	leisure	private	leisure
Valea lui Mihai	public	leisure	public	abandoned

Based on the above classifications, a comparative analysis of the exploitation of the thermal resource in rural localities and in the new tourist resorts of Bihor County was carried out, from the development until the 1989 Revolution and from 1990 until the present (Figure 90). The comparative analysis targets the variables given by the form of exploitation of the balneary source (heating, vegetable growing, leisure, balneary treatment, dermato-cosmetic industry, wellness and

spa, fish farming, mineral water spring, thermal water drilling, mineral water drilling) and the form of administration (public or private) involved in its exploitation in the two periods.

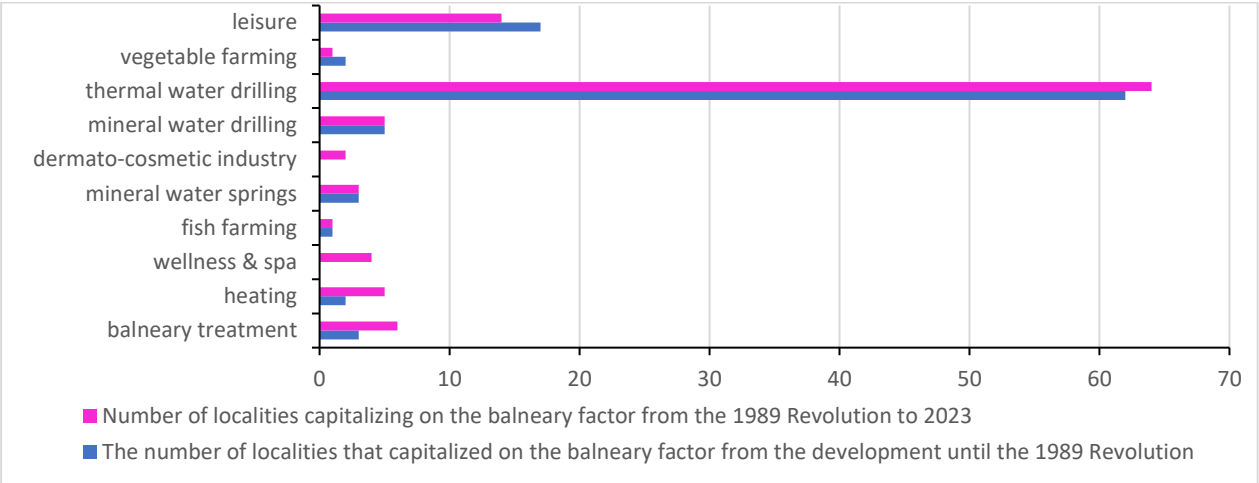


Figure 90. Comparative analysis of thermal water valorization in the periods 1960 - 1989 and 1990 - 2024.

Thus, the evolution of the "balneary phenomenon" in the new democratic period of the country was identified, by increasing the number of localities that capitalize on thermal water in various ways. The new forms of exploitation of geothermal water that emerged after the Revolution are the wellness and spa sector and the dermato-cosmetic industry. However, while some balneary resources have developed or been newly established (new drillings), other balneary resources have remained in ruins. From the Revolution to the present (2024), with the exception of Oradea, only two new thermal bath have been built, in Beiuș and Sânnicolau de Munte for recreation, and new thermal water drillings have been carried out (Ștei, Beiuș, Oradea and Sântandrei).

Thus, in Bihor County, part of the local administrative factor can be said to have fulfilled its duties in the development of balneary tourism, a fact demonstrated by the achievements it has made: geothermal water heating in Beiuș, Oradea, Ștei, Marghita, Livada de Bihor and Săcueni; the development of the balneary complex in Sarcău; the establishment of the thermal bath in Beiuș, as well as in Sânnicolau de Munte where a leisure balneary center was inaugurated next to the old thermal bath. But considering the balneary potential of Bihor County, the administrative factor would still need to be more consistently involved, in order to achieve the maximum use of balneary resources.

The socio-economic potential directly influences the valorization of hydromineral balneary resources, and the development of balneary and tourist infrastructure, in turn, contributes to local economic and social growth.

7. Personal contributions regarding the directions of capitalizing on the balneoclimatic potential

The balneary potential of Bihor County is a significant element in socio-economic development, by attracting investments, developing tourism and improving the quality of life. The valorization of these resources in balneary resorts and localities with balneary resources has made Bihor County an important hub of balneary tourism at national and international level.

Balneary resorts are characterized by the use of natural resources and focus on holistic well-being, they are increasingly located in rural areas where they capitalize on the unique ecological and cultural attributes of these areas (Mijatov et al., 2024).

Each balneary resort and locality with a balneary function begins its story with the discovery of natural factors whose therapeutic value has been clinically and experimentally proven by scientific figures of the time. The dissemination of information led to a local reputation, and the status of a balneary resort was acquired by promoting the qualities of the natural resources found.

The development of balneary tourism in Romania takes place in the context of the need for investments in affected accommodation structures and the objectives of sustainable tourism development, which require an integrative and innovative approach to this sector. The aging population and the increasing incidence of pathologies influenced by sedentary lifestyle are factors that will support the development of balneary tourism strategies (Țuțui, 2016).

The diversity of natural balneary resources of Bihor County has determined that the resorts can offer therapeutic solutions for a wide range of conditions. These represent the main attraction in balneary tourism, to which the climatic factors that complete the palette are successfully added. The spread of natural healing factors throughout the area allows the practice of balneary tourism in mountain areas, hills and plains, the climatic conditions adapted to the needs of tourists (Turtureanu et al., 2020).

7.1. Current state of research on the valorization of balneary resources in Bihor County

The „balneary phenomenon" in Bihor County combines harmoniously with the natural and anthropogenic landscape, the ionized air and the climate of the locations where it takes place. Balneary tourism is practiced for the purpose of medical, therapeutic and prophylactic recovery (Seite, 2013).

Current studies that refer to balneary tourism in Băile Felix and Băile 1 Mai have been carried out by several authors such as: (Florescu et al., 1966; Munteanu et al., 1979, 1979; Ilieș et al., 2009; Marian, 2012; Paál, 2013; Ilieș et al., 2015; Borodi et al., 2016; Handaric, 2018; Herman et al., 2018; Moţica, 2018; Ardelean et al., 2019; Cohut et al., 2019; Bronfort et al., 2021; Ciurba et al., 2022; Cuc et al., 2023; Moza et al., 2023; Trip et al., 2023).

Authors such as Baias et al., 2010 and Ilieș et al., 2011 have highlighted the importance of the balneary tourism potential of Băile Felix and Băile 1 Mai by creating geo-tourism maps containing a synthetic description of the main geological-geomorphological aspects, accompanied by photographs and relevant information about tourist routes, rules of conduct, restaurants, tourist attractions in neighboring areas, for the purpose of tourist information.

In the specialized literature, there are few studies that have referred to balneary tourism in Bihor County, beyond the famous resorts of Băile Felix and Băile 1 Mai. Authors, such as Marușca (2008) highlighted the special value of the balneary tourism potential in the area of the Western Hills and the Western Plain, which also included the lesser-known localities of Bihor County (Marghita, Balc, Sânnicolau de Munte and Tămășeu) that have exploited the balneary resource of thermal water in thermal baths. In the sixth chapter of his doctoral thesis entitled *The balneary tourism potential in the Western Carpathians. The Banato-Crișene Plain and Hills*, Marușca (2008) also presented the hydromineral tourism fund, including Bihor County. Linc and Marușca (2008) presented a brief history of the most important balneary resorts in the west of the country and mentioned the localities with thermal resources where this was poorly exploited (Sânnicolau de Munte, Săcueni, Tămăşeu, Marghita, Mădăras) or which were abandoned (Ciocaia, Răbăgani). Other authors, such as Gaceu et al., 2009, emphasized the need to promote the Băile Tinca resort, which has a remarkable natural and anthropic tourist potential, but it is little known. Despite the fact that the resort has a high potential, the flow of tourists is low.

Marușca and Moț (2010) mentioned the role of the natural factor, thermal water, in the development of balneary tourism in Bihor County by highlighting their valorization in the

established resorts and presented the characteristics of thermal waters in rural and small urban localities (Aleșd, Marghita, Sânnicolau de Munte, Cheșereu, Balc, Ciocaia, Săcueni, Tămășeu).

Other authors Teodoreanu and Gaceu (2013) presented, in relief steps, the network of localities in Romania in the balneary tourism circuit that benefit from natural therapeutic factors and can be valorized, including Băile Tinca, Băile Felix and Băile 1 Mai.

Ciurba et al. (2023) outlined the rural balneary potential of Bihor County, by highlighting the multiple characteristics of the geothermal resource as well as its impact on the quality of life of locals, the infrastructure and the forecast situation of local balneary tourism development.

7.2. Localities and infrastructures currently in use

In Bihor County, treatment facilities have been developed over time, based on the deposits rich in known thermal and mineral waters, in resorts of different levels, with seasonal or permanent regime. Thermal waters are the ones that started the valorization of the balneoclimatic potential of this area. Thus, they are valorized in Bihor County, in balneoclimatic resorts of national level (Băile Felix) or local level (Băile 1 Mai, Băile Tinca), as well as in localities with balneal resources that have acquired the status of tourist resort in the period 2020 - 2023 (Oradea, Beiuș, Mădăras, Săcueni, Ștei, Marghita). In addition to the established tourist and balneoclimatic resorts, the balneal resource has also been exploited for a long time in localities with balneal resources such as Aleșd, Sarcău, Sânnicolau de Munte, Tămășeu, Chișlaz, which have not yet been certified as tourist resorts, although they are visited and recognized as local tourism destinations and beyond. To these, there is the balneoclimatic resort Stâna de Vale, defined by the oligomineral, ferruginous, hypotonic mineral water (bottled under the name Izvorul Minunilor).

Regarding the current state of exploitation of hydrothermal resources in Bihor County, the existing situation of hydrothermal balneal resources was monitored, as well as the definition of sustainability assessment criteria for balneology and tourism. Thus, all locations that utilize the balneary resource were inventoried to highlight the forms of balneary (therapeutic, recreational) and alternative valorization (in district heating for heating, dermato-cosmetic industry, fish farming, vegetable farming).

Table 53 lists the balneary localities in Bihor County with or without the status of tourist resorts and that utilize the hydromineral resource for balneary purposes, their geographical coordinates, the characteristics of the thermomineral water, the therapeutic indications according to the test report of each location, the form of valorization as well as the status of the town.

Table 53. Localities in Bihor County that capitalize on the balneary resource.

Nr crt	**Locality with exploited balneary resource**	**Latitude N Longitude E**	**Alt. (m)**	**Water temperature (°C)**	**Flow rate (l/s)**	**Water type**	**Therapeutic indications**	**The form of capitalization of thermal water**	**Status of the locality**
1.	**Aleșd**	47°3′26″ 22°23′49″	224	40		bicarbonated sulfated calcic	not analyzed	leisure	tourist town
2.	**Băile 1 Mai**	46°59′47″ 21°59′46″	140	36 - 48	50	oligometallic bicarbonated calcic sodium	degenerative rheumatism inflammatory rheumatism non-articular rheumatism post-traumatic disorders neurological disorders neuromuscular disorders conditions associated with metabolic diseases gynecological conditions (chronic metronome, minor puberty or menopause disorders) respiratory conditions	treatment, leisure	balneoclimatic resort
3.	**Băile Felix**	46°98′99″ 21°98′21″	155	49	196	oligometallic bicarbonated calcic sodium oligominerall	degenerative rheumatic diseases inflammatory rheumatic diseases non-articular rheumatic diseases disorders post-traumatic neurological disorders neuromuscular disorders conditions associated with metabolic diseases diseases respiratory	treatment, leisure, dermato- cosmetic industry	balneoclimatic resort
4.	**Beiuș**	46°66′67″ 22°35′76″	418	80	46	bicarbonated sulfated	not analyzed	heating, leisure dermato-cosmetic industry	tourist resort
5.	**Chișlaz**	47°16′38″ 22°14′05″	114	70	20	chloride bicarbonated sodium	rheumatism degenerative non-articular rheumatism affection posttraumatic pathologies neurologic peripheral	leisure	tourist town
6.	**Livada de Bihor**	47°00′99″ 21°80′86″	196	92	22	bicarbonated calcic chloride	not analyzed	leisure, agriculture heating	tourist town

7.	**Mădăras**	46°82′88″ 21°67′73″	92	62	21	bicarbonated chlorosodic hypotonic	rheumatism chronic degenerative non-articular rheumatism post-traumatic states disorders neurologic peripheral	leisure	tourist resort
8.	**Marghita**	47°20′30″ 22°19′50″	131	62 70	10 5	bicarbonated chloride hypotonic	rheumatism chronic degenerative non-articular rheumatism post-traumatic sequelae conditions gynecological chronic	treatment, leisure heating	tourist resort
9.	**Oradea** (the historic center and the Crișul Repede River)	47°04′20″ 21°55′16″	142	70-105	140	bicarbonated chlorinated sulfated	not analyzed	leisure, heating	tourist and balneoclimatic resort
10.	**Săcueni**	47°21′19″ 22° 4′ 60″	130	65	7-35	bicarbonated ferruginous sodium hypotonic	not analyzed	heating leisure	tourist resort
11.	**Sarcău**	47°21′08″ 22°15′27″	200	43	1,5	brominated ferruginous iodized, sodium chloride hypotonic	rheumatism chronic degenerative non-articular rheumatism post-traumatic sequelae disorders circulatory vein disease gynecological	treatment leisure	tourist town
12.	**Sânnicolau de Munte**	47°30′03″ 22°13′85″	132	70	4-5	bicarbonated calcic, sodium chloride	rheumatism chronic degenerative non-articular rheumatism post-traumatic sequelae	leisure	tourist town
13.	**Sânmartin**	46°59′02″ 21°58′35″	148			oligometallic bicarbonated calcic, sodium	not analyzed	leisure	tourist town
14.	**Ștei**	46°32′24″ 22°28′12″	275	50	5,8	ferruginous fluoride sulfated	rheumatic disease neurologic disease trauma	treatment leisure	tourist resort
15.	**Tămășeu**	47°12′09″ 21°54′20″	100	78-116	3	bicarbonated chlorosodic hypotonic	rheumatism chronic degenerative non-articular rheumatism post- traumatic states disorders neurologic peripheral	leisure	tourist town
16.	**Tinca**	46°77′59″ 21°92′36″	131	26	3,4	bicarbonated chloride hypotonic	rheumatism chronic degenerative non-articular rheumatism post- traumatic sequelae conditions gynecological chronic	treatment leisure	balneoclimatic resort

Within the perimeter of Bihor County, there are 16 locations (balneoclimatic and tourist resorts and balneary localities) that exploit the hydromineral resource mainly for recreational and treatment purposes. The existence of treatment facilities is quite low. Only six localities have a balneary treatment facility, others are found within the balneology departments of some hospitals (Marghita, Ștei).

The alternative exploitation of the hydromineral balneary resource is used for district heating, in vegetable farming, in fish farming and the dermato-cosmetic industry.

The Băile Felix - Băile 1 Mai system represents one of the most significant permanent balneary balneary tourist destinations in Romania. Before 1990, 21 wells were in operation (Vasilescu and Nechiti 1964, Flamaropol 1975), while another eight wells were drilled more recently, after 2002 (Ţenu, 2015).

The exploitation of the thermal aquifer in the Băile Felix - Băile 1 Mai area is carried out through the 13 wells authorized by the National Agency for Mineral Resources, but also through illegal drillings whose number and characteristics are unknown.

Băile Felix is the balneoclimatic resort of national interest belonging to the Sânmartin commune, located 10 km from Oradea, at an altitude of 155 m. It is the largest balneoclimatic resort with permanent regime in Romania. It was documented in 1221 under the name Băile Sânmartin. Monk Felix from the Sânmartin monastery contributed to their development and modernization between 1711 and 1722. During this period, the first sites organized for treatment appeared under the name Baia lui Felix. The first certification of the resort dates back to 1763 and contains notes regarding the construction of a swimming bath. In 1771 the wooden bath was transformed into a stone bath. The first building was built between 1766 and 1772 (Cohut and Paal, 2019).

In 1885, a new thermal spring (Balint) was drilled, with a temperature of 49°C and a flow rate of 17,000 liters of water/day. This was the first anthropogenic intervention on the thermal water deposit at Băile Felix - Băile 1 Mai, following the Izbuc well (1886) at Băile 1 Mai. In 1857, a treatment fee was introduced for people staying more than four days. This is the starting point for balneary tourism, even if the most spectacular developments did not begin until 100 years later. Between 1965 and 1975, eight wells were dug and put into operation, so that the total possible flow rate through the wells was 260 l/s (between 1978 and 1982). This allowed the resort to reach a capacity of over 6,000 places in hotels, villas, guesthouses, private apartments (with the associated treatment facilities) (Cohut and Paal, 2019).

Currently, the Băile Felix resort is home to the only five-star thermal complex in Romania, inaugurated in 2015, with a capacity of 180 rooms and apartments, state-of-the-art therapy and SPA services, event halls, and an aquapark (Figure 91).



Figure 91. Lotus Therm Resort in Băile Felix.

The resort's accommodation infrastructure consists of hotels, guesthouses, villas, rooms and apartments for rent, as well as campsites (Table 54).

Table 54. The structure of accommodation units in Băile Felix.

Accommodation facilities	Star rating	**Number of accommodation units**	**Number of accommodation places**
Hotels	5 stars	1	262
	4 stars	5	1002
	3 stars	11	1990
	2 stars	3	1218
Guesthouses	2-3 daisies	119	2323
Rooms and apartments for rent	-	86	903
Camping	-	4	110
Total		**229**	**7808**

(source: www.turism.gov.ro).

In the Băile Felix balneoclimatic resort, there are 11 treatment facilities, nine of which are located within the hotels, and the two most important balneary treatment facilities are located in the two medical recovery hospitals, namely *the Băile Felix Clinical Medical Recovery Hospital* and *the Auxologico Hospital* inaugurated in 2021 (Figure 92). Both hospitals have complex and modern treatment facilities, offering multiple solutions for patients with different conditions.

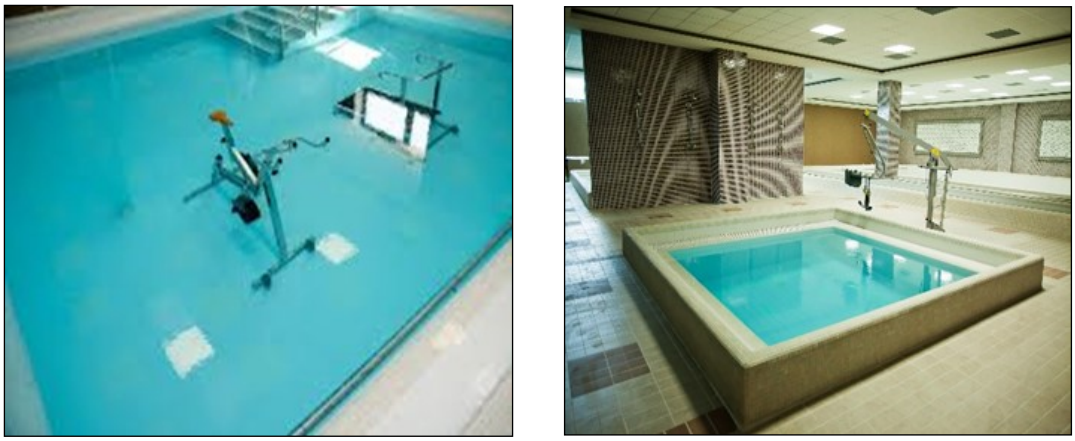


Figure 92. Auxologico Medical Recovery Hospital in Băile Felix.

Both recovery hospitals in Băile Felix offer treatment options for patients both on an outpatient basis and in continuous hospitalization, with specialized human resources and complex and modern treatment infrastructure (Table 55).

Table 55. Infrastructure of the treatment bases in Băile Felix.

Infrastructure / Resort with therapeutic bases	doctor's office	physiotherapy office	psychology office/ speech	robotic therapy office	virtual reality therapy room	electrotherapy room	thermotherapy room	massage parlor	occupational therapy office	thermal water bath	hydrotherapy	aerosols/saline	clinical laboratory	radiology
Clinical Hospital for Medical Recovery	*	*	*	*	*	*	*	*	*	*	*	*	*	
Auxologico Hospital	*	*		*		*	*	*		*	*			*
Hotel Termal	*	*				*	*	*		*	*			
Hotel President	*	*				*	*	*		*	*			
Hotel Poienita	*	*				*	*	*		*	*			
Hotel Padis	*	*				*	*	*		*	*			
Hotel Mureș	*	*				*	*	*		*	*	*		
Hotel Muncel	*	*				*	*	*		*	*			
Hotel Lotus Therm	*	*				*	*	*		*	*	*		
Hotel Internațional	*	*				*	*	*		*	*	*		
Hotel Crișana	*	*				*	*	*		*	*			

Note: * - represents the equipment of the treatment bases

The infrastructure of the treatment centers in Băile Felix is complex and includes medical offices, physiotherapy, electrotherapy, therapeutic massage, swimming bath, hydrotherapy regăstie offices in each treatment center. In addition to these, of great importance are the robotic therapy and virtual reality offices in the two medical recovery hospitals, providing state-of-the-art therapy possibilities.

In 2022, the most extensive rehabilitation and modernization project of the past 30 years was completed in the Băile Felix resort, under the initiative *„The Lotus of Romanian Tourism"*, funded by European Union grants. The project included the modernization of road and IT infrastructure, the construction of sidewalks, a 150-space parking lot, green areas, and a bicycle path (Figure 93).



Figure 93. Road and pedestrian infrastructure in Băile Felix (2023).

The tourist destination Băile Felix - Băile 1 Mai offers multiple leisure opportunities: baths and relaxation in swimming baths and thermal baths, fun in aquaparks, field trips in the forest near the resort, horse riding in the nearby town (Hidișelul de Jos), paragliding on Dealul Șomleu (Bronfort et al., 2021), other cultural and entertainment events in clubs, restaurants and terraces, aquazumba and foam parties in swimming baths, outdoor concerts (Felix Folk Festival, Enjoy Music Băile Felix International Festival, Wave Festival Băile 1 Mai, Thermal Days Festival, at Băile Felix). In essence, it is a modern destination with a complex offer of cultural, artistic and entertainment activities.

Băile 1 Mai is a local balneary resort belonging to the Sânmartin commune, located in a forest of ancient oak trees, 2 km from Băile Felix and 8 km from the city of Oradea, at an altitude of 140 m.

Over time, Băile 1 Mai has had several names (Băile Sfântului Ladislau, Băile Haieului and then Băile Episcopești), and since 1374 it has been owned by the Roman Catholic Diocese of Oradea, which built the facilities necessary for the operation of a resort. The first treatments were carried out by applying mud from the bed of the Peța stream. The knowledge of the geothermal deposit began with the digging of the Balint and Izbuc boreholes, in 1885 - 1886 (Orășeanu, 2020). The first treatment facilities were built between 1950-1960. Since 1978, the resort has been continuously developing by expanding the accommodation infrastructure through the construction of villas, guesthouses and hotels.

In Băile 1 Mai there is the oldest thermal water wave bath in Romania. The Venus bath is the largest thermal bath in the resort (4.3 hectares) which, after a long period of rehabilitation, was transformed into a modern aquapark, reopened in 2023.

In the Băile 1 Mai area there are three treatment facilities (Table 56) with a long and renowned history, especially the Medical Recovery Hospital - the pediatric department belonging to the Medical Recovery Hospital in Băile Felix.

The treatment facility within the Perla hotel complex is a modern prophylaxis and treatment center, equipped with state-of-the-art equipment and offering high-quality complex procedures for various conditions.

Table 56. Baile 1 Mai. Infrastructure of the balneary treatment facilities.

Infrastructure / Resort with therapeutic bases	doctor's office	physiotherapy office	psychology office/speech	electrotherapy room	thermotherapy room	massage parlor	occupational therapy office	virtual reality cabinet	robotic therapy office	thermal water bath	hydrotherapy rooms	aerosols/saline	clinical laboratory
Hotel Ceres	*	*		*	*	*				*	*	*	
Hotel Perlal	*	*		*	*	*				*	*	*	
Clinical Hospital for Medical Recovery - pediatric department	*	*	*	*	*	*	*	*	*	*	*	*	*

Note * - represents the equipment of the treatment bases

In 2023, the resort's rehabilitation project was completed, with financing from European funds, by modernizing the road infrastructure, creating a bicycle path, sidewalks and green spaces, as well as providing urban furniture.

Oradea is a tourist resort (since 2020) and balneoclimatic resort (since 2022), the county seat, located in the central-western part of Bihor County, in the North-West Development Region, between the hills that separate the Crișuri Plain from the hilly ends of the Apuseni Mountains, on the banks of the Crișul Repede River. Access to the city of Oradea is achieved both by road, rail and air.

The development trend of the city of Oradea after 1990 is influenced by several factors. The European level focuses mainly after the start of the European integration process of Romania, especially from a legislative point of view and development policies and strategies, influencing the national, regional and local levels, but also from the point of view of free movement, freedom of initiative or foreign investments (Chiriac and Bucur, 2015).

It is among the localities with geothermal water resources, exploited in leisure and as a thermal agent for heating for over 50 years.

The exploitation of geothermal water for recreational purposes is carried out within the Nymphaea Aquapark, inaugurated in 2016. There is an ongoing project for the construction of the Ioșia Thermal Garden, located on part of the site of the current Ioșia thermal bath (www.oradea.ro).

Today Oradea is an attractive and modern tourist city, which represents one of the most beautiful urban destinations in Romania. In 2022, it was designated the most beautiful Art Nouveau destination in Europe (www.urban.ro).

Băile Tinca is a permanent balneoclimatic resort of local interest, located in the Crișuri Plain, in the southern part of Bihor County, in the homonymous locality, 40 km from Oradea, at an altitude of 130 m.

The history of the baths begins in 1884 when the first buildings and baths appeared. Currently, it has a treatment center, hotel accommodation, restaurant and cafeteria with 140 seats, terrace, natural park, outdoor bath, parking spaces (Figure 94).



Figure 94. Treatment, accommodation and restaurant infrastructure at Băile Tinca.

The treatment base is recognized both locally and nationally. It offers medical assistance and complex balneal treatment. Within the resort there are thermal water baths, with therapeutic indications for crenotherapy.

Beiuș is a locality that valorization on the thermal resource and is located in the southern part of the county, in the homonymous depression. It was certified as a tourist resort of local interest in December 2020 (H.G. no. 1073, 2020). The area has natural healing factors, such as geothermal water and bioclimate that increase the effectiveness of balneal therapy. The main natural therapeutic factor is geothermal water exploited from a depth of 2500 - 3000 meters with a temperature of 70 - 84°C (Orășeanu, 2016).

Thermal water is utilized for recreational purposes at the Laguna thermal complex, which was established in 2006 (Figure 95).



Figure 95. The Laguna thermal complex in Beiuș.

Another way to capitalize on the active principle of thermal water is in the natural cosmetics industry, made through innovative pharma-type technology and manufacturing, established in 2018 (www.beiuscosmetics.ro).

Beius is powered by centrally produced thermal energy, designating it the only city in the country where the thermal agent is made exclusively based on geothermal water, this fact giving it the name of the Green City.

Marghita is a balneoclimatic locality in the northern part of Bihor County, located approximately 60 km from Oradea, at an altitude of 130 m, on the right bank of the Barcău River. The municipality of Marghita is located in a hilly area with rich oil deposits, but also geothermal water that was and is used for therapeutic, recreational and thermal purposes.

The first documentary attestation of Marghita dates back to 1216 in the document called the Oradea Register. In the 14th century, it became the center of a Hungarian feudal estate, being documented in 1332 under the name Margitfalva. In 1376, it received from the Hungarian king Louis

the Great the privilege of organizing weekly fairs, thus becoming a polarizing center for the inhabitants of the neighboring territories, first commercially, and then administratively and socio-culturally. Marghita was declared a city in 1967, being the second economic power of Bihor County after Oradea Municipality and starting from 2003 it was raised to the rank of municipality. It has been certified as a tourist resort of local interest since 2008.

The utilization of geothermal water for recreational purposes is found at Hotel-Strand, and the utilization for therapeutic purposes is done within the Municipal Hospital in the balneology department.

Aleșd is an urban locality that has geothermal resources. It is located in the eastern part of Bihor County, 38 kilometers east of Oradea, in the Crisului Repede Valley.

In Aleșd, geothermal water is exploited, drilled in 1979 - 1980, at a depth of 1575 m, and there is a single borehole that supplies the swimming bath and the day center for the elderly. The thermal bath in the locality was established in 1991 and is public property, with a total area of 4632 m2 (Figure 96). Cultural, tourist and entertainment events are organized in the bath. For balneary treatment purposes, the thermal water is used at the Day Center for the Elderly, which has a very small and modest balneary treatment bases (Figure 97).



Figure 96. The thermal bath in Aleşd.

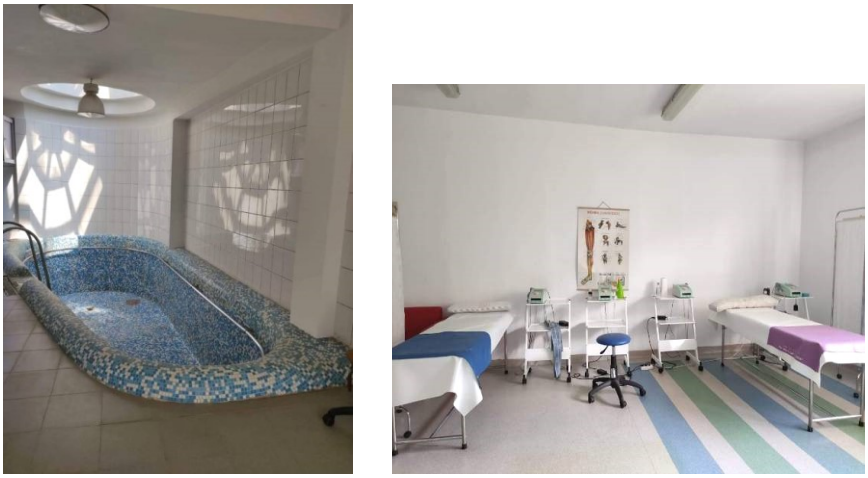


Figure 97. The treatment base at the Day Center for the Elderly in Aleşd.

Săcueni is a tourist resort with a balneary function located in the north of Bihor County, on the Ier River, 40 km from Oradea (on the European road E671). Documents show that it has been attested since 1214 and in the Middle Ages it was a prosperous city, recently regaining this status. The town was declared a city in 2004. In 2021 it was certified as a tourist resort of local interest.

The first time in 1980 was thermal water intercepted at a depth of 1226 - 1446 m in the upper Pannonian layer. The use of thermal water in the area of the city of Săcueni is for recreational purposes and in district heating for heating. The use of geothermal water for recreational purposes is done at the Săcueni thermal bath (Figure 98). It has been operating since the 1980s, was modernized in 2024 and is located in a park with centuries-old trees and has continuous activity throughout the year.



Figure 98. The thermal bath in Săcueni.

Sarcău is a rural locality in the Sârbi commune. It is located in the northeastern part of the county, 36 km from Oradea. The thermal water near the locality is exploited in the Adorianis complex

with a modern balneary tourist infrastructure. It consists of a modern accommodation base (two three-star guesthouses and a villa), a balneary treatment base that provides complex medical assistance and treatment, as well as a modern leisure base.

Sânnicolau de Munte is a rural locality with a balneary resource exploited for leisure purposes, which belongs to the city of Săcueni, at an altitude of 218 m. The thermal bath in Sânnicolau de Munte was inaugurated on May 1, 1971, being built by members of the cooperative. In addition to the old thermal bath (Figure 99), which has been operating for over 50 years, in 2022, a modern thermal bath was inaugurated (Figure 100).



Figure 99. The old thermal bath in Sânnicolau de Munte

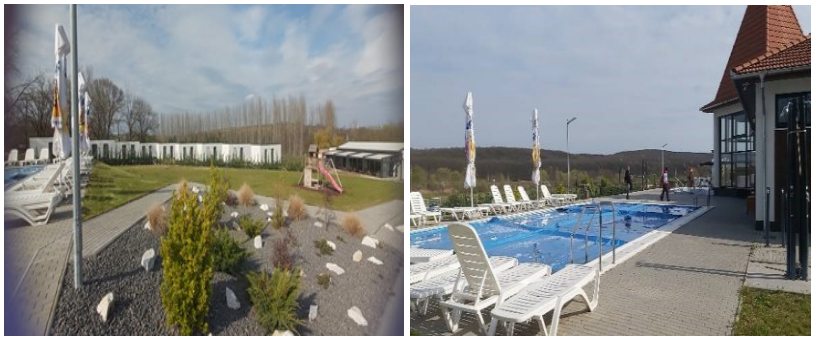


Figure 100. The new thermal bath in Sânnicolau de Munte.

Livada de Bihor is a rural locality with a balneary resource belonging to the Nojorid commune located in the western part of Bihor County. Since 1980, it has benefited from geothermal water, which is used as a thermal agent for heating in institutions and homes, and since 1985 it has served the largest station for raising fish fry in thermal water in Europe. In 1982, the thermal bath was built, which operated until 2007, then from the same year, the geothermal water served the tomato greenhouses in the locality. The bath reopened in 2020 (Figure 101).



Figure 101. The thermal bath in Livada de Bihor.

Mădăras is a rural locality with a well-developed thermal resource located in the southwest of Bihor County, 37 km from Oradea and 5 km from Salonta. As an administrative organization, it was established in 1968, and was certified as a tourist resort of local interest in 2020 (H.G. 1073/2020). Although the therapeutic effects of thermal water were known since 1980, they were only certified in 2014 by the National Institute of Physical Medical Rehabilitation and Balneoclimatology, Bucharest. The thermal water is utilized at the Madăras thermal bath, which has been operational since 1975 and is the main tourist attraction of the commune (Figure 102).



Figure 102. Thermal bath in Mădăras.

Tămășeu is a rural locality with hydrothermal resources exploited for recreational purposes. It is located in the west of Bihor County, 20 km from Oradea and 20 km from Săcueni. The first written mention of the village of Tămășeu dates back to 1291 in the registers of the Oradea Episcopate regarding the tithe. The geothermal water is exploited in the local thermal bath, which has been operating since the 1970s (Figure 103).



Figure 103. Thermal bath in Tămășeu.

Chișlaz is a rural locality with a exploited balneary resource in Bihor County, located in the contact part of the Barcăului Plain with the Barcăului Hills, on the Barcău River. The exploitation of thermal water for recreational purposes is done at the local thermal bath, established in the 1970s, which represents the only tourist attraction of the village (Figure 104).



Figure 104. Thermal bath in Chișlaz.

Sântandrei is a commune located in the western part of Bihor County, 7 km from the city of Oradea, which has been exploiting thermal water for fish farming since 1993 when drilling was carried out. The physical properties and chemical effects of thermomineral water therapy can play an important role in the treatment of rheumatic diseases. The most important physical characteristics of mineral water are: density, buoyancy, specific gravity, viscosity, hydrostatic pressure, temperature and dissolved substances in water (Bengtsson et al., 1996).

All of these aforementioned properties have made balneotherapy an increasingly popular form of treatment with multiple effects on the neuro-immuno-endocrine system (Roos et al., 2003; Gill et al., 2012).

It is worth noting that the therapeutic effects of natural mineral waters depend on their chemical compositions, being able to produce analgesic, anti-inflammatory and antioxidant effects, cartilage protection and immunosuppression (Silva et al., 2020, 2023).

Mineral-rich water used in balneotherapy often contains bicarbonate, calcium and magnesium ions, which are believed to have analgesic, anti-inflammatory and antioxidant effects. The therapeutic indications of the thermomineral waters from the balneary resorts and localities in Bihor County are presented in Table 57.

Table 57. Therapeutic indications of thermomineral waters from balnery resorts and tourist localities of Bihor County.

Therapeutic indications of thermomineral waters	**Localities in Bihor County with thermomineral resources**										
	Băile Felix	**Băile 1 Mai**	**Băile Tinca**	**Sarcău**	**Marghita**	**Mădăras**	**Sântimreu**	**Tămășeu**	**Sânnicolau de Munte**	**Beiuș**	**Ștei**
degenerative rheumatic diseases	*	*	*	*	*	*		*	*	*	*
inflammatory rheumatic diseases	*	*	*	*				*			
non-articular rheumatic diseases	*	*	*	*	*	*		*	*	*	*
disorders of the musculoskeletal system	*	*	*	*	*	*		*	*	*	*
neurological disorders	*	*	*		*			*			*
neuromuscular disorders	*	*									
conditions associated with metabolic disease	*	*									
chronic gynecological conditions	*	*	*	*	*						
digestive tract diseases			*				*	*			
infertility			*								
affect hepatobiliary			*				*	*			
respiratory tract diseases	*	*	*								
scars, irritations and skin inflammations	*									*	
cardiovascular diseases (external cure)			*				*		*		

Note: * - therapeutic indications of water from existing locations

The therapeutic indications of the thermal waters in Bihor County mainly target degenerative rheumatic, inflammatory, neuromuscular abarticular diseases as well as post-traumatic sequelae of the locomotor system.

In the case of neuromuscular diseases, the thermal water of Băile Felix, from Băile 1 Mai, Băile Tinca, Marghita, Tămășeu and Ștei is indicated. Particular cases are at Băile Felix and Băile 1 Mai where the therapeutic indications of the waters target neuromuscular pathologies, pathologies associated with metabolic diseases and only at Băile 1 Mai are functional orthopedic diseases in pediatrics treated. The thermal waters of Băile Felix and Beiuș have also proven to be effective in skin diseases (scars, irritations and inflammations).

The mineral waters of Tinca and Sântimreu, in addition to the therapeutic effect of cardiovascular diseases through external treatment, present therapeutic indications researched in digestive tract diseases and hepatobiliary diseases through internal treatment (crenotherapy).

The effectiveness of balneotherapy in improving symptoms in different pathologies is influenced by the association with different physical and electro-thermotherapeutic procedures presented below. The procedures of balneal treatment in the treatment bases are recommended by the doctor depending on the type of disease and associated pathologies (Table 58).

Table 58. Therapeutic procedures performed in treatment facilities in the studied locations.

Localities / Therapeutic procedures	Băile Felix	Băile 1 Mai	Băile Tinca	Marghita	Sarcău	Ștei	Aleșd
balneotherapy	*	*	*	*	*	*	*
physio therapy	*	*	*	*	*	*	*
hydrokinetotherapy	*	*		*	*	*	
therapeutic massage	*	*	*	*	*	*	*
ultrasonic	*	*	*	*	*	*	*
laser	*	*	*		*	*	
microwave	*	*					
magnetodiaflux	*	*	*	*	*	*	
paraffin wraps	*	*	*		*	*	
galvanic baths	*	*	*	*		*	
ionization	*	*		*		*	
venolymphatic drainage	*	*	*	*	*		
tense	*	*	*	*		*	
travertine	*	*	*			*	
sheath	*	*	*	*			
mineralized mud wraps	*	*	*				
shockwave therapy	*			*	*	*	
aerosol	*	*	*	*			
occupational therapy and ergotherapy	*	*	*				*
salinity	*	*	*				
oxygen	*						
multisensory stimulation therapy	*	*					
robotic therapy	*	*					
virtual reality therapy	*	*					
magnetic stimulation	*						
speech	*	*					
psychotherapy	*	*					
botulinum toxin therapy	*						

For a good approach to balneary treatment, it is important that the tourist/patient benefits from accommodation and meal options at the treatment bases location. The tourist accommodation infrastructure in locations that capitalize on the hydrothermal balneary resource for treatment and recreation purposes is presented in Table 59.

Table 59. Tourist infrastructure of balneary localities.

Types of accommodation structures in locations that capitalization resource hydrothermal in Bihor County														
Nr. crt.	**Locality with capitalization balneary resource**	**Camping**	**Wooden house, bungalow, house furniture**	**Room, apartment**	**Tourist guesthouse 2****	**Tourist guesthouse 3*****	**Hostel**	**Motel**	**Villa**	**Hotel 2****	**Hotel 3*****	**Hotel 4******	**Hotel 5 *******	**Total places**
			Number of seats											
	Aleșd	0	0	0	0	0	0	0	0	0	0	0	0	0
	Băile 1 Mai	0	0	327	0	1157	0	0	118	0	508	112	0	2222
	Băile Felix	24	56	951	18	921	0	0	508	1336	1555	890	262	6521
	Băile Tinca	0	0	0	0	0	0	0	0	0	70	0	0	70
	Beiuș	0	0	45	0	0	16	24	44	0	44	0	0	173
	Chișlaz	50	43	0	0	0	0	0	0	0	0	0	0	93
	Livada de Bihor	12	8	0	0	0	0	0	0	0	0	0	0	20
	Mădăras	100	0	33	0	0	0	0	0	0	0	0	0	133
	Marghita	114	100	0	0	0	0	0	0	96	0	0	0	310
	Săcueni	120	40	0	0	409	0	0	0	0	0	0	0	569
	Sânnicolau de Munte	8	98	0	0	0	0	0	0	0	12	0	0	118
	Sarcău	0	0	0	0	48	0	0	24	0	0	0	0	72
	Ștei	0	0	70	0	0	0	0	0	0	0	0	0	70
	Tămășeu	50	0	0	0	0	0	0	0	0	0	0	0	50
	Total	**478**	**345**	**1426**	**18**	**2535**	**16**	**24**	**694**	**1432**	**2189**	**1002**	**262**	**10421**

In locations renowned for balneary treatment, the accommodation infrastructure is well developed. Băile Felix has the largest number of accommodation facilities in Bihor County and in Romania. Among rural localities, except Băile Tinca, Sarcău is the only one that has treatment and tourism infrastructure.

The tourist catering infrastructure in locations that capitalize on the hydrothermal resource is represented by restaurants (10,848 seats), terraces (2,458 seats), snack bars, pizzerias and fast food (2,376 seats) (Table 60). The largest number of seats is found in Băile Felix (over 9,000). Of course, the fewest catering facilities are located in locations in rural areas. Some of these locations do not have a restaurant (Chișlaz and Aleșd), here you can only find fast food or snack bars. While other locations in the rural area have modern restaurants and terraces (Beiuș, Ștei, Marghita, Sânnicolau de Munte, Tămășeu, Săcueni).

Table 60. Public catering infrastructure in locations that capitalize on the hydrothermal resource.

Nr.crt.	Location with valorized balneary resource	Tourist reception structures with public catering function			
		Restaurant	Terrace	Fast food pizzerias	Total
		Number of seats			
	Aleșd	0	50	50	100
	Băile 1 Mai	1125	328	518	1971
	Băile Felix	6716	1180	1239	9135
	Beiuș	360	300	158	818
	Chișlaz	0	20	30	50
	Livada de Bihor	50	60	10	225
	Mădăras	264	10	160	434
	Marghita	1423	50	36	1509
	Săcueni	200	50	0	400
	Sarcău	60	50	0	110
	Sânnicolau de Munte	150	180	0	330
	Ștei	70	30	20	120
	Tămășeu	100	50	0	150
	Tinca	280	50	0	330
	Total	**10848**	**2458**	**2376**	**15682**

Leisure is an important component of an attractive tourist offer, which constitutes a fundamental element in satisfying the needs of tourists, regardless of the holiday motivation or the form of tourism practiced, regardless of the age or socio-professional profile of tourists. The diversity and originality of the leisure offer can be decisive elements in attracting tourist flows. The main dimension of the leisure concept is entertainment, well-being, and any tourist activity or concern capable of disconnecting the tourist falls within the scope of this side of tourism.

Leisure facilities are an integral part of the tourist infrastructure, which is an indispensable pillar of general economic and tourist development (Mandić et al., 2018).

The existence of leisure facilities as well as their diversification and development contribute to increasing tourist attractiveness with an important role in increasing the economic efficiency of local tourism. The recreational infrastructure in rural locations that capitalize on the hydromineral resource consists of, in addition to the thermal water pool, sports fields and modest playgrounds (Figure 105).



Figure 105. The playground in the Chişlaz thermal bath.

In the famous resorts of Bihor County (Băile Felix, Băile 1 Mai and Oradea) the leisure infrastructure includes complex water parks.

The wellness and spa sector is found in two locations in the rural area in Sarcău and Sânnicolau de Munte. Although the leisure facilities in the thermal baths in the rural area are modest, cultural, artistic and thematic events (foam parties, children's camps) are organized in almost every location. Other leisure objectives nearby are wineries. Local wine tastings are organized at the thermal bath in Sânnicolau de Munte (Table 61).

In Bihor County, the long tradition of vaorification of geothermal waters for tourism and balneology (Băile Felix, Băile 1 Mai and Băile Tinca) has proven obvious characteristics of sustainability.

Table 61. Recreational infrastructure in locations that capitalize on the hydro-mineral resource in Bihor County.

Nr. crt	**Location with valorized balneary resource**	**Swimming pool with thermal mineral water/ valves**	**Cold water pool**	**Wave pool**	**Waterpark**	**Wellness and spa**	**Playground**	**Sports field**	**Cycling track**	**Wineries**	**stud**	**Cultural and artistic events**
	Aleșd	*	*				*					
	Băile 1 Mai	*	*	*	*	*	*	*	*		*	*
	Băile Felix	*	*		*	*	*		*		*	*
	Băile Tinca	*	*				*					
	Beiuș	*	*			*	*	*				*
	Chișlaz	*	*				*					*
	Livada de Bihor	*					*	*				*
	Mădăras	*	*									
	Marghita	*				*	*			*		*
	Oradea	*	*		*		*		*			*
	Săcueni	*					*	*		*	*	*
	Sânnnnicolau de Munte	*				*	*			*		*
	Sarcău	*	*			*		*				
	Ștei	*	*				*	*				
	Tămășeu	*										*

7.3. Localities with immediate potential for the utilization of balneary resources

The development trends of balneotherapy and balneoclimatic tourism in several localities of Bihor County, supported by the association of balneal resources, with their natural, anthropogenic and socio-cultural potential, in the case of systematic and organized valorization, could contribute to the sustainable development of the local „balnear phenomenon".

In order to assess whether this resource has sufficient potential for the sustainable development of balneology in Bihor County, it was necessary, first of all, to know the origin of these waters and to understand to what extent they have sustainable volume and favorable physico-chemical characteristics for balneal treatment.

The research results indicated that 15 localities have immediate potential for the balneal exploitation of hydromineral resources for water heating, of the type of water (Table 62).

Regarding the identification of the prospects for sustainable development of balneology and seaside tourism in Bihor County, the main characteristic is the similarity of geothermal water dependent on the connection between aquifers, regardless of their age. The profitability of geothermal water exploitation would be sustainable in any form in which it will be exploited because the source is difficult to exhaust, and the physical and chemical characteristics are quite constant. The use for heating is well known, and the great advantage is given by the low cost per gigacalorie. The exploitation for the purpose of the agreement and for the purpose of balneal treatment involves the arrangement and maintenance of swimming pools and the development of a specific infrastructure by creating stable jobs and, consciously, increasing the local budget by paying taxes. Thus, the quality of local life could increase, especially in rural areas.

Of great importance for sustainable development could be informing medical specialists about the benefits of each therapeutic characteristic of geothermal water, according to the indications established by the National Institute of Recovery, Physical Medicine and Balneology (the specific structure for approving organized treatment in Romania), regardless of whether the location is included in the national balneological circuit or not. This institute should make therapeutic recommendations for geothermal water, by analyzing the physical-chemical indicators, for the benefit of the public or private administrative entities that have custody of the geothermal source.

The advantages could be even greater for the population, if agreements were signed between existing or newly formed balneary resorts and the National Pension House, respectively the National

Health Insurance House (in Romania) that would grant beneficiaries social insurance, rights and access facilities to prophylactic, therapeutic and recovery balneary treatments, by allocating subsidies or free vouchers for balneary treatment. This measure could be extremely beneficial for the development of locations with local balneary potential and their inclusion in the national balneary-tourism circuit.

Table 62. Localities that have wells with immediate potential for balneary capitalize of hydromineral resources.

Nr. crt.	Locality with hidromineral resources	Territorial administrative unit	Altitude (m)	Temperature (°C)	Flow (l/s)	Water type	Current capitalization	Valorization projects	Pathologies that could be improved (depending on the type of water)
1.	Balc	Balc	166	46	5,5	brominate iodinate chloride sodium hypotonic	balneary reserve fund	Yes (www.comunabalc.ro)	chronic degenerative rheumatism post-traumatic sequelae non-articular rheumatism
2.	Borș	Borș	103	107	30	chlorinate sodium bicarbonate hypotonic	heating agent balneary reserve fund	Yes (www.primăriabors.ro)	chronic degenerative rheumatism non-articular rheumatism post-traumatic sequelae peripheral neurological disorders
3.	Ceica	Ceica	153	19,6	0,19	bicarbonatecarbonatewater iodide oligomineral	balneary reserve fund	not	chronic degenerative rheumatism non-articular rheumatism post-traumatic sequelae chronic gynecological conditions peripheral neurological disorders
4.	Cherechiu	Cherechiu	104	90	20	oligomineral sulfate bicarbonate sodium chlorinate	balneary reserve fund	Yes (www.cherechiu.ro)	chronic degenerative rheumatism non-articular rheumatism post-traumatic sequelae peripheral neurological disorders
5.	Cheșereu	Cherechiu	106	88	5-6	bicarbonate of sodium chlorinate sodium hypotonic	balneary reserve fund	not	chronic degenerative rheumatism non-articular rheumatism post-traumatic sequelae peripheral neurological disorders
6.	Ciocaia	Săcueni	104	72	34	hypotonic sodium bicarbonate ferruginous	balneary reserve fund	not	chronic degenerative rheumatism non-articular rheumatism post-traumatic sequelae neurological conditions gynecological conditions
7.	Ghiorac (Cighid)	Ciumeghiu	93	70	4-5	not analyzed	heating agent	not	not yet analyzed

8.	Mihai Bravu	Roșiori	104	67-98	4,5	oligomineral	balneary reserve fund	not	chronic degenerative rheumatism non-articular rheumatism
9.	Răbăgani	Răbăgani	158	24	12	iodizebrominate oligomineral	balneary reserve fund	not	chronic degenerative rheumatism non-articular rheumatism post-traumatic states
10.	Roșiori	Roșiori	110	60	4,5	oligomineral	balneary reserve fund	yes	chronic degenerative rheumatism; non-articular rheumatism; post-traumatic sequelae
11.	Salonta	Salonta	90	101	15	oligomineral	balneary reserve fund	ongoing	chronic degenerative rheumatism non-articular rheumatism post-traumatic sequelae
12.	Sântandrei	Sântandrei	107	80	40	not analyzed	pisciculture	yes (www.primăriasântandrei.ro)	not yet analyzed
13.	Sântimreu	Sălard	124	cold	8	calcic bicarbonate sodium		not	digestive tract diseases hepatobiliary disorders cardiovascular diseases
14.	Stâna de Vale	Budureasa	1102	cold	15,6	ferruginous hypotonic		not	chronic degenerative rheumatism non-articular rheumatism post-traumatic states
15.	Valea lui Mihai	Valea lui Mihai	127	40	9-10	sodium bicarbonate chloride	balneary reserve fund	not	chronic degenerative rheumatism post-traumatic disorders non-articular rheumatism

The study of locations with potential for balneal valorization provides concrete arguments in support of proving that balneal tourism based on thermal waters in Bihor County has a future and that its potential meets the conditions of sustainability. However, the transition from the finding of the existence of the potential to the higher level of organized and efficient practice of thermal water-based therapies still requires the fulfillment of certain material, legislative, medical and economic conditions.

First of all, the state, through laws and regulations, should intervene concretely to supervise the three dimensions of the sustainability of geothermal water exploitation in balneology (environmental protection, economic development and social development).

The need for state supervision of the three dimensions of the sustainability of geothermal water exploitation is justified. The most important premise for the exploitation of thermal water is that the water source is renewable, but its discharge into nature, after it has been used, must be done without endangering the sustainability of the quality of the environment, therefore, a precautionary principle must be respected first and foremost. Any ecological system has a certain capacity for resistance, and as regards the extraction of thermal waters and the development and exploitation of an infrastructure for tourist or balneological purposes, it must not diminish the system's capacity for resistance. Therefore, local or national authorities should implement a package of principles adapted both to the optimal functioning of the process of efficient use of thermal waters in tourism and balneology at the local level, as well as strict rules for preserving the system's resistance and pollution inhibition activities. Environmental costs are quite difficult to estimate in the long term, but national institutions must impose, through appropriate legislation, clear rules on the exploitation of thermal waters, because their exploitation in tourism and balneology generates both value and costs. In this way, the state ensures that it supervises the three dimensions of the sustainability of the exploitation of thermal waters in balneology and tourism at the local scale of human settlements.

Secondly, we can consider that the balneary activity based on geothermal waters could function as a system. The inputs are known, i.e. geothermal water, we also know the objective, i.e. therapeutic indications, but as for the outputs from the system, it is obvious that it is necessary to analyze the natural and socio-economic limitations regarding the sustainability of balneology.

Thirdly, the results of this study should be compared with the conclusions reached by various Romanian or international experts who analyzed the effectiveness of balneary based on geothermal waters, depending on the desire to improve the health, well-being and quality of life of the population.

Fourthly, we must analyzed the ways in which local developers, through partnerships with public or private administrations, could transform locations with geothermal potential into balneotherapy destinations integrated into both national and international tourism circuits.

It is necessary to justify the state supervision of the three dimensions of the sustainability of geothermal water exploitation in balneary locations, in order to capitalize on them. The need for projects to transform a location with geothermal potential into a balneary destination is justified.

The results of the study show that in Bihor County, 50 locations with geothermal water drillings have not yet been exploited. In Romania, geothermal water resources are considered useful mineral resources, subject to Mining Law no. 61 of March 5, 1998. Since the drillings have already been executed, but not yet exploited, it would be necessary to carry out projects to transform a location with geothermal potential into a balneary destination. Whether it is a private developer or a state-owned company, the acts of giving under administration or under concession, after the drilling has already been carried out, are mentioned in letters d-h of art. 6 of the Implementing Rules to the Mining Law of 25.09.1998 (Law no. 61, 1998): a) license to have under administration for exploitation; b) exploitation concession license; c) exploitation permit; d) agreement of the National Agency for Mineral Resources regarding the association of the license holder with other legal entities, in order to carry out the mining activities provided for in the administration or concession license; e) opinion of the National Agency for Mineral Resources regarding the transfer of an exploration or exploitation concession license to another legal entity.

Based on the operating authorization, specific works can be performed: arrangement of swimming pools, construction of buildings, installation of equipment, etc.

Based on art. 11 of the Mining Law, quantitative assessments of geothermal resources, physico-chemical analyses and environmental protection measures can be established, all of which together outline the hydrogeological documentation. The balneary operation is conditioned by the establishment of the list of therapeutic indications by the National Institute of Recovery, Physical Medicine and Balneology. In the next phase of the project, which refers to the transformation of a location with geothermal potential into a balneary destination, the technical, economic and medical conditions for the use of geothermal water for balneary treatment will be established.

Article 19 of the Law's Implementation Rules specifies that public institutions and Romanian or foreign legal entities, which express their interest in obtaining the exploitation license, may exercise their right of initiative throughout the calendar year. Article 24 shows that the exploitation license is granted to Romanian or foreign legal entities, under the terms of the law, based on an application accompanied by a feasibility study that ensures the exploitation of the reserves of useful mineral substances and the protection of the deposit, the environmental impact study (environmental balance and restoration plan), approved according to the law and accompanied by a bank guarantee for the restoration of the environment.

Following the field analysis and the studied bibliography, possible limitations to the sustainable development of the balneary function in the studied area were concluded.

Thermal waters from the Triassic aquifer in Oradea and used for heating have an unacceptable concentration of sulfate ions (Setel et al., 2010). This result suggests the need to pay attention to the risk of pollution caused by exploited geothermal waters.

The discharge of thermal waste waters into the surface discharges of the hydrographic network can cause the infiltration of pollutants, which, although it is a very slow process, can intersect the thermal aquifer at some point. The Ier River basin overlaps the area of the Săcuieni geothermal aquifer and a high proportion of chloride ions of petroleum hydrocarbons and phenolic compounds was found in the analyzed samples (Setel et al., 2010). The same study mentions that sometimes the temperature of the thermal water at the discharge, even after its use, is too high.

Another limitation that could be caused by possible sudden changes in volumetric distribution ratios between aquifers. Although geothermal water is considered to be a renewable resource, in some places even inexhaustible, reservoir modeling is particularly important. When short-term profit is sought by overexploiting large volumes, this could be followed by reduced production in the future.

The change of the administrative factor could be an impediment to the sustainable development of balneology. By selling the location with a balneal resource, where the administrative entity is private, and the purchasing administrative factor is not concerned with the maintenance or development of natural resource exploitation services, for various reasons, financial priorities or other nature. If the geothermal natural resource belongs to a public administrative entity, its sustainable development could be jeopardized by the termination of the mandate and change of the position of the person representing the entity (the mayor). This fact can negatively influence the sustainable development of the balneal resource, by channeling financial and human resources to other priorities, considered important in the life of the local community.

The results of the research conducted by Sunkar et al. (2022), on tourist attractions in the Sangkulirang-Mangkalihat karst region, promote the idea of controlling the number of tourists accessing the karst region to ensure the sustainability of geosites. In the idea that Bihor County will become a strong tourist area based on the exploitation of geothermal waters in tourism and balneotherapy, natural or biological hazards are less likely, but the risk of administrative or management errors such as the lack of modernization of the tourist and balneological infrastructure or the low quality of the services offered may arise.

Conclusions

The thesis entitled *The balneoclimatic potential of Bihor County (Romania) and its therapeutic valorization* is an interdisciplinary and transdisciplinary study in which scientific methods and instruments offered by several sciences were used, namely: Geography (through the branches of Climatology, Hydrology, Geography of tourism - respectively balneary tourism), Geology (through Hydrogeology), Balneology, Kinetology and the socio-economic component in order to provide a unitary and complex approach to the topic addressed.

To achieve this, a series of means and methods were employed to obtain a diverse database, including bibliographic resources, field investigations, geothermal water test reports, physical-chemical and microbiological analyses of cold mineral waters, climatic data, and statistical data from patient records and annual balance sheets. Additionally, questionnaires, objective and clinical patient evaluations, and legislative frameworks were utilized.

The entire scientific approach, guided by the applied methodology, enabled the systematic investigation of the balneoclimatic potential of Bihor County.

The conceptual approach highlights the notions established in the specialized literature over time within the previously mentioned scientific fields, while the methodological component is based on the analysis and identification of the instruments and courses of action necessary for the therapeutic valorization of the balneoclimatic potential of Bihor County.

The research approach followed a threefold perspective: analyzing the geographical offerings of Bihor County to outline its balneoclimatic potential; addressing the therapeutic exploitation of mineral resources; and identifying locations with immediate potential for balneotherapy development.

In outlining the balneoclimatic potential of Bihor County, a rich and diverse range of balneal resources was highlighted primarily thermal waters, mineral waters, therapeutic muds, and bioclimate mostly located within the plain area.

The analysis of the natural framework was a significant factor in defining the balneoclimatic potential, as the relief, geological structure, climatic characteristics, and hydrographic network directly influence the formation and properties of hydromineral balneal resources and the bioclimate.

Its existence and variety are due to the geographical location and complex geological structure, characterized by sedimentary formations and tectonic faults that shaped the 'chess-board structure' of the basement. This configuration plays a vital role in the formation of deep aquifers, facilitating the ascent of geothermal waters and their enrichment with dissolved minerals.

The subsoil of the county contains almost all types of thermal waters (bicarbonate, calcium-rich, sodium chloride, alkaline, ferruginous, sulfate, iodide, alkaline, hypotonic), characterized by a varied chemical composition and degree of mineralization.

The relief, vegetation, and fauna of Bihor County were analyzed based on bibliographic sources, highlighting their stratification into three major relief units: the Crișurilor Plain, part of the Western Hills, and the mountainous frame represented by the Codru Moma Mountains, the Bihor Mountains, and part of the Vlădeasa Mountains.

With regard to hydromineral resources, a total of 81 locations have been identified in Bihor County, of which 50 locations have boreholes that are currently not exploited. In 16 locations (tourist and balneoclimatic resorts and tourist localities), hydromineral resources are utilized for balneary purposes (therapeutic and recreational), as well as for alternative uses, such as heat supply for heating, the dermato-cosmetic industry, pisciculture, and vegetable cultivation. An additional 15 locations possess immediate potential for balneary valorization due to the type of water, temperature, or borehole discharge. Based on the centralization of the physico-chemical properties of thermomineral waters, a database was developed that can be continuously updated and includes the characteristics of hydromineral resources from twenty localities, regardless of whether they are currently exploited or not.

The complex and modern balneotherapeutic procedures, applied according to the specific characteristics of each resort and the facilities of the treatment bases existing in Bihor County, contribute significantly to improving human health and to the development of balneary tourism. Thus, Bihor County hosts the most important balneoclimatic resort of national interest (Băile Felix), which includes the only five-star thermal complex. In addition to the county's established balneoclimatic resorts, other balneary tourist locations have been identified both in rural areas (Sarcău, Sânnicolau de Munte, Livada de Bihor, Mădăras, Tămășeu, Chișlaz) and in small towns (Aleșd, Marghita, Săcueni, Ștei, Beiuș), which could develop into recreational balneary destinations or even therapeutic ones (Sarcău).

Climate particularities were assessed by analyzing air temperature, precipitation, relative humidity, and wind velocity. The study utilized a 60-year meteorological series (1961–2020) from regional stations, with Chișineu Criș and Vlădeasa 1800 serving as comparative references. The stations are distributed across three topographical zones: plains (Săcueni, Oradea, Chișineu Criș), hills (Borod, Holod, Ștei), and mountains (Dumbrăvița de Codru, Stâna de Vale, Vlădeasa).

Data processing revealed that the multi-annual average temperature in Bihor County was 9.5°C for the 1961–2020 period. In the lowland areas, the multi-annual thermal average is 10.7°C; in the hilly regions, it is 10.1°C, while in the mountainous areas, the multi-annual average reaches 4.4°C.

Temperature deviations highlight the non-periodic variations of temperature, and by applying the Hellmann criterion, the years in the data series were thermally characterized. The results showed that 45% of the total years fell into the category of thermally normal years, while the categories of hot and cold years each accounted for 10%, and 22% of the years were classified as cool years.

From the analysis of the particularities of the rainfall regime, it resulted that at the level of Bihor county the multiannual average of precipitation was 810.1 mm. When analyzed by relief units, the multiannual average precipitation was 576.4 mm in the plains, 704.8 mm in the hilly areas, and 1656.6 mm in the mountainous areas. Negative deviations from the multiannual average, indicating precipitation deficits, highlight drought years, such as 1961 with -318 mm, while positive deviations, reflecting precipitation surpluses above the multiannual average, correspond to particularly wet years, which occurred in six of the 60 years analyzed.

The hydrographic characterization refers to the surface water network, based on bibliographic sources, while the groundwater resources were analyzed in terms of structure, hydrochemical types, thermal characteristics, and the terrestrial mode of occurrence of balneary resources (through boreholes and springs).

The therapeutic effect of Bihor County's thermo-mineral waters through external treatment (balneotherapy) is influenced by their physicochemical properties, which grant them numerous physiological effects that trigger changes in the neuro-immuno-endocrine system. Consequently, these waters have therapeutic indications for various conditions—such as degenerative, inflammatory, and abarticular rheumatism, neurological and muscular disorders, conditions associated with metabolic diseases, and gynecological disorders—all of which are certified by the National Institute of Rehabilitation, Physical Medicine, and Balneoclimatology in Romania.

The therapeutic effect of mineral water crenotherapy on health is determined both by the chemical composition of the water and by its mode of administration, specifically the procedure through which mineral waters are used in internal therapeutic treatment via ingestion. Crenotherapy can contribute to improved outcomes by complementing the effects of primary dietary, pharmacological, and surgical therapies in the management of various conditions (digestive, hepatobiliary, metabolic, and urinary disorders).

To demonstrate the efficacy of mineral water balneotherapy in managing the symptoms and signs of osteoarthritis in patients with gonarthrosis, two patient samples were selected: an experimental group at Băile Tinca and a control group at the Fizio Help Med medical recovery clinic in Salonta.

Patient assessments included the administration of questionnaires and functional and somatometric tests. The tests used are recommended and approved by the International

Osteoarthritis Research Society. All subjects participated in 10 rehabilitation treatment sessions over a period of two weeks. The intervention consisted of electrotherapy and kinesitherapy for both groups, while the experimental group additionally received balneotherapy.

The results showed significant improvements in both groups for the visual analog scale (VAS) ($p = 0.001$), the Lequesne algofunctional index ($p = 0.001$), and the sit-to-stand test ($p = 0.001$). However, the mean improvement was greater in the experimental group compared to the control group for these parameters. The results of the walking test were significantly better in the experimental group ($p = 0.001$), whereas no improvement was observed in the control group ($p = 0.688$). The stair-climbing test, the knee osteoarthritis outcome score, and the Lysholm index did not show significant improvements in either group.

The pilot study indicates that balneotherapy, alongside traditional kinesitherapy and electrotherapy, contributes significantly to the treatment of knee osteoarthritis. The combination of these treatment modalities may represent a strong, multimodal strategy for pain relief and improvement of knee function in patients with osteoarthritis.

The bioclimatic potential was highlighted through the analysis of several bioclimatic indices relevant to balneotherapy and health tourism, such as: the effective equivalent temperature, the thermo-hygrometric index, the wind chill, and its equivalent temperature, by processing the specific variables for each index.

The bioclimatic indices were analyzed using the 60-year dataset, divided into two distinct intervals (1961–1990 and 1991–2020) to allow for a comparative evolution of the values. Based on this comparative analysis of the two 30-year periods, it was possible to establish the bioclimatic classification for both the localities currently exploiting balneal resources and those with immediate potential for development.

The bioclimatic characteristics recorded at the Săcueni meteorological station were presented in detail, as this locality is scarcely documented in the specialized literature, despite possessing significant and exploited hydromineral resources. The importance of detailing this area is further emphasized by its proximity to other localities with already exploited hydromineral resources (such as Marghita, Sânnicolau de Munte, Chișlaz, Tămășeu, or Valea lui Mihai) or with immediate balneary valorization potential (Ciocaia, Cherechiu, Cheșereu, Ciocaia, Mihai Bravu, Roșiori, Sântimreu, Valea lui Mihai).

By tracking the evolution of the bioclimatic index values analyzed for the studied meteorological stations, the significant influence of the stations' positioning across different hypsometric levels of the relief was highlighted, as well as the impact of other geographic and anthropogenic factors within their areas.

In the territorial distribution of the annual values of the effective equivalent temperature index in Bihor County, for the two analyzed periods, the trend of variation of this index was identified. Heat discomfort, with suffocating weather conditions, was observed at the Dumbrăvița de Codru and Ștei meteorological stations during the 1991–2020 period, whereas in the 1961–1990 period, the index could not be calculated at these stations due to applicability limits (the index can only be applied at air temperatures above 20°C).

From the territorial distribution of the thermohygrometric index in Bihor County, for the two analyzed periods, higher values were observed during the 1991–2020 interval compared to 1961–1990, reflecting an expansion of heat-related bioclimatic discomfort across the entire analyzed area. Thus, the comparative analysis of the two periods shows that the minimum values of the thermohygrometric index decrease from the mountainous areas toward the plains.

The spatial distribution of the annual mean values of the wind cooling index indicates the predominance of cooling-related bioclimatic discomfort throughout the year in both periods (1961–1990 and 1991–2020), as a result of the moderating effect of wind on the thermal regime, under the influence of temperate-oceanic air masses from the western regions of the country.

Regarding the territorial distribution of the multi-annual mean values of the wind chill equivalent temperature index, the bioclimatic characteristics identified in Bihor County were defined by the expansion of bioclimatic comfort regions. This expansion resulted from an increase in index values, driven by rising thermal levels.

The trend of evolution of the frequency of occurrence of extreme values of the reference bioclimatic indices, expressed by the representative percentile method, calculated for the maximum and minimum values of variation of the bioclimatic indices of interest, indicated, on the one hand, that the number of exceeding the maximum values (90p max) in the period 1991 - 2020 is increasing and, on the other hand, that the frequency of occurrence of minimum values (the number of minimum values that do not exceed the 10p min percentile) is decreasing compared to that in the previous period (1961 - 1990), this fact reflects the same process of increasing thermal values.

Since the balneary and socio-economic potential are interconnected, the administrative factor of the balneary resource was identified and a comparative analysis of the valorization of hydrothermal resources was carried out in the time intervals 1960 - 1989 and 1990 - 2023. In this way, the importance of the administrative factor in the valorization and sustainability of the local balneary resource was highlighted.

The socio-economic analysis led to the identification of several aspects. Thus: a classification of the forms of administration of balneary resources of local interest was carried out; alternative ways of capitalizing on thermal water were identified at the level of rural localities and

in the new tourist resorts in Bihor County; the risk of unsustainability of the exploitation of balneary resources in rural localities was found and a classification of localities was made according to the current stage of exposure of the balneary resource. In this context, it would be appropriate to impose a balance between the intensive capitalization of balneary resources and their long-term protection, through an integrated approach that takes into account both the potential of balneary resources and socio-economic realities, so that Bihor County can consolidate its position as a balneary tourism pole at national and international level.

The new tourist resorts are represented by several rural and urban localities that were certified as resorts in the period 2020-2022. Alongside the well-known balneary resorts (Băile Felix, Băile 1 Mai, Băile Tinca and Stâna de Vale), eight other localities with balneary resources have acquired the status of tourist resort (Salonta, Beiuș, Ștei, Marghita, Săcueni, Mădăras and Borș) and balneary resort (Oradea). With the valuable tourist resource "thermal water", the resort status facilitates access to national and European funding axes that can support local development.

The comparative analysis of the valorization of the balneary resource revealed that the development of the „balneary phenomenon", from the developments in the 1960s-1970s to the present, took place sequentially, being influenced by the political environment and the administrative factor from the pre-revolution and post-revolution periods.

In the period prior to the 1989 Revolution, all balneary sources were managed by the public administrative factor (Agricultural Production Cooperatives or People's Councils). In the post-revolution period, capitalist policies influenced both positively and negatively the development of the "balneary phenomenon" in rural settlements and newly established tourist resorts in Bihor County. Evidence of a positive influence includes the Adorianis Complex in Sarcău, featuring tourist and balneary infrastructure, the newly built thermal pool complex in Sânnicolau de Munte, and the Laguna thermal complex in Beiuș. However, unfavorable influences are also evident through the abandonment of thermal pools (in Mihai Bravu, Cadea, Ciocaia, Valea lui Mihai, and Balc) or even their demolition (in Răbăgani).

The directions for alternative valorization of balneary resources in Bihor County represent a fairly diverse range, encompassing the dermato-cosmetic industry (Beyus products in Beiuș and Synergy Therm products in Băile Felix), district heating as a thermal agent for space heating (in Oradea, Beiuș, Săcueni, Marghita, Livada de Bihor, and Ștei), vegetable cultivation (in Livada de Bihor and Toboliu), and pisciculture (in Sântandrei).

Taken as a whole, the balneoclimatic potential of Bihor County represents a rich resource that can contribute to the development of balneotherapy and balneary tourism, influencing local development, by investing in the quality of infrastructure and services, especially in rural localities, where thermal baths are the only local tourist attraction.

Bibliographic references

1. Aalto, J., Pirinen, P., Heikkinen, J. and Venäläinen, A. (2013), Spatial Interpolation of Monthly Climate Data for Finland: Comparing the Performance of Kriging and Generalized Additive Models. *Theoretical and Applied Climatology,* 112(1): 99–111.
2. Abbaspour, N., Hurrell, R. and Kelishadi, R. (2014), Review on iron and its importance for human health. *Journal of Research in Medical Sciences: The Official Journal of Isfahan University of Medical Sciences,* 19(2): 164.
3. Ahlquist, L., Kubilius, R., Rapoliene, L., Bartuseviciute, R., Balcius, A., Ramanauskas, K. and Nedzelskiene, I. (2020), The Effect of Balneotherapy and Peloid Therapy on Changes in the Functional State of Patients with Knee Joint Osteoarthritis: A Randomized, Controlled, Single-Blind Pilot Study. *International Journal of Biometeorology*, 64(6): 955–964.
4. Airinei, S. (1981), *Potentialul geotermic al subsolului Romaniei. (The Geothermal Potential of Romania's Subsoil),* Scientific and Publishing House Encyclopedic, Bucharest.
5. Airinei, S. (1987), *Geotermia cu aplicatii la teritoriul României (Geothermy with Applications in the Territory of Romania).* Scientific Ed. and Encyclopedic, Bucharest.
6. Albertini, M.C., Albertini, M., Dachà, Teodori, L. and Conti, M.E. (2007), Drinking Mineral Waters: Biochemical Effects and Health Implications - The State-of-the-Art. *International J. Environmental Health Int. J. Environmental Health*, 1: 153–169.
7. Alcoforado, M.J. (2001), Some Aspectos da Bioclimatologia: A Climate and Human Organism. *Study Center.*
8. Aleksić-Milenković, I., Stojanović, S., Stamenković, B., Jevtović-Stoimenov, T., Šarić, S. and Danković, G. (2025), The Impact of Balneotherapy on IL-6 Cytokine Levels, Disease Activity, Functional Ability, Fatigue and Depression in Patients with Rheumatoid Arthritis. *Serbian archive for the whole Medicine,* (00): 6–6.
9. Alexa-Stratulat, T., Neagu, M., Neagu, A.I., Alexa, I.D. and Ioan, B.G. (2018), Consent for Participating in Clinical Trials - Is It Really Informed? *Developing world bioethics,* 18(3): 299–306.
10. Altman, R., Asch, E., Bloch, D., Bole, G., Borenstein, D., Brandt, K., Christy, W., Cooke, T.D., Greenwald, R. and Hochberg, M. (1986), Development of Criteria for the Classification and Reporting of Osteoarthritis. Classification of Osteoarthritis of the Knee. Diagnostic and Therapeutic Criteria Committee of the American Rheumatism Association. *Arthritis and Rheumatism,* 29(8): 1039–1049.
11. Aluculesei, A.C. (2016), Innovative ways to capitalize on Romania's natural spa resources through tourism services. *Cactus Tourism Journal*, 14 (2): 55-56.
12. Andreu, M.G., Font-Barnet, A. and Roca, M.E. (2021), Wellness Tourism-New Challenges and Opportunities for Tourism in Salou. *Sustainability,* 13(15). available at https:// www.mdpi.com /2071-1050/13/15/8246
13. Aniței, L., Băican, I., Berlescu, E., Chirvasie, L., Conu, A., Degeratu, C., Dumitrescu, S., Florian, M., Samson Gheorghievici, S., Gavrilescu, M., Hoancă, V., Iaroslav, K., Luca, I., Lucescu, V., Lungu, P., Moldovan, S.Y., Mustață, E., Persache, C., Roboș, G., Rădulescu, A., Sbenghe, T., Swoboda, D., Sdic, L., Teleki, N., Teodoreanu, E. and Teveau, E. (1986), *Cura Balneoclimatică. Indicații și contraindicații (Balneoclimatic Cure. Indications and Contraindications).* Medical Publishing House, Bucharest.

14. Ardelean, I. and Barnea, M. (1972), *Elemente de bioclimatologie medicală (Elements of Bioclimatology Medical).* Medical Publishing House, Bucharest.

15. Transylvania, S.-V. and Teusdea, AF (2019), Health Tourism in Two Spa Resorts: Băile Felix (Romania) and Balaruc -Les-Bains (France). A Comparative View. *Oradea Journal of Business and Economics,* 4(special): 69–79.

16. Ardıç, F., Özgen, M., Aybek, H., Rota, S., Çubukçu, D. and Gökgöz, A. (2007), Effects of Balneotherapy on Serum IL-1, PGE2 and LTB4 Levels in Fibromyalgia Patients. *Rheumatology International,* 27(5): 441–446.

17. Ariani, A., Bedogni, G., Biasi, G., Cozzi, F., Formisano, S., Roberto, G., Guiducci, S., Maccarone, MC, Masiero, S., Montalbano, S., Muratore, M., Nacci, F., Quarta, E., Regazzo, G., Regola, F., Terribili, R., Tirri, E., Tirri, R., Vitale, M. and Manica, P. (2025), Balneotherapy in Fibromyalgia Syndrome: Protocol of " Fibrotherm, a Prospective Multi-Center, Two-Cohort Observational Study. *International Journal of Biometeorology.*

18. Asghari, M., Ghalhari, G.F., Pirposhteh, E.A. and Dehghan, S.F. (2022), Spatio -Temporal Evolution of the Thermo-Hygrometric Index (THI) during Cold Seasons: A Trend Analysis Study in Iran. *Sustainability,* 14(24): 16774.

19. Auliciems, A., De Dear, R., Fagence, M., Kalkstein, L., Kevan, S. and Szokolay, S. (1998), *Human Bioclimatology.* Springer.

20. Baburin, V.L., Tikunov, V.S., Badina, S.V. and Chereshnia, O.Y. (2018), The Assessment of Socio-Economic Potential Density of Arctic Territories in Russia. *Regional Science Inquiry,* 10(2): 37–44.

21. Badea, L. (2008), *Unităţile de relief ale României III. Dealurile Pericarpatice – Dealurile Crişanei şi Banatului. Subcarpaţii (Relief units of Romania III. The hills Pericarpathian – Hills Crisana and Banat. Subcarpathians),* Ars Docendi Publishing House, Bucharest.

22. Badea, L., Buza, M., Sandu, M., Sima, M., Micu, M. and Jurchescu, M. (2011), *Unitaţile de relief ale României. V Câmpiile Pericarpatice Câmpia Banatului şi Crişanei, Câmpia Română, Lunca Dunării, Delta Dunării şi Câmpia Litorală (Relief units of Romania. V Plains Carpathian Plain Banat and Crişanei, Câmpia Romanian, Meadow Danube, Danube Delta and Plain Litoral).* Editure Ars Docendi, Bucharest.

23. Baias, Ș, Blaga, L, Dehoorne, O, Grama, V, Gozner, M, Herman, G, Ilieș, D.C., Ilieș, A, Josan, I. and Morar, C. (2010), Băile Felix - Băile 1 Mai - Betfia (Bihor County), Map Geotourism. *Publishing House University of Oradea, Oradea.*

24. Baiulescu, George (1904), Hidroterapia medicală (Medical Hydrotherapy), Minerva Publishing House, Brașov.

25. Banc, Ș., Croitoru, A.E., David, N.A. and Scripcă, A.S. (2020), Changes Detected in Five Bioclimatic Indices in Large Romanian Cities over the Period 1961–2016. *Atmosphere,* 11(8): 819.

26. Bannuru, R.R., Osani, M.C.., Vaysbrot, EE., Arden, N.K., Bennell, K., Bierma-Zeinstra, S.M. A., Kraus, V.B., Lohmander, L.S., Abbott, J.H., Bhandari, M., Blanco, F.J, Espinosa, R., Haugen, I.K., Lin, J., Mandl, L.A., Moilanen, E., Nakamura, N., Snyder-Mackler, L., Trojian, T., Underwood, M., and McAlindon, T.E. (2019), OARSI Guidelines for the Non-Surgical Management of Knee, Hip, and Polyarticular Osteoarthritis. *Osteoarthritis and Cartilage,* 27(11): 1578–1589.

27. Barnea, M., Țicu, C. and Milea, E. (1968), *Contributie la studiul influentei maselor de aer asupra incidentei mortalitatii prin boli cardiovasculare în orasul Bucuresti (Contribution to*

the study of influence air masses on incidence mortality by diseases cardiovascular in the city Bucharest), Collection of Works of the Meteorological Institute for the year 1966.

28. Barnich, N., Rodrigues, M., Sauvanet, P., Chevarin, C., Denis, S., Le Goff, O., Faure-Imbert, D., Hanh, T., Roques, C.F., and Chassaing, B. (2021), Beneficial Effects of Natural Mineral Waters on Intestinal Inflammation and the Mucosa-Associated Microbiota. *International Journal of Molecular Sciences,* 22(9): 4336.
29. Bendea, C., Antal, C., Crăciun, M., Gavrilescu, O. and Bococi, D. (2003), *Geotermalism şi ape termale* (*Geothermalism and thermal waters),* Publishing house University of Oradea.
30. Bender, T., Karagülle, M., Bálint, G., Gutenbrunner, C., Bálint, P. and Sukenik, S. (2005), Hydrotherapy, Balneotherapy, and Spa Treatment in Pain Management. *Rheumatology international,* 25: 220–4.
31. Bengtsson, J., Möllborg, J. and Werner, S. (1996), A Study for Testing the Sensitivity and Reliability of the Lysholm Knee Scoring Scale. *Knee Surgery, Sports Traumatology, Arthroscopy,* 4: 27–31.
32. Bențe, F. (1999), *Depresiunea Şimleului (Depression Şimleului),* Cluj-Napoca: Dacia Publishing House.
33. Berchez, O. (2019), *Solurile României. Cambisolurile şi spodisolurile (Soils Romania. Cambisols and the spodisols),* Publishing house University of Oradea, Oradea.
34. Berindei, O.I., Măhăra, Gh., Pop, G..P and Posea, A. (1977), *Cîmpia Crişurilor: Cercetări în geografia României. Crişul Repede. Ţara Beiuşului* (*Plain Crişurilor: Research in geography Romania. Crişul Quickly. Country Beiuşului),* Scientific and Publishing House Encyclopedic, Bucharest.
35. Berindei, O.I. and Pop, I.Gr. (1972), *Judeţul Bihor (Bihor County),* Publishing House Academy RSR, Bucharest.
36. Berlescu, E. (1998), *Enciclopedia de balneoclimatologie a României (Encyclopedia of Balneoclimatology of Romania)* All Publishing House, Bucharest.
37. Besancenot, J.P. (1970), Introduction à l'étude Geography of Bioclimate Humain des Petites Antilles Françaises. *Bulletin de l'Association de Géographes Français,* 47(382): 167–179.
38. Besancenot, J.P. (1974), Premières Données Sur Les Stress Bioclimatiques Moyens En France, 497–530, Armand Colin.
39. Besancenot, J.P. (1985), Bioclimatologie Humaine et Limite Du Domaine Méditerranéen Dans Le Midi de La France. Reflections on the Notion of Climate Limits. *Ecology mediterranea,* 11(4): 61–73.
40. Besancenot, J.P. (1986), Réflexions Sur Le Pouvoir Réfrigérant Du Vent Dans Les Montagnes Nord- Mediterranéeennes. *Revue de Géographie Alpine,* 74(1): 11–20.
41. Besancenot, J.P. (1993), Le Climat et l'homme à Essaouira. Hander M. (1993), Contribution à l'étude de La Bioclimatologie Humaine Au Maroc: L'exemple d'Essaouira. *Méditerranée,* 78(3): 110–111.
42. Besancenot, J.P. (1997a), Climat, Climats et Santé: Introduction à La Bioclimatologie Humaine. *La Presse thermale et climatique,* 134(4): 207–212.
43. Besancenot, J.P. (1997b), Climate, Comfort, Santé et Aménagement des Villes Tropicales /Climate, Comfort, Health and the Development of Tropical Towns. *Géocarrefour,* 72(4): 323–331.

44. Besancenot, J.P. (2001a), Chapter II. La Notion d'homéothermie et La Thermorégulation. *Medicine and society:* 19–32.

45. Besancenot, J.P. (2001b), Chapter IV. Le Complexe Thermo- Hygrométrique: La Température Effective. *Medicine and society:* 40–47.

46. Besancenot, J.P., Handschumacher, P., Ndione, J.A., Mbaye, I. and Laaidi, K. (2004), Climat, Eau et Santé Au Sahel Ouest-Africain. *Sécheresse,* 15(3): 33–41.

47. Bestaş, E., Dündar, Ü., Köken, T., Koca, B. and Yeşil, H. (2021), The Comparison of Effects of Balneotherapy, Water-Based and Land-Based Exercises on Disease Activity, Symptoms, Sleep Quality, Quality of Life and Serum Sclerostin Level in Patients with Ankylosing Spondylitis: A Prospective, Randomized Study. *Archives of Rheumatology,* 37(2): 159–168.

48. Bîdiliță, V. (2009), Dealurile Crasnei -Studiu geomorfologic cu privire specială asupra proceselor actuale (The Hills Crasnei - Study geomorphologically regarding special on process current.

49. Bijlsma, J.W. J., Berenbaum, F. and Lafeber, F.P.J.G. (2011), Osteoarthritis: An Update with Relevance for Clinical Practice. *Lancet (London, England),* 377(9783): 2115–2126.

50. Bistricean, P.I. (2018), Potenţialul balneoclimatic al staţiunilor turistice din Moldova (The Potential balneoclimatic of resorts tourism from Moldova), Stefan cel Mare University, Suceava, available at [22 January 2023].

51. Bistricean, P.I., Mihăilă, D. and Lazurca, AL.G.. (2017), Bioclimatic Regionalization of Moldova West of the Prut River. *Present Environment and Sustainable Development,* (1): 45–54.

52. Blazejczyk, K., Baranowski, J. and Błażejczyk, A. (2015), *Wpływ Klimatu Na Stan Zdrowia w Polsce.*

53. Błażejczyk, K. and Twardosz, R. (2010), Long-Term Changes of Bioclimatic Conditions in Cracow (Poland), 235–246, in: Przybylak, R. (Ed.), *The Polish Climate in the European Context: An Historical Overview.* Dordrecht: Springer Netherlands. available at https:// doi.org/10.1007/978-90-481-3167-9_10

54. Bleahu, M. and Bordea, S. (1981), *Munţii Bihor – Vlădeasa (*Bihor *Mountains – Vlădeasa),* Sport - Tourism Publishing House, Bucharest.

55. Blidaru, V., Georgescu, I., Gheorghiu, I.M. and Vllădecu, D. (1962), *Hidroameliorațiile în R.P.R. Monografie (Hydro-improvements in RPR. Monograph).* Agro-Silvică Publishing House, Bucharest.

56. Bódi, E., Buday, T., Kovács, L., McIntosh, R.W. and Kozák, M. (2015), *Thermal Water Utilization and Its Possible Development in the Early 21st Century in Hajdúság, East Hungary.* Center for Economic and Regional Studies, Pécs, Hungary, 91(9), 227-238.

57. Bodor, K., Bodor, Z., Szép, A. and Szép, R. (2021), Classification and Hierarchical Cluster Analysis of Principal Romanian Bottled Mineral Waters. *Journal of Food Composition and Analysis,* 100: 103903.

58. Bohannon, R.W. (1997), Comfortable and Maximum Walking Speed of Adults Aged 20-79 Years: Reference Values and Determinants. *Age and aging,* 26(1): 15–19.

59. Boko, N.P., Medeou, F., Vissin, E. and Blazejczyk, K. (2014), Characterization of Bioclimatique Ambiances In Les Villes Littorales Du Bénin (Afrique de l'ouest). *In Acte de colloque, XXVIIème Colloque de l'Association Internationale de Climatologie (pp. 605-611).*

60. Bontius J. (1642), De medicina Indorum, Lugduni Batavorum (On medicine Indorum, Lugduni Batavorum), Apud Franciscum Hackium, 212 S.

61. Borodi, D. and Nemet, B. (2016), Radioactivitatea apelor termale din Băile Felix (Radioactivity water thermal baths in Băile Felix), *Physics Magazine medical.*

62. Borović, S., Marković, T., Larva, O., Brkić, Ž. and Mraz, V. (2016), Mineral and Thermal Waters in the Croatian Part of the Pannonian Basin. *Mineral and Thermal Waters of Southeastern Europe:* 31–45.

63. Borze (Ursu), T.F., Pallag, A., Tarcău, E., Ciobanu, DI., Andronie-Cioară, FL., Nistor-Cseppento, C.D., Ciavoi, G. and Mureșan, M. (2025), The Impact of Standard Care Versus Intrinsic Relaxation at Home on Physiological Parameters in Patients with Fibromyalgia: A Comparative Cohort Study from Romania. *Medicina,* 61(2): 285.

64. Boubaker, H.B. (2007), Climate, Tourism and Environment. *Colloque de l'AIC, 20, Carthage, Tunisie, 2007-09-03, Collection Publications de l'Association Internationale de Climatology, 2007, number of pages: 603.*

65. Bradley, L.A. (2009), Pathophysiology of Fibromyalgia. *The American Journal of Medicine,* 122(12): S22 – S30.

66. Bradu, M., Chiriac, A., Măhăra, G., Ilies, A., Puscaș, C, Apati, C., Tarau, A., Mihoc, B., Andras, E., Palfi, J., Matyas, A., Buzogany -Csoma, I., Seidler, A., Noane, D., Milian, R., Romînașu, R., Moisa, G., Babeș, P.A., Zintz, M. and Mihalcea, V. (2010), *Monografia Județului Bihor (Monograph Bihor County Monograph),* Publishing House University of Oradea.

67. Bronfort, G., Banto, N., Caciora, T., Grama, V., Trojan, J., Unguenu, M., Furdui, S., Garai, D., Buhaș, R. and Buhaş, S. (2021), Considerations Regarding the Profile of Tourists from Băile Felix – Băile 1 Mai Spa Destination, Romania. *Baltic Journal of Health and Physical Activity,* 13: 157–168.

68. Cannistraro, G., Cannistraro, M. and Restivo, R. (2014), A Smart Thermo-Hygrometric Global Index for the Evaluation of Particularly Critical Urban Areas Quality: The City of Messina Chosen as a Case Study. *Smart Science,* 2(1): 29–35.

69. Capurso, A., Solfrizzi, V., Panza, F., Mastroianni, F., Torres, F., Del Parigi, A., Colacicco, A.M., Capurso, C., Nicoletti, G., Veneziani, B., Cellamare, S. and Scalabrino, A. (1999), Increased Bile Acid Excretion and Reduction of Serum Cholesterol after Crenotherapy with Salt-Rich Mineral Water. *Aging (Milan, Italy),* 11(4): 273–276.

70. Carbajo, J.M. and Maraver, F. (2017), Sulfurous Mineral Waters: New Applications for Health. *Evidence-Based Complementary and Alternative Medicine,* 2017: 11.

71. Carroll, L.M., Volpe, D., Morris, M.E., Saunders, J. and Clifford, A.M. (2017), Aquatic Exercise Therapy for People with Parkinson's Disease: A Randomized Controlled Trial. *Archives of Physical Medicine and Rehabilitation,* 98(4): 631–638.

72. Carțiș, H.L. (2017), Studiu geografic de dezvoltare a județului Bihor ca destinație turistică (Study geographical development of Bihor County as a destination tourist).

73. Cetin, M. (2015), Determining the Bioclimatic Comfort in Kastamonu City. *Environmental monitoring and assessment,* 187(10): e640 – e640.

74. Çetinkaya, F.N., Koçak, F.A., Kurt, E.E., Güçlü, K., Tuncay, F., Şaş, S. and Erdem, H.R. (2020), The Effects of Balneotherapy on Oxidant/Antioxidant Status in Patients with Fibromyalgia: An Observational Study. *Archives of Rheumatology,* 35(4): 506–514.

75. Chary- Valckenaere, I., Loeuille, D., Jay, N., Kohler, F, Tamisier, J.N., Roques, C.-F., Boulange, M. and Gay, G. (2018), Spa Therapy Together with Supervised Self- Mobilisation Improves Pain, Function and Quality of Life in Patients with Chronic Shoulder Pain: A Single-

Blind Randomized Controlled Trial. *International Journal of Biometeorology,* 62(6): 1003–1014.

76. Chaurasia, N., Singh, A., Singh, I.L., Singh, T. and Tiwari, T. (2020), Cognitive Dysfunction in Patients of Rheumatoid Arthritis. *Journal of Family Medicine and Primary Care,* 9(5): 2219–2225.
77. Cheleschi, S., Gallo, I. and Tenti, S. (2020), A Comprehensive Analysis to Understand the Mechanism of Action of Balneotherapy: Why, How, and Where They Can Be Used? Evidence from in Vitro Studies Performed on Human and Animal Samples. *International Journal of Biometeorology,* 64: 1247–1261.
78. Cherevaschenko, L.A., Serebryakov, A.A., Kulikov, N.N., Tereshin, A.T. and Cherevashchenko, IA (2018), Balneotherapy and Physiotherapy in Treatment of Cognitive and Psychoemotional Disorders in Patients with Chronic Cerebral Ischemia. *Russian Journal of Physiotherapy, Balneology and Rehabilitation,* 17(4): 178–184.
79. Chiriac, C. and Bucur, L. (2015), Aspecte ale evoluţiei urbanistice a municipiului Oradea înainte şi după anul 1990 (Aspects of evolution urban planning of the municipality of Oradea next and after 1990), *Publishing House of the Country Museum Crişurilor, Oradea,* XLV: 197–206.
80. Chiriță, C.D., Doniță, D., Ivănescu, I., Lupe, I., Milescu, V. and Stănescu, I. (1981), *Pădurile României. Studiu Monografic (Romania's Forests. Monographic Study),* Publishing House Academy Romanian, Bucharest.
81. Cineti, A. (1990), *Resursele de ape subterane ale României (*Romania *'s underground water resources),* Technical Publishing House, Bucharest.
82. Ciprian, L., Lo Nigro, A., Rizzo, M., Gava, A., Ramonda, R., Punzi, L. and Cozzi, F. (2013), The Effects of Combined Spa Therapy and Rehabilitation on Patients with Ankylosing Spondylitis Being Treated with TNF Inhibitors. *Rheumatology International,* 33(1): 241–245.
83. Ciulache, S. and Ionac, N. (1998), Climatologie comportamentală (Behavioral Climatology) *Publishing House University of Bucharest.*
84. Ciurba, A.P., Aur, C. and Linc, R. (2025), Balneo physio gynecology in Bihor County. *Roumanian journal of physical therapy,* 31(54): 14–19.
85. Ciurba, A.P., Haidu, I., Gaceu, O. and Aur, C. (2023), Therapeutic Valorisation of Thermal Waters from Rural Locations of Bihor County. *Air and Water – Components of the Environment, Conference Proceedings:* 200–212.
86. Ciurba, A.P., Haidu, I., Gaceu, O., Biriș (Matei), M., Meșter, C., and Ianc, D. (2022), The Thermal Water in Bihor County and Its Benefits for Treating Arthritis. A Case Study: Baile 1 Mai Resort. *Air and Water – Components of the Environment, Conference Proceedings:* 225–240.
87. Ciurba, A.P., Haidu, I. and Ianc, D. (2023), Administrative Aspects Regarding the Valorisation of Geothermal Waters for Balneological Purposes in Bihor County, Romania. *Sustainability,* 15(13): 10320.
88. Ciurba (Pastor), A.P., Haidu, I., Sârbu, E., Gavriliu, G.A., Marcu, F, Motofelea, A.C., Boca, I.C. and Ianc, D. (2023), The Impact of Mineral Water Balneotherapy on Pain and Physical Function in Patients with Knee Osteoarthritis: A Pilot Study. *Balneo and PRM Research Journal,* 4(14).
89. Clauw, D.J. (2014), Fibromyalgia: A Clinical Review. *JAMA,* 311(15): 1547–1555.

90. Cohut, I. and Paal, G. (2019), Recviem pentru rezervația naturală „Pârâul Peța" de la Băile 1 Mai (Requiem for reserve natural " The stream" " The Fish " from Băile 1 Mai), *Folia naturae Bihariae Oradea,* XLIV: 77–92.

91. Cojocaru, M., Cojocaru, I.M., Silosi, I., Vrabie, C.D. and Tănăsescu, R. (2010), Extra-Articular Manifestations in Rheumatoid Arthritis. *Maedica,* 5(4): 286–291.

92. Cornea, S. (2007), Consideraţii referitor la relaţiile administraţiei publice cu mediul politic (Considerations Regarding the Relations of the Public Administration with the Political Environment). available at https://www.researchgate.net/publication/327107435 [3 February 2023].

93. Costantino, M., Izzo, V., Conti, V., Manzo, V., Guida, A. and Filippelli, A. (2020), Sulphate Mineral Waters: A Medical Resource in Several Disorders. *Journal of Traditional and Complementary Medicine,* 10(4): 320–326.

94. Costa-Vieira, D., Monteiro, R. and Martins, M.J. (2019), Metabolic Syndrome Features: Is There a Modulation Role by Mineral Water Consumption? A Review. *Nutrients,* 11(5): 1141.

95. Cozzi, F., Ciprian, L., Carrara, M., Galozzi, P., Zanatta, E., Scanu, A., Sfriso, P. and Punzi, L. (2018), Balneotherapy in Chronic Inflammatory Rheumatic Diseases - a Narrative Review. *International Journal of Biometeorology,* 62(12): 2065–2071.

96. Crespo, P.V., Campos, F., Leal, Manuel and Maraver, F. (2021), Effects of Sodium Chloride-Rich Mineral Water on Intestinal Epithelium. Experimental Study. *International Journal of Environmental Research and Public Health,* 18(6): 3261.

97. Cristea, M. (2004), *Riscurile climatice din bazinul hidrografic al Crişurilor (Risks climate in the basin Hydrographic map of the Crişuri),* Ababadba Publishing House, Oradea.

98. Croitoru, A.E., Piticar, A., Ciupertea, AF and Roşca, CF (2016), Changes in Heat Waves Indices in Romania over the Period 1961–2015. *Global and Planetary Change,* 146: 109–121.

99. Croitoru, A.E. and Sorocovschi, V. (2012), *Introducere în biometeorologie umană (Introduction in biometeorology Human),* Publishing House of the Science Book House in Cluj-Napoca;

100. Csapó, J. and Marton, G. (2017), The Role and Importance of Spa and Wellness Tourism in Hungary's Tourism Industry. *Czech Journal of Tourism,* 6(1): 55–68.

101. Cuc, N., Satmari, L., Popa, C., Bcter, R. and Gherdan, A.E.M. (2023), The Quality of the Services Offered in the Balneo -Climate Resort Baile Felix, Bihor County. *Agricultural Management/ Works Scientific Series I, Agricultural Management,* 25(3):192.

102. Dani, Z. and Nagy, M. (2017), *Szalárd És Vidéke, Tegnap Es Ma (Salard and Its Countryside, Yesterday and Today).* Nyomdaban Europrint publishing house, Oradea.

103. Delgado, D.A., Lambert, B.S., Boutris, N., McCulloch, P.C., Robbins, A.B., Moreno, M.R. and Harris, J.D. (2018), Validation of Digital Visual Analog Scale Pain Scoring with a Traditional Paper-Based Visual Analog Scale in Adults. *Journal of the American Academy of Orthopedic Surgeons. Global Research & Reviews,* 2(3): e088.

104. Di Marco, R., Pistonesi, F., Cianci, V., Biundo, R., Weis, L., Tognolo, L., Baba, A., Rubega, M., Gentile, G., Tedesco, C., Carecchio, M., Antonini, A. and Masiero, S. (2022), Effect of Intensive Rehabilitation Program in Thermal Water on a Group of People with Parkinson's Disease: A Retrospective Longitudinal Study. *Healthcare,* 10(2): 368.

105. Dincă, A.I., Micu, D., Dragotă, C. and Surugiu, C. (2013), Influences of Changing Bioclimatic Conditions on Outdoor Tourism Activities in Campulung Moldovan: Vatra

Dornei Mountain Area. *Proceedings PEEC 2013, Supplement of" Quality-access to success,* 14: 214–221.

106. Dobrinescu, A., Busuioc, A., Birsan, M.V., Dumitrescu, A. and Orzan, A. (2015), Changes in Thermal Discomfort Indices in Romania and Their Connections with Large-Scale Mechanisms. *Climate Research,* 64(3): 213–226.

107. Dogaru, G., Ciubean, A.D., Marinescu, L., Pop, B.M., Pașca, G.S. and Ciumărnean, L. (2025), The Effectiveness of Balneotherapy on Pain, Walking, and Function in Patients with Diabetic Neuropathy: A Prospective Observational Study. *International Journal of Biometeorology,* 69(2): 319–329.

108. Dogaru, G., Motricală, M., Molnar, A., Stanescu, I., Bulboaca, A., Ciumărnean, L. and Rus, Vasile (2018), Biochemical Changes after Consumption of Mineral Water from Spring 3 in Baile Tusnad in Experimentally Induced Alcoholic Liver Disease Study. *Balneo Research Journal,* 9: 346–351.

109. Dogaru, G., Muresan, D., Stănescu, I., Motricala, M. and Ákos, M. (2016), The Therapeutic Benefits of Natural Therapeutic Factors in Baile Tusnad for the Rehabilitation of Patients with Parkinson's Disease. *Balneo Research Journal,* 7(4): 116–124.

110. Donati, F. (2022), A Direct Method to Delimit Weir Pools. *Geographia Technica,* 17(2): 47–53.

111. Dragotă, C. and Runcanu, T. (1993), *Particularităţi ale stresului climatic cutanat în zona municipiului Iaşi, (Peculiarities of Cutaneous Climatic Stress in the Municipality Area Iasi),* The Works Seminary Geographically.

112. Drignei, D. (2009), A Kriging Approach to the Analysis of Climate Model Experiments. *Journal of Agricultural, Biological, and Environmental Statistics,* 14(1): 99–114.

113. Drugescu, C. (1994), *Zoogeografia României (Zoogeography Romania),* All Publishing House, Bucharest, 140 pages.

114. Ducamp, P., Sichère, P., Gayum, H., Dubourg, K. and Roques, C.F. (2022), Republication de: Éducation Thérapeutique des Patients Pour La Fibromyalgie During La Cure Thermale: L'essai Controlled, Randomized FiETT. *Douleurs: Évaluation -Diagnostic- Traitement,* 23(6): 228–241.

115. Dulamă, M.E. (2003), Thermal-Mineral Waters of Felix – 1 Mai Spas. Present and Prospective Usage of Their Touristic Resources. Studia *Publishing House, Cluj-Napoca:* 263–268.

116. Dumitrescu, M., Iliescu, M.G., Mazilu, L., Micu, S.I., Suceveanu, A.P, Voinea, F., Voinea, C., Stoian, AP and Suceveanu, AI (2022), Benefits of Crenotherapy in Digestive Tract Pathology (Review). *Experimental and Therapeutic Medicine,* 23(2): 122.

117. Eberhard R.R. (2011), Memorabilia Europe, Reprinted, Nabu Press, 722 pages.

118. Enescu, C. and Gheorghe, F. (2016), The Efficiency of Balneokinetic Rehabilitation Therapy for the Post-Traumatic Hip. *Balneo Research Journal, 7(4):110-113.*

119. Erdeli, G., Dincă, AI, Gheorghilas, A. and Surugiu, C. (2011), Romanian Spa Tourism: A Communist Paradigm in a Post Communist Era. *Human Geographies,* 5(2): 41–56.

120. Eusébio, C., Carneiro, M.J., Kastenholz, E. and Alvelos, H. (2013), The Economic Impact of Health Tourism Programs. *Quantitative methods in tourism economics:* 153–173.

121. Farcaș, D.M. (2005), Therapeutic Effects of the Geothermal Water in the Felix SPA, Romania, World Geothermal Congress, Antalya.

122. Ferrara, E., Scaramuzzino, M., Murmura, G., D'Addazio, G. and Sinjari, B. (2025), *Emerging Evidence on Balneotherapy and Thermal Interventions in Post-COVID-19 Syndrome: A Systematic Review*, 96, MDPI. In *Healthcare*,Vol. 13, No. 2, p. 96.

123. Feru, A. (2012), *Ghidul apelor minerale naturale (Guide to Natural Mineral Waters).* APEMIN Mineral Waters Patronage, Bucharest. available at https://www.apeleminerale.ro/_res/pdf/Ghidul-Apelor-Minerale_22.08.pdf (accessed on March 15, 2021).

124. Fiaschetti, D., Grignaffini, A., Cavatorta, E., Rastelli, A.V., Gramellini, D. and Chiavazza, F. (1982), Thermal Therapy in Gynecology. *Acta Bio-medica de L'ateneo Parmense: Organo Della Societa di Medicina e Scienze Naturali di Parma,* 53(6): 399–403.

125. Filatova, E., Boulakh, O., Polkovnikova, E., Privalova, N. and Malaev, Kh. (2017), Exercise Therapy on Unstable Support and Hydrokinetic Therapy in the Rehabilitation of Patients with Back Pain. *Research'n Practical Medicine Journal,* 4: 58–66.

126. Filimon, L. (2012), *Țara Beiușului. Studiu de geografie regională (Beiuș Country. Regional geography study),* University Press Publishing House Cluj-Napoca.

127. Fioravanti, A., Cantarini, L., Guidelli, G.M. and Galeazzi, M. (2011), Mechanisms of Action of Spa Therapies in Rheumatic Diseases: What Scientific Evidence Is There? *Rheumatology international,* 31: 1–8.

128. Fioravanti, A., Giannitti, C., Bellisai, B., Iacoponi, F. and Galeazzi, M. (2012), Efficacy of Balneotherapy on Pain, Function and Quality of Life in Patients with Osteoarthritis of the Knee. *International journal of biometeorology,* 56(4): 583–590.

129. Fioravanti, A., Karagülle, M., Bender, T. and Karagülle, M. (2017), Balneotherapy in Osteoarthritis: Facts, Fiction and Gaps in Knowledge. *European Journal of Integrative Medicine,* 9:148-150.

130. Florescu, G. and Alexandrescu, I. (1966), *Oradea, Băile Felix și Băile 1 Mai-Mic îndreptar turistic* (*Oradea, Băile Felix and Baile 1 Mai-Small guide tourist),* Meridiane Publishing House, Bucharest.

131. Forestier, R., Erol Forestier, F. and Francon, A. (2016), Spa Therapy and Knee Osteoarthritis: A Systematic Review. *Annals of Physical and Rehabilitation Medicine,* 59(3): 216–226.

132. Fraioli, A., Mennuni, G., Fontana, M., Nocchi, S., Ceccarelli, F., Perricone, C. and Serio, A. (2018), Efficacy of Spa Therapy, Mud-Pack Therapy, Balneotherapy, and Mud-Bath Therapy in the Management of Knee Osteoarthritis. A Systematic Review. *BioMed Research International,* 2018.1: 1042576.

133. Fraioli, A., Menunni, G., Petraccia, L., Fontana, M., Nocchi, S. and Grassi, M. (2010), Sulphate-Bicarbonate Mineral Waters in the Treatment of Biliary and Digestive Tract Diseases. *La Clinica Terapeutica,* 161(2): 163–168.

134. Franke, A., Reiner, L. and Resch, K.L. (2007), Long-Term Benefit of Radon Spa Therapy in the Rehabilitation of Rheumatoid Arthritis: A Randomized, Double-Blinded Trial. *Rheumatology International,* 27(8): 703–713.

135. Frumkin, H. (2001), Beyond Toxicity: Human Health and the Natural Environment. *American journal of preventive medicine,* 20(3): 234–240.

136. Gaceu, O. (2001), *Elemente de climatologie practică (Elements of practical climatology)* Publishing house University of Oradea.

137. Gaceu, O. (2005), *Clima și riscurile climatice din Munții Bihor și Vlădeasa (Climate and risks climatic conditions of the Bihor Mountains and Vladeasa),* 284 pag. Publishing House University of Oradea.

138. Gaceu, O. (2009), Thermic inversions in the area of Oradea. *Studia UBB Geography, LIV, 2, Cluj-Napoca:* 63–70.

139. Gaceu, O., Trif, O and Vlaicu, M (2009), The touristical potential, landscaping and advertising possibilities of Băile Tinca Spa. *GeoJournal of Tourism and Geosites,* 4: 186–202.

140. Gebretsadik, A. (2023), Effect of balneotherapy on skin lesions at hot springs in southern Ethiopia: A Single-Arm Prospective Cohort Study. *Clinical, Cosmetic and Investigational Dermatology:* 1259–1268.

141. George, Al. and Grăciun, P. (1993), Thermal aquifers in Romania. *Journal of Hydrology,* 145(1–2): 111–123.

142. Gheorghe, I. and Ionescu, S. (2016), *Fitosociologie si vegetaţia României (Phytosociology and vegetation of Romania).* University Ecological, Bucharest.

143. Gianfaldoni, S., Tchernev, G., Wollina, U., Roccia, M.G., Fioranelli, M., Gianfaldoni, R. and Lotti, T. (2017), History of the Baths and Thermal Medicine. *Open Access Macedonian Journal of Medical Sciences,* 5(4): 566–568.

144. Gilău, L., Stănășel, O., Gilău, D. and Dobjanschi, L. (2001), Chemical characterization of geothermal waters from the West Field of Romania. IV. Geothermal Waters from North of Field, 444, in: Stanford Geothermal Program, Stanford University.

145. Gill, S.D., De Morton, N.A. and Mc Burney, H. (2012), An Investigation of the validity of six measures of physical function in people awaiting joint replacement surgery of the hip or knee. *Clinical rehabilitation,* 26(10): 945–951.

146. Gin, H., Demeaux, J.L., Grelaud, A., Grolleau, A., Droz-Perroteau, C., Robinson, P., Lassalle, R., Abouelfath, A., Boisseau, M. and Toussaint, C. (2013), Observation of the long-term effects of lifestyle intervention during balneotherapy in metabolic syndrome. *Therapies,* 68(3): 163–167.

147. Głogowski, A., Perona, P., Bryś, T. and Bryś, K. (2022), Changes of bioclimatic conditions in the Kłodzko Region (SW Poland). *Sustainability,* 14(11): 6770.

148. Grassi, M., Fraioli, A. and Messina, B. (1992), Valutazione Dell'effetto di Un'acqua Minerale Bicarbonato-Calcica Sul pH Esofageo e Gastrico, *Clinica Dietologica,* 19(3): 213–218.

149. Grassi, M., Fraioli, A., Messina, B., Germani, M., Caputo, V. and Mazzarino, E. (1987), Modifications of Beta- Endorphin Plasmatics in Health Volunteers Dopo Assunzione di Acqua Minerale Bicarbonato-Calcica (Sangemini). Aqua Minerals and Endocrine-Paracrine Gastro-Entero-Pancreatic System. *Thermal Clinic,* 40(4): 175–178.

150. Grigore, E. (2013), Interannual Variation of the average values of thermo-hygrometer index on the South Dobrogea Territory. *Present Environment & Sustainable Development,* 7(2).

151. Grigore, E., Constantin, D.M. and Bogan, E. (2016), Effective equivalent temperature index in South Dobroudja Plateau and on the Romanian Black Sea Coast. Case Study: Spatial Distribution and Identification of Bioclimatic Risk Areas. *Quality,* 17(S1): 304.

152. Grigore, E., Constantin Oprea, O.D., Bogan, E., Cristea, M.A. and Tatu, F. (2020), The thermo-hygrometric index on the territory of the Southern Dobrogea Plateau–a Component

of the Balneoclimateric Treatment. *Present Environment and Sustainable Development,* (1): 89–98.

153. Guidelli, Gi.M., Tenti, S., De Nobili, E. and Fioravanti, A. (2012), fibromyalgia syndrome and spa therapy: Myth or Reality? *Clinical Medicine Insights,* 5: CMAMD.S8797.

154. Guillemin, F., Virion, JM, Escudier, P., De Talancé, N. and Weryha, G. (2001), Effect on Osteoarthritis of Spa Therapy at Bourbonne -Les-Bains. *Joint Bone Spine,* 68(6): 499–503.

155. Gulyás, Á. (2005), Differences in Human Comfort Conditions within a Complex Urban Environment: A Case Study. *Acta Climatologica et Chorologica, Acta Universitatis Szegediensis, 38,* 39: 71–84.

156. Gulyás, A. and Matzarakis, A. (2007), Selected examples of bioclimatic analysis applying the physiologically equivalent temperature in Hungary. *Acta climatologica et chorologica,* 40(41): 37–46.

157. Gyorfi, M., Rupp, A. and Abd-Elsayed, A. (2022), Fibromyalgia pathophysiology. *Biomedicines,* 10(12): 3070.

158. Habek, D., Cerovac, A., Kamerić, L., Nevačinović, E. and Šerak, A. (2021), Balneogynaecology in the 21st Century: Increasingly Recommended Primary and Complementary Treatment of Chronic Gynecological Diseases. *Med Glas (Zenica),* 18(1): 1–6.

159. Haidu, I., Ciurba, A.P., Ianc, D. and Gaceu, O. (2023), 75 Localities with geothermal water in Bihor County (Romania) and the Potential for the Sustainability of Balneology. *Present Environment and Sustainable Development,* 17(2): 165–187.

160. Haidu, I., Ionac, N. and Irașoc, A. (2024), The new climatic normals and their impact on bioclimatic indices. Case Study: Oradea (Romania). *Present Environment and Sustainable Development,* 18(2): 5–19.

161. Handaric, A.G. (2018), Cercetări privind dezvoltarea turismului termomineral în partea de vest luând modelul occidental (Research on the development of thermomineral tourism in the western part taking the western model), Summary of the Doctoral Thesis. *University of Agricultural Sciences and Veterinary Medicine of Banat "King Mihai I to Romania, Timişoara.*

162. Heaney, R.P. (2006), Absorbability and utility of calcium in mineral waters. *The American Journal of Clinical Nutrition,* 84(2): 371–374.

163. Herman, G.V., Peptenatu, D., Grama, V. and Pintilii, Radu-D. (2018), Tourism and Local Development. Study Case: Băile Felix - Băile 1 Mai Tourism System, Bihor County, Romania. *Annals University of Oradea, Geography Series,* 28(1): 131–137.

164. Herman, G.V. and Tătar, C. (2015), Trends and Prospects in the Evolution and Dynamics of the Felix-1 Mai Spas Tourist System. *Annals University of Oradea, Geography Series,* 24(1): 116–126.

165. Hirsch, A. (1881), Handbuch der historisch-geographischen Pathologie, Vol. 1, Enke.

166. Hitchon, C.A. and El- Gabalawy, H.S. (2004), Oxidation in Rheumatoid Arthritis. *Arthritis Res Ther,* 6: 1–14.

167. Horejsí, J., Kotásek, A., Jirásek, K. and Věrná, M. (1981), Gynecologic spa therapy for children. Present status, indications and guidelines for recommending spa therapy for children at the Pediatric Gynecologic Spa in Frantiskovy Spa. *Czechoslovak Gynecology,* 46(10): 787–791.

168. Huang, A., Seité, S. and Adar, T. (2018), The Use of Balneotherapy in Dermatology. *Clinics in Dermatology,* 36(3): 363–368.

169. Ianc, T.P. (2006), Strategii dezvoltare a turismului balnear în România în perspectiva integrării europene (Strategies tourism development balneary in Romania in perspective integration European), Doctoral thesis summary, *Academy of Studies Economic, Bucharest, 351 p.*

170. Ichim, P.and Sfîcă, L. (2020), The influence of urban climate on bioclimatic conditions in the city of Iași, Romania. *Sustainability,* 12(22): 9652.

171. Ilies, D.C., Buhas, R., Ilies, A., Morar, C. and Herman, G. (2015), Nymphaea Lotus Var. Thermalis (Pârâul Peţea Nature Reserve), Brand near Extinction of the Băile Felix - Băile 1 Mai (Romania) Spa Tourism System. *GeoJournal of Tourism & Geosites,* 15(1).

172. Ilieş, D.C., Ilieş, A., Herman, G.V., Baias, Ş. and Morar, C. (2011), Geotourist Map of the Băile Felix– Băile 1 Mai- Betfia Area (Bihor County, Romania). *GeoJournal of Tourism and Geosites,* 2(8): 219–226.

173. Ilieş, D.C. and Josan, I. (2009), The Tourist Complex Spa Băile Felix- Băile 1 Mai– Personality, Distinctiveness by Protection versus Depersonalization and Nonspecific by Globalization. Conceptual and Practical Aspects Regarding the Role of the Natural and Anthropic Setting in Tourist Fitting. *GeoJournal of Tourism and Geosites,* 2(4): 179–185.

174. Ionac, N. (1998), *Clima şi comportamentul uman* (*Climate and behavior human),* Encyclopedic Publishing House, Bucharest.

175. Ionac, N. (2000), *Mic tratat de geografie medicală (Small treatise on medical geography),* Publishing House University of Bucharest.

176. Ionac, N. and Ciulache, S. (2004a), Bioclimatic Considerations on the Moldavian Plain (Article in Romanian), 20–29.

177. Ionac, N. and Ciulache, S. (2004b), Principalele carecteristici bioclimatice ale Deltei Dunării (The main characteristics bioclimatic features of the Delta Danube), *Geographica Timisiensis, University of Bucharest,* 13(1): 5–14.

178. Ionac, N. and Ciulache, S. (2006), Le stress bioclimatique au froid en Roumanie. *Les risques liés au temps et au climate:* 328.

179. Ionac, N. and Ciulache, S. (2007a), Bioclimatic Stress Due to Overheating in Romania. In 3rd International Conference on Energy and Environment. CIEM2007.

180. Ionac, N. and Ciulache, S. (2007b), The Bioclimatic Stress in Dobrudja. *Present environment and sustainable development,* 1: 168–78.

181. Ionac, N. and Ciulache, S. (2008), *Atlasul bioclimatic al României (Bioclimatic atlas of Romania),* Ars Docendi Publishing House, Bucharest.

182. Ionac, N. and Ciulache, S. (2009), Repartiţia indicelui temperatură-umiditate pe teritoriul României (Distribution index temperature-humidity in the territory Romania), *Publishing House University of Bucharest.*

183. Ionac, N. and Ciulache, S. (2010), *Riscuri bioclimatice pe teritoriul României (Risks bioclimatic conditions on the territory Romania),* Ars Docendi Publishing House, Bucharest.

184. Ionac, N. and Grigore, E. (2012), The Bioclimatic Stress Due to Overcooling in the Southern Dobrudjan Tableland Area. *Present Environment and Sustainable Development,* 6(2): 235–246.

185. Ionac, N., Tăbleţ, P. and Mihoc, A.C. (2012), Heat Waves: Meteorological Characteristics and Biometeorological Influences (Case Study: Romania, 14-16TH July 2011). *Present Environment and Sustainable Development,* (1): 181–194.

186. Iosub, M.E., Ianc, D., Tirla, S., Yaran, M. and Lazăr, L. (2024a), Impact of Vojta Therapy Combined with Standard Care on Psychometric and Functional Parameters in Patients with Chronic Lower Back Pain: A Randomized Controlled Trial. *Chron Pain Manag,* 17(5): 478.

187. Iosub, M.E., Ianc, D., Tirla, S., Yaran, M. and Lazăr, L. (2024b), The Change with Thermal Water Therapy in Pain, Depression, and Self-Esteem in Patients with Lumbar Disc Herniation: Study from a Single Center Database. *Chron Pain Manag,* 8: 156.

188. Jones, C.J., Rikli, R.E. and Beam, W.C. (1999), A 30-s Chair-Stand Test as a Measure of Lower Body Strength in Community-Residing Older Adults. *Research quarterly for exercise and sport,* 70(2): 113–119.

189. Jordan, J.M., Helmick, C.G., Renner, J.B., Luta, G., Dragomir, Anca D, Woodard, J., Fang, F., Schwartz, T.A., Abbate, L.M. and Callahan, L.F. (2007), Prevalence of Knee Symptoms and Radiographic and Symptomatic Knee Osteoarthritis in African Americans and Caucasians: The Johnston County Osteoarthritis Project. *The Journal of rheumatology,* 34(1): 172–180.

190. Josan, N. and Sabău, N. (2004), *Hazarde şi riscuri naturale şi antropice în Bazinul Barcăului (Hazards and risks naturally and antropic in basin Barcaului.* Oradea: Publishing House University of Oradea.

191. Karagülle, M., Kardeş, S. and Karagülle, M.Z. (2018), Long-Term Efficacy of Spa Therapy in Patients with Rheumatoid Arthritis. *Rheumatology International,* 38(3): 353–362.

192. Karagülle, M., Kardeş, S., Karagülle, O., Dişçi, R., Avcı, A., Durak, İ. and Karagülle, M.Z. (2017), Effect of Spa Therapy with Saline Balneotherapy on Oxidant/Antioxidant Status in Patients with Rheumatoid Arthritis: A Single-Blind Randomized Controlled Trial. *International Journal of Biometeorology,* 61(1): 169–180.

193. Kauffels, W. and Mesrogli, M. (1996), Praxis Der Gynäkologischen Balneotherapie, 548–560, in: Springer.

194. Kazandzhieva, V. (2014), Trends in the Development of Spa and Wellness Tourism, In International Tourism Forum "Spa and Wine,1–8.

195. Kebiche, M. (1996), Le Bioclimat Humain de Sétif (Algérie): Effects Physiologiques et Therapeutiques. *Climat et santé (Dijon),* (15): 81–90.

196. Kennedy, D.M., Stratford, P.W., Wessel, J., Gollish, J.D. and Penney, D. (2005), Assessing Stability and Change of Four Performance Measures: A Longitudinal Study Evaluating Outcome Following Total Hip and Knee Arthroplasty. *BMC musculoskeletal disorders,* 6: 1–12.

197. Kesiktas, N., Karakas, S., Gun, K., Gun, N., Murat, S. and Uludag, M. (2012), Balneotherapy for Chronic Low Back Pain: A Randomized, Controlled Study. *Rheumatology International,* 32(10): 3193–3199.

198. Khaltaev, N., Solimene, U., Vitale, F. and Zanasi, A. (2020), Balneotherapy and Hydrotherapy in Chronic Respiratory Disease. *Journal of thoracic diseases,* 12(8): 4459.

199. Kocyigit, B.F. and Akyol, A. (2022), Fibromyalgia Syndrome: Epidemiology, Diagnosis and Treatment. *Rheumatology,* 60(6): 413–421.

200. Koçyiğit, H., Aydemir, Ö., Fişek, G., Ölmez, N. and Memiş, A. (1999), Reliability and Validity of the Turkish Version of Short Form-36 (SF-36). *J Med Treat,* 12: 102–106.

201. Kodintsev, V.V., Lenda, IV, Ponomarev, AV, Naumov, NA and Salatov Ya, S. (2022), Sodium as One of the Basic Elements in Human Life. *European Journal of Natural History,* 5: 4–7.

202. Kolasinski, S.L., Neogi, T., Hochberg, M.C., Oatis, C., Guyatt, Gordon, Block, J., Callahan, L., Copenhaver, C., Dodge, C., Felson, D., Gellar, K., Harvey, W.F., Hawker, G., Herzig, E., Kwoh, C.K., Nelson, A.E., Samuels, J., Scanzello, C., White, D., Wise, B., Altman, RD, DiRenzo, D., Fontanarosa, J., Giradi, G., Ishimori, M., Misra, D., Shah, AA, Shmagel, A.K., Thoma, L.M., Turgunbaev, M., Turner, A.S. and Reston, J. (2020), American College of Rheumatology/Arthritis Foundation Guideline for the Management of Osteoarthritis of the Hand, Hip, and Knee. *Arthritis & Rheumatology (Hoboken, NJ),* 72(2): 220–233.

203. Koleva, I., Yoshinov, R., Marinov, M. and Hadjijanev, A. (2015), Efficacy of Hydro-, Balneo - and Peloidotherapy in the Pain Management and Quality of Life of Patients with Socially-Important Diseases and Conditions of the Locomotive and Nervous System: Bulgarian Experience. *IV CIBAP 2015 OX.*

204. Kovács, C., Bozsik, Á., Pecze, M., Borbély, I., Fogarasi, A., Kovács, L., Tefner, IK and Bender, T. (2016), Effects of Sulfur Bath on Hip Osteoarthritis: A Randomized, Controlled, Single-Blind, Follow-up Trial: A Pilot Study. *International Journal of Biometeorology,* 60(11): 1675–1680.

205. Kuczera, M. and Kokot, F. (1996), Effect of spa therapy on the endocrine system. I. Stress reaction hormones. *Polskie Archiwum Medicines Internal,* 95(1): 11–20.

206. Kulaoğlu, O., Elden, H. and Doğan, A.G. (2023), The Effect of Balneotherapy and Physical Therapy Applied to Patients with Chronic Low Back Pain on Pain Intensity, Quality of Life, Disability and Mental Symptoms. *Journal of Orthopedics Research and Rehabilitation,* 1(1): 5–10.

207. Kurek, KA, Heijman, W., Van Ophem, J., Gędek, S. and Strojny, J. (2020), Geothermal Spas as a Local Development Factor, the Case of Poland. *Geothermics,* 85: 101777.

208. Kyle, WJ. (1992), Summer and Winter Patterns of Human Thermal Stress in Hong Kong, 557–583, in: *Proceedings of the 2nd Int. Conference on East Asia and Western Pacific Meteorology and Climate, Hong Kong, (Eds.).*

209. Labenz, J., Anschütz, M., Walstab, J., Wedemeyer, R., Wolters, H. and Schug, B. (2023), Heartburn Relief with Bicarbonate-Rich Mineral Water: Results of the Randomised, Placebo-Controlled Phase-III Trial STOMACH STILL. *BMJ open gastroenterology,* 10(1): e001048.

210. Lange, U., Müller-Ladner, U. and Schmidt, KL. (2006), Balneotherapy in Rheumatic Diseases–an Overview of Novel and Known Aspects. *Rheumatology international,* 26: 497–499.

211. Lebedeva, M.G., Lupo, A.R., Henson, C.B., Solovyov, A.B., Chendev, Y.G. and Market, P.S. (2018), A Comparison of Bioclimatic Potential in Two Global Regions during the Late Twentieth Century and Early Twenty-First Century. *International journal of biometeorology,* 62(4): 609–620.

212. Lequesne, M.G., Mery, C., Samson, M. and Gerard, P. (1987), Indexes of Severity for Osteoarthritis of the Hip and Knee: Validation–Value in Comparison with Other Assessment Tests. *Scandinavian Journal of Rheumatology,* 16(sup65): 85–89.

213. Linc, R. and Kortik, E. (2007), Resursele naturale din bazinul petrolier al Barcăului - suportul dezvoltării socio-economice din acest areal (Resources of the Barcău Oil Basin-the Support of socio- economic development in this area), *Geographica,* 2(2).

214. Linc, R. and Marușca, AI (2008), Spas at the West of the country-past, present and future. *Review of Historical Geography and Toponomastics,* 2(5–6): 115–126.

215. Linc, R., Pantea, E., Șerban, E., Ciurba (Pastor), AP and Serban, G. (2023), Hydrochemical and microbiological investigations and the therapeutic potential of some mineral waters from Bihor County, Romania. *Sustainability,* 15(21): 15640.

216. Lombard, H.C. (1887), Traité de climatology physician including meteorology médicale et l'étude des influences physiologiques, pathologiques, prophylactics et thérapeutiques du climat sur la Santé, vol. 1(4), Baillière, Paris.

217. Lupu (Mereț), R. (2017), Apele minerale din județul Brașov și Valorificarea lor (Mineral Waters from Brașov County and Their Utilization), Publishing house Transversal, Târgoviște.

218. Lv, X., Wang, J., Bao, Y., Tang, Y., Xing, W., Wu, Qi., Mao, G. and Wang, G. (2021), The Effectiveness of Balneotherapy and Aquatic Exercise on Bone Metabolism: A Systematic Review and Meta-Analysis. *Complementary Therapies in Clinical Practice,* 44: 101429.

219. Lysholm, J. and Gillquist, J. (1982), Evaluation of Knee Ligament Surgery Results with Special Emphasis on Use of a Scoring Scale. *The American journal of sports medicine,* 10(3): 150–154.

220. Ma, T., Song, X., Ma, Y., Hu, H., Bai, H., Li, Y. and Gao, L. (2021), The Effect of Thermal Mineral Waters on Pain Relief, Physical Function and Quality of Life in Patients with Osteoarthritis. *Medicine,* 100(4). available at https:// www.ncbi.nlm.nih.gov / pmc /articles/ PMC7850667 / [7 April 2021].

221. Maccarone, M.C., Magro, G., Albertin, C., Barbetta, G., Barone, S., Castaldelli, C., Manica, P., Marcoli, S., Mediati, M., Minuto, D., Poli, P., Sigurtà, C., Raffaetà, G. and Masiero, S. (2023), Short-Time Effects of Spa Rehabilitation on Pain, Mood and Quality of Life among Patients with Degenerative Diseases. or Post-Surgery Musculoskeletal Disorders. *International Journal of Biometeorology,* 67(1): 29–36.

222. Maccarone, M.C. and Masiero, S. (2022), Can Spa Rehabilitative Interventions Play a Role for Patients Suffering from Neurodegenerative Disorders at the Early Stages? A Scoping Review. *International Journal of Biometeorology,* 66(12): 2369–2377.

223. Maftei, C. and Buta, C. (2017), Application of Thermal Discomfort Indices for the Coastal Zone of Black Sea, in Dobrogea Region. *Ovidius University Annals of Constanta-Series Civil Engineering,* 19(1): 87–100.

224. Măhăra, Gh. (1977), *Câmpia Crişurilor, în volumul Câmpia Crişurilor, Crişul Repede, Ţara Beiuşului (Plain Crişurilor, in volume Plain Crişurilor, Crişul Fast, Country Beiuşului),.* Scientific and Publishing House Encyclopedic, Bucharest.

225. Măhăra, Gh., Josan, N., Bențe, F., Petrea, D., Ilies, A., Petrea, R., Linc, R., Nistor, S., Păle, L., Vlaicu, M., Stașac, M.S. and Gaceu, O. (1999), *Potenţialul turistic al bazinului hidrografic al Crişului Repede (The Potential tourist of the basin hydrographic map of Crişul Repede),* Publishing house University of Oradea

226. Măhăra, Gh. and Linc, R. (1993), Anomalii termice în Munţii Codru Moma (Anomalies termic in Mountains Codru Moma). *Annals University of Oradea,* III: 57–63.

227. Maindet, C., Maire, A., Vermorel, C., Cracowski, C., Rolland, C., Forestier, R., Comte, A., Roques, C.-F., Serra, E. and Bosson, JL. (2021), Spa Therapy for the Treatment of Fibromyalgia: An Open, Randomized Multicenter Trial. *The journal of pain,* 22(8): 940–951.

228. Man, G.S. and Mologhianu, G. (2014), Osteoarthritis Pathogenesis - a Complex Process That Involves the Entire Joint. *Journal of Medicine and Life,* 7(1): 37–41.

229. Mandić, A., Mrnjavac, Ž. and Kordić, L. (2018), Tourism Infrastructure, Recreational Facilities and Tourism Development. *Tourism and hospitality management,* 24(1): 41–62.

230. Marian, E.C. (2012), Evoluţia funcţiei balneoclimaterice în Câmpia și Dealurile de Vest (The evolution service balneoclimatic in Plain and Western Hills), Doctoral thesis summary.

231. Marin, C.A., Gheorghiu, G. and Lipară, D. (2019), Perspectives of the Balneary Tourism in Romania. *Ovidius University Annals, Economic Sciences Series, 19* (1), 238-245.

232. Marușca, A. (2024), *Dezvoltarea turismului balnear și impactul asupra mediului: Strategii de dezvoltare a turismului balnear și impactul asupra mediului înconjurător (Development tourism balneary and the impact on environment: Tourism development strategies balneary and the impact on environment surrounding (Romanian Edition).* Globe Edit Publishing House.

233. Marușca, A. and Moț, G. (2010), Rolul factorului terapeutic natural „apa minerală şi termală" în dezvoltarea turismului balnear din judeţul Bihor (The role factor natural therapeutic "water mining and thermal" in development balneary tourism in Bihor County). Romanian Association of Linmogeography, Târgoviște.

234. Marușca, A.-I. (2008), The Balneary Resources of the Western Hills: Between Now and the Perspective. *Annals University of Oradea, Geography Series,* 18: 125–132.

235. Masiero, S., Maghini, I., Mantovani, M.E., Bakdounes, L., Koutsikos, K., Del Felice, A. and Sale, P. (2019), Is the Aquatic Thermal Environment a Suitable Place for Providing Rehabilitative Treatment for Person with Parkinson's Disease? A Retrospective Study. *International Journal of Biometeorology,* 63(1): 13–18.

236. Masterton, J.M. and Richardson, F.A. (1979), Humidex: A Method of Quantifying Human Discomfort Due to Excessive Heat and Humidity. *Environment Canada, Atmospheric EnvironmentToronto, Canada.*

237. Mekis, É., Vincent, L., Zhang, X. and Shephard, M. (2015), Observed Trends in Severe Weather Conditions Based on Humidex, Wind Chill, and Heavy Rainfall Events in Canada for 1953–2012. *Atmosphere-ocean,* 53: 383–397.

238. Meng, Q., Liu, Z. and Borders, BE (2013), Assessment of Regression Kriging for Spatial Interpolation–Comparisons of Seven GIS Interpolation Methods. *Cartography and geographic information science,* 40(1): 28–39.

239. Mennuni, G., Petraccia, L., Fontana, M., Nocchi, S., Stortini, E., Romoli, M., Esposito, E., Priori, F., Grassi, M., Geraci, A., Serio, A. and Fraioli, A. (2014), The Therapeutic Activity of Sulphate-Bicarbonate-Calcium- Magnesic Mineral Water in the Functional Disorders of the Biliary Tract. *La Clinica Terapeutica,* 165(5): e346 -352.

240. Mennuni, G., Serio, A., Fontana, M., Nocchi, S., Costantino, C., Tanzi, G., Stornelli, G. and Fraioli, A. (2015), Prevention and Treatment of Nephrolithiasis: A Review on the Role of Spa Therapy. *La Clinica Terapeutica,* 166(5): e344 -356.

241. Meyer, H.P. and Med, M. (2002), Myofascial Pain Syndrome and Its Suggested Role in the Pathogenesis and Treatment of Fibromyalgia Syndrome. *Current Pain and Headache Reports,* 6(4): 274–283.

242. Michalkó, G. and Rátz, T. (2010), Hungarian Spa Destinations in the Tourism-Oriented Property Market. *Hungarian Geographical Bulletin,* 59(2): 131–146.

243. Mihăilă, D. (2014), *Atmosfera terestră. elemente de favorabilitate și nefavorabilitate pentru organismul uman și activitățile turistice (Atmosphere terrestrial. favorable elements and unfavorability for body human and activity tourist information),* Publishing House Sedcom Libris, Iași.

244. Mihăilă, D. and Bistricean, P.I. (2018), The Suitability of Moldova Climate for Balneary-Climatic Tourism and Outdoor Activities-a Study Based on the Tourism Climate Index. *Present Environment and Sustainable Development,* (1): 263–282.

245. Mihăilă, D., Bistricean, P.I. and Briciu, A.E. (2019), Assessment of the Climate Potential for Tourism. Case Study: The North-East Development Region of Romania. *Theoretical and Applied Climatology,* 137(1): 601–622.

246. Mihăilă, D., Bistricean, P.I., Gaceu, R.O., Emandi, E.M., Mihăilă, E.V. and Horodnic, V.D. (2024), A bioclimatic evaluation of sustainable tourist activities in western Romania. *Heliyon,* 10(8): e29510.

247. Mihăilă, D., Bistricean, P.I. and Lazurca, L.G. (2016), Spatial and Temporal Relevance of Some Bioclimatic Indexes for the Study of the Bioclimate of Moldova (West of the Prut River). *Globe,* 48(15): 43–329.

248. Mihăilă, D., Briciu, A.E., Bistricean, P.I. and Lazurca, L.G. (2015), The Analysis of the Spatial Distribution and Temporal Trends of THI Index in the Republic of Moldova. *International Multidisciplinary Scientific GeoConference: SGEM,* 4(1): 1105–1112.

249. Mihăilă, D., Piticar, A., Briciu, A.E., Bistricean, P.I., Lazurca, A.L.G. and Puțuntică, A. (2018), Changes in Bioclimatic Indices in the Republic of Moldova (1960-2012): Consequences for Tourism. *Boletín de Asociación de Geógrafos Españoles,* (77): 521–548.

250. Mihăilă, N. (1971), *Cercetări hidrogeologice și hidrochimice în cuprinsul foilor Oradea-Aleșd (Hydrogeological and Hydrochemical Researches within the Oradea- Aleșd Sheets),* Geological Institute, Bucharest. available at https://igr.ro/wp-content/uploads/2021/03/STE_E_v09.pdf

251. Mihăilescu, V. (1966), *Dealurile și Câmpiile României (The hills and plains Romania).* Scientific Publishing House, Bucharest.

252. Mijatov Ladičorbić, M., Dragin, A.S., Surla, T., Tešin, A., Amezcua-Ogáyar, J.M., Calahorro -López, A., Stojanović, V., Zadel, Z., Košić, K., Ivanović, O.M., Džigurski, A.I., Vujičić, M.D., Knežević, M.N., Bibić, L.I., Tomić, S. and Anđelković, Ž. (2024), Towards Healthy and Sustainable Human Settlement: Understanding How Local Communities Perceive and Engage with Spa Tourism Development Initiatives in Rural Areas. *Land,* 13(11): 1817.

253. Mitrașca, M.A. (2006), Contribuţii la studiul proceselor de tratare a apelor geotermale (Contributions to the study of treatment processes a water geothermal). Doctoral dissertation, " Politehnica " University of Timişoara, Faculty of Hydrotechnics. available at [15 August 2023].

254. Mizauld, A. (1548), Le Mirouer de l'air, Chaudiere, Paris.

255. Morar, C. (2013), *Turism şi dezvoltare regională durabilă în zonele miniere defavorizate din judeţul Bihor (Tourism and development regional sustainable in Zone mining disadvantaged in Bihor County),* Publishing House University of Oradea.

256. Morer, C., Roques, C.-F., Françon, A., Forestier, R. and Maraver, F. (2017), The Role of Mineral Elements and Other Chemical Compounds Used in Balneology: Data from Double-Blind Randomized Clinical Trials. *International journal of biometeorology,* 61: 2159–2173.

257. Moţica, A.M. (2018), Spa Tourism Economy Băile Felix Balneoclimateric Resort-Short Presentation. *Manager,* (27): 18–29.

258. Moza, M. and Ban, O. (2023), Analysis of the Digitization Level of Small and Medium Enterprises in Tourism. Identifying the Level of Digitization of Businesses from Băile Felix, Bihor, Romania. *Studia Universitatis Babes-Bolyai, Negotia,* 68(3).

259. Munier, B. (2017), *Le Thermalisme en Lorraine au fil de l'eau.* Vademecum Conseil.

260. Munteanu, C. (2013), *Ape minerale terapeutice (Mineral waters therapeutics),* Balnear Publishing House, Bucharest. available at http:// bioclima.ro / APE%20TERAP.pdf

261. Munteanu, C. and Dogaru, G. (2020), *Bioclimatologie: Bioclimatologie umană (Bioclimatology: Bioclimatology human),* Balnear Publishing House. available at http:// bioclima.ro / Bioclimat.pdf

262. Munteanu, C., Munteanu, D. and Onose, G. (2021), Hydrogen Sulfide (H2S)-Therapeutic Relevance in Rehabilitation and Balneotherapy Systematic Literature Review and Meta-Analysis Based on the PRISMA Paradigm. *Balneo and PRM Research Journal,* 12(3): 176–195.

263. Munteanu, L., Berindei, L. and Ludovic, I. (1979), *Mic îndreptar turistic. Băile Felix - Băile 1 Mai* (*Little Guide tourist. Băile Felix - Băile 1 Mai),* Sport – Tourism Publishing House, Bucharest.

264. Munteanu, L., Stoicescu, C., Teleki, N. and Teodoreanu, E. (1984), *Cura balneo-climatica în România (Balneo-climatic cure in Romania),* Sport- Tourism Publishing House, Bucharest

265. Nasermoaddeli, A. and Kagamimori, S. (2005), Balneotherapy in Medicine: A Review. *Environmental Health and Preventive Medicine,* 10(4): 171–179.

266. Nicula, M.A. (2021), *Caracteristici geochimice ale apelor termale şi minerale din Munţii Apuseni (*Characteristics geochemistry of waters thermos and minerals from the Mountains Apuseni), Summary PhD thesis. Babes-Bolyai University, Cluj - Napoca.

267. Oláh, M., Koncz, Á., Fehér, J., Kálmánczhey, J., Oláh, C., Nagy, G. and Bender, T. (2011), The Effect of Balneotherapy on Antioxidant, Inflammatory, and Metabolic Indices in Patients with Cardiovascular Risk Factors (Hypertension and Obesity)—a Randomised, Controlled, Follow-up Study. *Contemporary clinical trials,* 32(6): 793–801.

268. Onat, Ş.Ş., Taşoğlu, Ö., Güneri, F.D., Özişler, Z., Safer, VB and Özgirgin, N. (2014), The Effectiveness of Balneotherapy in Chronic Low Back Pain. *Clinical rheumatology,* 33(10): 1509–1515.

269. Orășeanu, I. (2016), *Hidrogeologia carstului din Munții Apuseni (Hydrogeology karst in the Mountains Apuseni),* Belvedere Publishing House, Oradea.

270. Orășeanu, I. (2020), Dynamics of the Felix - 1 Mai Thermal Aquifer (Bihor County, Romania). *Nymphaea Folia Naturae Bihariae, Publishing House Museum country Crisurilor, Oradea,* XLIV.

271. Orășeanu, I. and Malacu, F. (2016), Raport asupra monitorizării dinamicii acviferului termal din zona Lacului Ochiul Mare (Zona Felix-1 Mai) (Report on monitoring dynamics aquifer thermal from the Lake area The Big Eye (Felix Zone-May) 1st (Period) September 2014-February 2016.

272. Özkuk, K. and Uysal, B. (2020), The effectiveness of balneotherapy in patients with ankylosing spondylitis and its effect on inflammation, A Pilot Study. *Ege Tıp Bilimleri Dergisi,* 3(3): 84–92.

273. Paál, G. (2013), Sinteza particularităților hidrogeologice ale acviferului termal de La Băile Felix - 1 Mai (Synthesis particularities hydrogeological characteristics of the aquifer Thermal Spa of La Băile Felix – 1 Mai). *Magazine. Nymphaea, Museum country Crişurilor, Oradea,* XL.

274. Pabisiak, K. and Klatkowska, M. (2020), Thermal Therapy in Chronic Kidney Disease, 107–115

275. Paucă, M. (1988), *Fenomen climatic interesant la Dumbrăviţa de Codru (Jud. Bihor)* (*Interesting climatic phenomenon at Dumbrăviţa de Codru (Bihor County)),* Crisia, Museum country Crisurilor, Oradea.

276. Pendleton, A., Arden, N., Dougados, M., Doherty, M., Bannwarth, B., Bijlsma, JWJ., Cluzeau, F., Cooper, C., Dieppe, PA, Günther, KP., Hauselmann, HJ, Herrero-Beaumont, G., Kaklamanis, PM, Leeb, B., Lequesne, M., Lohmander, S., Mazieres, S. B., Mola, E.M., Pavelka, K., Serni, U. and Zimmermann-Gorska, I. (2000), EULAR Recommendations for the Management of Knee Osteoarthritis: Report of a Task Force of the Standing Committee for International Clinical Studies Including Therapeutic Trials (ESCISIT). *Annals of the rheumatic diseases,* 59(12): 936–944.

277. Pérez-Fernández, M.R., Calvo-Ayuso, N., Martínez- Reglero, C., Salgado-Barreira, Á. and Muiño López-Álvarez, JL. (2019), Efficacy of Baths with Mineral-Medicinal Water in Patients with Fibromyalgia: A Randomized Clinical Trial. *International Journal of Biometeorology,* 63(9): 1161–1170.

278. Péter, I., Jagicza, A., Ajtay, Z., Boncz, I., Kiss, I., Szendi, K., Kustán, P. and Németh, B. (2017), Balneotherapy in Psoriasis Rehabilitation. *in vivo,* 31(6): 1163–1168.

279. Petraccia, L., Liberati, G., Giuseppe Masciullo, S., Grassi, M. and Fraioli, A. (2006), Water, Mineral Waters and Health. *Clinical Nutrition,* 25(3): 377–385.

280. Petrea, R., Olău, P.E. and Nemeș, V. (2009), Alesd - Issues of Organization, Town Planning and Geospatial Integration. *Annals of University of Oradea,* XIX: 133–140.

281. Petrea, R. and Petrea, D. (1994), Tipurile genetice de relief din Dealurile de Vest (Types Genetic relief of the Western Hills), *Annals of the University of Oradea, Geography section:* 16–24.

282. Piery, M. (1934), Traité de climatology bioclinique et médicale, I-III, Publisher Maison, Paris.

283. Pop, G. (2005), *România. Dealurile de Vest și Câmpia de Vest Romania (The Western Hills and the Western Plain),* University Press Publishing House Clujeană, Cluj-Napoca.

284. Pop, G. (2006), *Carpații și Subcarpații României* (*Carpathians and Subcarpathians Romania),* Publishing House academic Cluj -Napoca.

285. Posea, A. (1977), *Bazinul Crisului Repede, In Vol. Câmpia Crişurilor, Crişul Repede, Ţara Beiuşului (The Crişului Repede Basin, In Vol. The Crişului Plain, Crişul Repede, Beiuş Country).* Scientific Publishing House and encyclopaedic Bucharest.

286. Posea, G. (1982), *Enciclopedia geografică a României (Encyclopedia Geographical map of Romania),* Scientific and Publishing House Encyclopedia, Bucharest.

287. Posea, G. (1997), *Câmpia de Vest a României (Câmpia Banato-Crişană) (Western Plain of Romania (Western Plain of Romania (Banato-Crişană)).* Publishing House of the Western Romania Foundation, Bucharest.

288. Posea, G. (1999), *România, Geografie și Geopolitică (Romania, Geography and Geopolitics),* Romania of Tomorrow Foundation Publishing House, Bucharest.

289. Pospíšil, P., Konečný, L., Zmeškalová, M., Srovnalova, H., Rektorova, I., Nosavcovová, E. and Siegelova, J. (2007), Balneotherapy in Patients with Parkinson's. *Scr Med,* 80(5): 233–238.

290. Preda, I. and Țenu, A. (1981), *Resurse de ape minerale şi termale. Note de curs şi lucrări practice (Mineral and Thermal Water Resources. Course Notes and Practical Works)*. Technical Publishing House, Bucharest.

291. Pricăjan, A. (1972), *Apele minerale şi termominerale din România (Mineral and thermomineral waters of Romania).* Technical Publishing House, Bucharest.

292. Pricăjan, A. (1985), *Substanţele minerale terapeutice din România (Substances mineral therapeutics from Romania).* Scientific Publishing House and Encyclopedic, Bucharest.

293. Pricăjan, A. and Airinei, S. (1981), *Bogăția hidrominerală balneară din România (Wealth hydro balneology in Romania).* Scientific and Publishing House Encyclopedic, Bucharest.

294. Printz-Markó, Erzsébet, Darabos, Ferenc and Ivancsone Horvath, ZS (2017), Dimensions of Wellness Tourism in Hungary. *Knowledge Horizons–Economics,* 9(1): 24–35.

295. Protano, C., Fontana, M., De Giorgi, A., Marotta, D., Cocomello, N., Crucianelli, S., Del Cimmuto, A. and Vitali, M. (2023), Balneotherapy for Osteoarthritis: A Systematic Review. *Rheumatology International,* 43(9): 1597–1610.

296. Protano, C., Vitali, M., De Giorgi, A., Marotta, D., Crucianelli, S. and Fontana, M. (2024), Balneotherapy Using Thermal Mineral Water Baths and Dermatological Diseases: A Systematic Review. *International Journal of Biometeorology,* 68(6): 1005–1013.

297. Qiu, Y., Zhu, Y., Jia, W., Chen, S. and Meng, Q. (2014), Spa Adjuvant Therapy Improves Diabetic Lower Extremity Arterial Disease. *Complementary Therapies in Medicine,* 22(4): 655–661.

298. Quintela, J.A. (2023), Contribution of Health and Wellness Tourism to Happiness and Quality of Life–A Comparative Study between Portugal and Hungary. *European Journal of Tourism Research,* 34: 3413–3413.

299. Radu, A.F. and Bungău, S.G. (2021), Management of Rheumatoid Arthritis: An Overview. *Cells,* 10(11): 2857.

300. Rădulescu, A. and Teodoreanu, E. (2014), *Notiuni de balneofizioterapie si balneoclimatologie (Notions of balneophysiotherapy and balneoclimatology).* Medical Publishing House, Bucharest.

301. Rădulescu, N. (2011), Turismul balnear românesc direcții de dezvoltare în contextul european Actual (Tourism balneary Romanian development directions in Background Current European). available at https://turismuldesanatate.ro/wp-content/uploads/2011/12/Turismul-Balnear-Romanesc-2011-Nicu-Radulescu1.ppt

302. Rico- Villademoros, F., Postigo-Martin, P., Garcia-Leiva, J.M., Ordoñez-Carrasco, J.L. and Calandre, E.P. (2020), Patterns of Pharmacologic and Non-Pharmacologic Treatment, Treatment Satisfaction and Perceived Tolerability in Patients with Fibromyalgia: A Patients' Survey. *Clinical and Experimental Rheumatology,* 38 Suppl 123(1): 72–78.

303. Rivas-Martínez, S., Rivas-Sáenz, S. and Penas, AS (2011), Worldwide Bioclimatic Classification System. *Global Geobotany,* 1(1).

304. Roba, C.A. (2010), *Fenomenul geotermic din vestul României. Impactul asupra mediului datorat exploatării apelor geotermale din perimetrele Oradea și Săcueni* (The Phenomenon geothermal from the west Romania. The impact on environment due exploitation water

geothermal areas in Oradea and Săcueni). Summary doctoral thesis, Babes-Bolyai University, Cluj-Napoca.

305. Romay-Barrero, H., Herrero-López, J., Llorente-González, J., Melgar-Del Corral, G., Palomo-Carrión, R. and Martínez-Galán-Balneotherapy, I. (2022), Balneotherapy and Health-Related Quality of Life in Individuals with Rheumatoid Arthritis: An Observational Study Un-Der Real Clinical Practice Conditions. *Balneo and PRM Research Journal,* 13(4).

306. Roos, E.M. and Toksvig-Larsen, S. (2003), Knee Injury and Osteoarthritis Outcome Score (KOOS)-Validation and Comparison to the WOMAC in Total Knee Replacement. *Health and quality of life outcomes,* 1(1): 1–10.

307. Roșca, E.C., Tudor, R., Cornea, A. and Simu, M. (2021), Parkinson's Disease in Romania: A Scoping Review. *Brain Sciences,* 11(6): 709.

308. Roșca, M., Bendea, C. and Vîjdea, A.M. (2016), Mineral and Thermal Waters of Romania, 97–114, in: Papic, P. (Ed.), *Mineral and Thermal Waters of Southeastern Europe.* Cham: Springer International Publishing. available at https:// doi.org/10.1007/978-3-319-25379-4_6

309. Rosu, C. (2024), Evaluarea potențialului balneoclimatic și a riscurilor geografice produse în stațiunile turistice din Moldova situate în etajul bioclimatului sedativ-indiferent (Evaluation potential balneary and risks geographic products in resorts tourist attractions in Moldova located in floor bio-climate sedative-indifferent). Summary Doctoral Thesis. Stefan Cel Mare University, Suceava.

310. Roșu, C., Mihăilă, D. and Bistricean, P.I. (2022), Evaluation of the Bioclimate of Submontane Resorts Located between Sucevița and Slănic Moldova Based on the THI Index. *Geo Review,* 32(1): 4.

311. Saabner-Tuduri, A. (1906), Apele minerale și stațiunile climatice din România (The mineral waters and climate resorts from Romania), Bucharest, Typography "Gutenberg" Joseph Göbl.

312. Sagtaganov, Z., Yessirkepov, M., Bekaryssova, D. and Suigenbayev, D. (2024), Managing Rheumatoid Arthritis and Cardiovascular Disease: The Role of Physical Medicine and Rehabilitation. *Rheumatology International,* 44(9): 1749–1756.

313. Saue, T. (2016), Directional Distribution of Chilling Winds in Estonia. *International Journal of Biometeorology,* 60(8): 1165–1173.

314. Schoppen, S., M. Pérez-Granados, A., Carbajal, Á., Sarriá, B., Navas-Carretero, S. and Pilar Vaquero, M. (2008), Sodium- Bicarbonated Mineral Water Decreases Aldosterone Levels without Affecting Urinary Excretion of Bone Minerals. *International Journal of Food Sciences and Nutrition,* 59(4): 347–355.

315. Schott, T. (1891), Balneo -Therapeutics and Mechanotherapeutics Applied to the Treatment of Chronic Heart Disease. *Medical Record (1866-1922),* 39(7): 198.

316. Sebeșan, R. and Sebeșan, M. (2014), Geochemical Studies about Well 4014 from Chișlaz Situated in Bihor County. *Annals University of Oradea, Fascicle protection Environment,* XXIII. available https://protmed.uoradea.ro/facultate/publicatii/protectia_mediului/2014B/im/34.%20Sebesan%20Radu.pdf

317. Sebeşan, R., Sebeşan, M. and Stănăşel, O. (2015), Interpretation of Chemical Data from Geothermal Wells: 1021 Tamaseu and 605 Mihai Bravu in Bihor County, Proceedings World Geothermal Congress.

318. Seidel, U., Baumhof, E., Hägele, F.A., Bosy-Westphal, A., Birringer, M. and Rimbach, G. (2019), Lithium-Rich Mineral Water Is a Highly Bioavailable Lithium Source for Human Consumption. *Molecular Nutrition & Food Research,* 63(13): 1900039.

319. Seite, S. (2013), Thermal Waters as Cosmeceuticals: La Roche-Posay Thermal Spring Water Example. *Clinical, cosmetic and investigative dermatology:* 23–28.

320. Șerban, E. (2010), *Hazarde climatice generate de precipitații în Câmpia de Vest Situată la nord de Mureș (Climatic hazards generated by precipitation in the Western Plain located north of Mureș).* Publishing House University of Oradea.

321. Şerban, E. (2012), Considerations on the Standardized Air Temperature Anomalies in the Western Plain of Romania, North of the Mureş River. *Annals University of Oradea, Fascicle protection Environment,* XVIII: 456–461.

322. Setel, A., Sebesan, M., Gabriela, B., Craciun Cornel, A. and Sebesan, R. (2010), Physico -Chemical Characterization of Geothermal Water from Wells 1704 Săcuieni and 752 Săcuieni in North-Western Romania with Ternary Diagrams. *International Review of Applied Sciences and Engineering,* 1(2): 31–34.

323. Sfică, L., Ichim, P., Apostol, L. and Ursu, A. (2018), The Extent and Intensity of the Urban Heat Island in Iași City, Romania. *Theoretical and Applied Climatology,* 134(3): 777–791.

324. Sfică, L., Ion-Sorin, S., Hrițac, R., Ichim, P. and Ilie, N. (2018), Favorabilitatea climatică a teritoriului României pentru activități turistice de tip balnear în sezonul estival (Favorability climate of the territory romania for balneary activity type tourism in season summer), 327–347, *Romanian Academy Publishing House.*

325. Shitzer, A. (2006), Wind-Chill-Equivalent Temperatures: Regarding the Impact Due to the Variability of the Environmental Convective Heat Transfer Coefficient. *International Journal of Biometeorology,* 50(4): 224–232.

326. Silișteanu, S.C., Mihăilă, D., Dogaru, G. and Bistricean, P.I. (2020), Balneoclimatology -Where To? *Georeview: Scientific Annals of Stefan cel Mare University of Suceava. Geography Series,* 30(1): 42–64.

327. Silva, A., Oliveira, A.S., Vaz, C.V., Correia, S., Ferreira, R., Breitenfeld, L., Martinez-de-Oliveira, J., Palmeira-de-Oliveira, R., Pereira, C.M.F., Palmeira-de-Oliveira, A. and Cruz, M.T. (2020), Anti-Inflammatory Potential of Portuguese Thermal Waters. *Scientific Reports,* 10(1): 22313.

328. Silva, J., Martins, J., Nicomédio, C., Gonçalves, C., Palito, C., Gonçalves, R., Fernandes, P.O., Nunes, A. and Alves, M.J. (2023), A Novel Approach to Assess Balneotherapy Effects on Musculoskeletal Diseases-An Open Interventional Trial Combining Physiological Indicators, Biomarkers, and Patients' Health Perception. *Geriatrics (Basel, Switzerland),* 8(3): 55.

329. Siple, P.A. and Passel, C.F. (1945), Measurements of Dry Atmospheric Cooling in Subfreezing Temperatures. *Proceedings of the American Philosophical Society,* 89(1): 177–199.

330. Sirangelo, B., Caloiero, T., Coscarelli, R., Ferrari, E. and Fusto, F. (2020), Combining Stochastic Models of Air Temperature and Vapor Pressure for the Analysis of the Bioclimatic Comfort through the Humidex. *Scientific Reports,* 10(1): 11395.

331. Sun, I. and Zugravu, G.A. (2014), The SPA Tourism Perception in Romania. *Annals of the University Dunarea de Jos of Galati: Fascicle: I, Economics & Applied Informatics,* 20(2).

332. Soldea, V. (2003), Peța și nufărul termal *(The Fish and lily Termal).* Publishing house University of Oradea.

333. Solomon, D.H., Bates, D.W., Panush, R.S. and Katz, J.N. (1997), Costs, Outcomes, and Patient Satisfaction by Provider Type for Patients with Rheumatic and Musculoskeletal Conditions: A Critical Review of the Literature and Proposed Methodologic Standards. *Annals of internal medicine,* 127(1): 52–60.

334. Stănășel, O. (2002), *Studii asupra compoziției chimice a apelor geotermale și monitorizarea depunerilor ce pot apărea în cazul utilizării lor* (*Studies on compounding chemistry a water*

geothermal and monitoring deposits what can happen in event their use), Doctoral Thesis, University Polytechnic, Timisoara.

335. Stănășel, O, Iovi, A., Kristmannsdóttir, H. and Stănășel, I. (2006), Physical-Chemistry Studies on Geothermal Waters and Scale Formations. *Revue Roumaine De Chimie, 51*(3), 179-185. available at https://www.semanticscholar.org/paper/Physical-chemistry-studies-on-geothermal-waters-and-Stanasel-Iovi/c35ebe67e01d077c46e6b742a06835a9ee1060fe [13 September 2023].

336. Stanciu, L.E., Uzun, A.B., Iliescu, M.G., Oprea, C., Oprea, D., Ionescu, E.V. and Mihailov, C.I. (2023), The Impact of Specific Balneotherapy on the Endocrine Physiopathological Mechanism in Obesity. *Balneo & PRM Research Journal,* 14(1).

337. Stephanus H. (1777), Thermae Varadienses, Viennae, Apud Rudolphum Graeffer, p. 63, 69, 163.

338. Sunkar, A., Lakspriyanti, A.P., Haryono, E., Brahmi, M., Setiawan, P. and Jaya, A.F. (2022), Geotourism Hazards and Carrying Capacity in Geosites of Sangkulirang-Mangkalihat Karst, Indonesia. *Sustainability,* 14(3): 1704.

339. Szabó, J. (2018), *Unknown Ermellék - Irasban ES Kepben.* Varadinum Script, Oradea.

340. Tarcău, E., Ianc, D., Sîrbu, E., Ciobanu, D., Boca, IC and Marcu, F. (2022), Effects of Complex Rehabilitation Program on Reducing Pain and Disability in Patients with Lumbar Disc Protrusion-Is Early Intervention the Best Recommendation? *Journal of Personalized Medicine,* 12(5): 741.

341. Tefner, IK, Németh, A., Lászlófi, A., Kis, T., Gyetvai, G. and Bender, T. (2012), The Effect of Spa Therapy in Chronic Low Back Pain: A Randomized Controlled, Single-Blind, Follow-up Study. *Rheumatology international,* 32(10): 3163–3169.

342. Teległów, A., Seremak, J., Golec, J., Marchewka, J., Golec, P., Marchewka, U., Maciejczyk, M. and Golec, E. (2023), The Effect of Sulfur Baths on Hemorheological Properties of Blood in Patients with Osteoarthritis. *Scientific Reports,* 13(1): 7960.

343. Teleki, N. (1984), *Cura balneoclimatică în România (Balneoclimatic cure in Romania).* Sport – Tourism Publishing House, Bucharest.

344. Teleki, N. and Munteanu, C. (2012), *SPA tourism în Romania balneo-turistică (SPA Tourism in Romania's spa- tourism.* Royal Company.

345. Tenti, S., Manica, P., Cheleschi, S. and Fioravanti, A. (2020), Sulfurous-Arsenical-Ferruginous Balneotherapy for Osteoarthritis of the Hand: Results from a Retrospective Observational Study. *International Journal of Biometeorology,* 64(9): 1561–1569.

346. Țenu, A. (1981), *Zăcămintele de ape hipertermale din Nord-Vestul României (Hyperthermal water deposits in North-West Romania).* Publishing House Academy Republic Socialist Romania, Bucharest.

347. Teodoreanu, E. (1983), Muzele şi vremea (Muses and the weather). *Publishing House Albatross. Bucharest.*

348. Teodoreanu, E. (1994), Caracteristici bioclimatice ale perioadei reci a anului (Characteristics bioclimatic conditions of the period cold a of the year), *SCG, XLI*.

349. Teodoreanu, E. (1995), Thermal Comfort in Romania as a Function of Solar Radiation. *Revue Roumaine de Géologie, Géophysique et Géographie,* 39.

350. Teodoreanu, E. (2002), *Bioclimatologie Umană (Bioclimatology Human).* Publishing House Academy Romanian.

351. Teodoreanu, E. (2004), Geografie medicală (*Medical Geography).* Publishing House. Academy Romanian, Bucharest.

352. Teodoreanu, E. (2015a), *Bioclimatologie umană în România (Bioclimatology humanity in Romania).* Outline History. *Studies and communications. Romanian Academy,* 8(8): 203–212.

353. Teodoreanu, E. (2015b), "Wind-Chill" bioclimatic index. *Present Environment and Sustainable Development,* 9: 237–242.

354. Teodoreanu, E. and Agache, I. (2009), The Balneary and Climatic Potential of Oglinzi Resort. *Present environment and sustainable development,* 3: 107–112.

355. Teodoreanu, E., Dacos -Swoboda, M., Ardeleanu, C. and Enache, L. (1984), *Bioclima staţiunilor balneoclimatice din România* (*Bioclima resorts balneoclimatic resorts in Romania).* Sport- Tourism Publishing House, Bucharest.

356. Teodoreanu, E. and Gaceu, O. (2013), *Turismul balneoclimatic în România (Tourism balneary in Romania).* Publishing house University of Oradea.

357. Teodoreanu, E. and Mihăilă, D. (2012), Is the Bioclimate of the Suceava Plateau Comfortable or Uncomfortable? Analysis Based on Wind Cooling Power Index and Skin and Lung Stress Index. *Present environment and sustainable development,* (1): 229–251.

358. Terjung, W.H. (1966), Physiologic Climates of the Conterminous United States: A Bioclimatic Classification Based on Man. *Annals of the Association of American Geographers,* 56(1): 141–179.

359. Thom, E.C. (1959), The Discomfort Index. *Weatherwise,* 12(2): 57–61.

360. Torres -Pruñonosa, J., Raya, JM, Crespo- Sogas, P. and Mur-Gimeno, E. (2022), The Economic and Social Value of Spa Tourism: The Case of Balneotherapy in Maresme, Spain. *PLOS ONE,* 17(1): e0262428.

361. Trașcă-Chiriță, N. (2016), Petrolul din șist (Oil from shale). *Art-Emis Academy Magazine.* available at http:// www.art - emis.ro / stiinta /3431 – oil – from – shale – 1.html

362. Trif, O. (2010), Studiul condiţiilor bioclimatice ale Dealurilor Crişene şi Silvano-Someşene şi influenţa lor asupra organismului uman (The study conditions bioclimatic conditions of the Hills Crisene and Silvano- Somesene and their influence on body human). Doctoral thesis summary, University of Oradea.

363. Trip, D.T., Simuț, R. and Badulescu, D. (2023), Do Size and Ownership Determine the Willingness for Sustainable Innovations in Spa and Health Tourism? A Case Study on Baile Felix Spa Resort, Romania. *Sustainability,* 15(19): 14501.

364. Turtureanu, A.G. (2011), Directions of Development of the Romanian SPA Tourism. *EIRP Proceedings,* 19(2).

365. Turtureanu, A.G. and Chitu, F. (2020), The Evolution of Balneary Tourism in Romania as an Integrated Part of Health Tourism. *EIRP Proceedings,* 15(1).

366. Ţuţui, D. (2016), Tourism Development between Potential and Strategies. The Case of Balneary Tourism. Annals of the University of Oradea, Fascicle: Ecotoxicology, Animal Husbandry and Food Industry Technologies, Vol. 15, No. A, 123-130 ref. 18.

367. Uivarosan, D., Abdel-Daim, M.M., Endres, L., Purza, L., Iovan, C., Bungau, S., Furău, C.G. and Tit, D.M. (2018), Effects of a Proteic Swine Extract Associated to Recovery Treatment on Functional Independence and Quality of Life in Patients Post Stroke. *Pharmacy,* 66(5): 826–830.

368. Uivaroșan, D., Tiț, D.M., Iovan, C., Nistor- Cseppento, D.C., Endres, L., Lazar, L., Sava, C., Sabau, A.M., Buhas, C., Moleriu, L.C., Bungau, S. and Aleya, L. (2019), Effects of Combining Modern Recovery Techniques with Neurotrophic Medication and Standard Treatment in Stroke Patients. *Science of The Total Environment,* 679: 80–87.

369. Ujvari, I. (1972), *Geografia apelor României (Geography of Romanian Waters).* Scientific Publishing House, Bucharest.

370. Ungureanu, A.E., Stanciu, L.E., Uzun, A.B., Gheorghe, E., Pazara, L., Miclaus, S.R., Ciortea, V.M., Suceveanu, AI and Iliescu, M.G. (2023), Multidisciplinary non-pharmacological treatments with effects on pain modulation and functioning in spondyloarthropathies–a systematic review. *Balneo & PRM Research Journal,* 14(3).

371. Van der Zee-Neuen, A., Strobl, V., Dobias, H., Fuchs, J., Untner, J., Foisner, W., Knapp, M., Edtinger, S., Offenbächer, M., Ritter, M., Hölzl, B. and Gaisberger, M. (2022), Sustained Improvements in EQ- 5D Utility Scores and Self-Rated Health Status in Patients with Ankylosing spondylitis. Spondylitis after Spa Treatment Including Low-Dose Radon – an Analysis of Prospective Radon Indication Registry Data. *BMC Musculoskeletal Disorders,* 23(1): 743.

372. Vannucci, L., Fossi, C., Quattrini, S., Guasti, L., Pampaloni, B., Gronchi, G., Giusti, F., Romagnoli, C., Cianferotti, L., Marcucci, G. and Brandi, ML. (2018), Calcium Intake in Bone Health: A Focus on Calcium-Rich Mineral Waters. *Nutrients,* 10(12): 1930.

373. Verhagen, A., Bierma-Zeinstra, S., Lambeck, J., Cardoso, JR, Rob, de B., Boers, M. and Henrica, CW de V. (2008), Balneotherapy for Osteoarthritis. A Cochrane Review. *The Journal of Rheumatology,* 35(6): 1118–1123.

374. Verhagen, A.P., Bierma-Zeinstra, S.M., Boers, M., Cardoso, J.R, Lambeck, J, Rob, de B. and Henrica, C.W de V. (2015), Balneotherapy (or Spa Therapy) for Rheumatoid Arthritis. *The Cochrane Database of Systematic Reviews,* 2015(4): CD000518.

375. Vernesu, M. (1988), Apele minerale (*Waters minerals).* Technical Publishing House, Bucharest.

376. Vescovi, PP, Gerra, G., Pioli, G., Pedrazzoni, M., Maninetti, L. and Passeri, M. (1990), Circulating Opioid Peptides during Thermal Stress. *Hormone and Metabolic Research, Hormon -Und Stoffwechselforschung; Hormones and Metabolism,* 22(1): 44–46.

377. Vierck, C.J. (2006), Mechanisms Underlying Development of Spatially Distributed Chronic Pain (Fibromyalgia). *Pain,* 124(3): 242–263.

378. Vincent, L.A., Wijngaarden, W. Van and Hopkinson, R. (2007), Surface Temperature and Humidity Trends in Canada for 1953-2005. *Journal of Climate,* 20(20): 5100–5113.

379. Vlăduț, A. (2015), Bioclimatic Stress within the Getic Subcarpathians, Museum Oltenia Craiova. Oltenia. Studies and communications. Natural Sciences. Vol. 31 (1):187–192.

380. Vlăduț, A. (2016), Thermal Comfort within Oltenia Plain. *Oltenia, Studies and Communications, Science Series Nature,* 32(1): 115-121.

381. Vlăduţ, A. (2011), Temperature-Humidity Index (THI) within the Oltenia Plain between 2000 and 2009. Geographical Forum, Citeseer 1(1): 149-156.

382. Vlaicu, M., Drăgan, O., Baias, S. and Gaceu, O. (2016), The Balneoclimatic Resort Stâna de Vale-Past, Present Perspectives. *Annals University of Oradea,* XXVI.

383. Wertheimer, M., (1853), Descrierea tuturor apelor minerale (The description of all mineral waters), Bucharest, Typografia Sf. Mitropolii.

384. Wójcik, M., Placek, K., Drejza, M., Goździewicz, T., Pisarska-Krawczyk, M., Luwański, D., Plagens-Rotman, K., Kędzia, W. and Jarząbek-Bielecka, G. (2023), Application of Balneoclimatology and Physiotherapy in Endometriosis. *Acta Balneologica,* 178(6).

385. Wray, M. and Weiler, B. (2013), Wellness Tourism: The Factors and Processes That Drive Sustainable Regional Destinations. *Wellness Tourism:* 78–98.

386. Wu, Y., Jing, W., Liu, J., Ma, Q., Yuan, J., Wang, Y., Du, M. and Liu, M. (2020), Effects of Temperature and Humidity on the Daily New Cases and New Deaths of COVID-19 in 166 Countries. *Science of the Total Environment,* 729: 139051.

387. Wynn, E., Krieg, M.A., Aeschlimann, J.M. and Burckhardt, P. (2009), Alkaline Mineral Water Lowers Bone Resorption Even in Calcium Sufficiency: Alkaline Mineral Water and Bone Metabolism. *Nursing,* 44(1): 120–124.

388. Yeğin, T., Altan, L. and Kasapoğlu Aksoy, M. (2017), The Effect of Therapeutic Ultrasound on Pain and Physical Function in Patients with Knee Osteoarthritis. *Ultrasound in Medicine & Biology,* 43(1): 187–194.

389. Yurtkuran, M., Yurtkuran, M., Alp, A., Nasırcılar, A., Bingöl, Ü., Altan, L. and Sarpdere, G. (2006), Balneotherapy and Tap Water Therapy in the Treatment of Knee Osteoarthritis. *Rheumatology International,* 1(27): 19–27.

390. Zajac, D. (2021), Inhalations with Thermal Waters in Respiratory Diseases. *Journal of Ethnopharmacology,* 281: 114505.

391. Zámbó, L., Dékány, M. and Bender, Tamás (2008), The Efficacy of Alum-Containing Ferrous Thermal Water in the Management of Chronic Inflammatory Gynecological Disorders-a Randomized Controlled Study. *European Journal of Obstetrics & Gynecology and Reproductive Biology,* 140(2): 252–257.

392. Zamfir, C. (2018), Tranziția la o Românie modernă de tip occidental (The transition to a modern Western-style Romania). *Romanian Sociology,* 16(1–6): 101–154.

393. Zaninović, K. and Matzarakis, A. (2007), Biometeorological Basis for Tourism, 257–265, in: *Tourism and Recreation.*

394. Zapolski, T., Kornecki, W. and Jaroszyński, A. (2024), The Influence of Balneotherapy Using Salty Sulfide–Hydrogen Sulfide Water on Selected Markers of the Cardiovascular System: A Prospective Study. *Journal of Clinical Medicine,* 13(12): 3526.

395. Zhang, W., Moskowitz, R.W., Nuki, G., Abramson, S., Altman, R.D., Arden, N., Bierma-Zeinstra, S., Brandt, K.D., Croft, P., Doherty, M., Dougados, M., Hochberg, M., Hunter, D.J., Kwoh, K., Lohmander, L.S. and Tugwell, P. (2008), OARSI Recommendations for the Management of Hip and Knee Osteoarthritis, Part II: OARSI Evidence-Based, Expert Consensus Guidelines. *Osteoarthritis and Cartilage,* 16(2): 137–162.

396. Ziemska, J., Szynal, T., Mazańska, M. and Solecka, J. (2019), Natural Medicinal Resources and Their Therapeutic Applications. *Roczniki Panstwowego Zakladu Hygiene,* 70(4): 407–413.

Works by collectives of authors

397. *** (1960) *Monografia Geografică a Republicii Populare Române (Geographical Monograph of the Romanian People's Republic)*, Physical Geography, vol. I, 742 pages.

398. *** (1962), *Clima R. P. Române (Climate of the Romanian Republic*), Meteorological Institute, Bucharest, vol. I, 164 pages.

399. *** (1968), *Monografia hidrologică a bazinului hidrografic Crișuri, Studii de hidrologie (Hydrological monograph of the Crișuri hydrographic basin, Hydrological Studies*), XXIV, IMH, Bucharest, 235 pages.

400. *** (1982), *Enciclopedia geografică a României (Geographical Encyclopedia* of Romania), Encyclopedic Publishing House, București 848 pages.

401. *** (1983), *Geografia României, Geografia fizică (Geography of Romania, Physical Geography*), vol. I, Romanian Academy Publishing House, vol. I, 663 pages.

402. *** (1987), *Geografia României, Carpații românești și Depresiunea Transilvaniei (Geography of Romania, Romanian Carpathians and the Transylvanian Depression),* Publishing House of the Academy of the Socialist Republic of Romania, vol. III, 655 pages.

403. *** (1992), *Geografia României, Regiunile pericarpatice: Dealurile și Câmpia Banatului și Crișanei, Podișul Mehedinți, Subcarpații, Piemontul Getic, Podișul Moldovei* (*Geography of Romania, Pericarpathian Regions: Hills and Plain of Banat and Crișana, Mehedinți Plateau, Subcarpathians, Getic Piedmont, Moldavian Plateau),* Romanian Academy Publishing House, vol. IV, 580 pages.

404. *** (2008), *Clima României (Climate of Romania*), National Meteorological Administration, Romanian Academy Publishing House, Bucharest, 308 pages.

405. *** (2010), *Monografia județului Bihor (Bihor County Monograph*y), Arca Publishing House, University Publishing House, Oradea, 290 pages.

Official documents and technical reports

406. Local development strategy 2014-2020 of the commune of Sălard

407. Test report Aleșd, 2015, SC. Compania de Apă Oradea SA. (SC. Oradea Water Company SA).

408. Test report Beiuș, 2018, SC. Compania de Apă Oradea SA. (SC. Oradea Water Company SA).

409. Test report Marghita, 2016, SC. Compania de Apă Oradea SA. (SC. Oradea Water Company SA).

410. Test report Mădăras, 2014, National Institute of Recovery, Physical Medicine and Balneoclimatology.

411. Test report Livada de Bihor, 2010, SC. Compania de Apă Oradea SA. (SC. Oradea Water Company SA).

412. Test report Ștei, 2021, SC. Compania de Apă Oradea SA. (SC. Oradea Water Company SA).

Legislative and regulatory documents

Directives

413. Council Directive 80/777/EEC of 15 July 1980, on the harmonisation of the laws of the Member States relating to the exploitation and marketing of natural mineral waters available at http://data.europa.eu/eli/dir/1980/777/oj (accessed 5 June 2022).

414. Directive 2009/54/EC of the European Parliament and of the Council of 18 June 2009 on the exploitation and marketing of natural mineral waters, https://eur-lex.europa.eu/legal-content/RO/TXT/?uri=CELEX:32009L0054 (accessed 5 January 2022).

Laws

415. **Law no. 275 of 27 November 2020** amending and supplementing the Mining Law no. 85/2003. Published in the Official Gazette no. 1166 of 2 December 2020, https://legislatie.just.ro/Public/DetaliiDocumentAfis/234018 (accessed 15 March 2022).

416. **Law No. 326 of October 1, 2019** on hydromineral resources. Published in Official Gazette of Romania, Part I , no. 815 of October 8, 2019, https://www.senat.ro/Legis/PDF/2019/19L326CR.pdf?nocache=true (accessed July 19 , 2022).

417. **Law no. 458 of July 8, 2002** (republished) on the quality of drinking water, published in the Official Gazette no. 875 of December 12, 2011, https://legislatie.just.ro/Public/DetaliiDocument/37723 (accessed March 15, 2022).

418. **Law No. 61 of March 5, 1998,** the Mining Law, published in the Official Gazette No. 113 of March 16, 1998, https://legislatie.just.ro/Public/DetaliiDocument/14244 (accessed April 29, 2022).

Substantiation Notes and Government Decisions

419. **Government Decision No. 1020 of September 1, 2005** for endorsement norms operating techniques and water marketing MINERAL natural. Published The Monitor Official No. 854 of September 22, 2005, https:// www.namr.ro /wp-content/uploads/2013/02/hotarare1020.pdf (accessed January 21, 2022).

420. **Government Decision No. 120 of February 17, 2010** on the approval of the List including tourism investment programs and projects and sources of financing for technical documentation and execution works of tourism investment programs and objectives. Published in Official Gazette No. 126 of February 24, 2010, https://www.namr.ro/wp-content/uploads/2013/02/hotarare1020.pdf (accessed on January 15, 2022).

421. **Government Decision No. 343 of March 19, 2021** for approving the certification of some localities or parts of localities as tourist resorts of local interest and regarding the amendment of Annex no. 5 to Government Decision no. 852/2008 for approving the norms and criteria for certification of tourist resorts (Salonta, Săcueni), Published in the Official Gazette no. 291 of March 23, 2021. https://legislatie.just.ro/Public/DetaliiDocumentAfis/239877 (accessed on December 16, 2022).

422. **Government Decision No. 532 of June 2, 2010** regarding the amendment and completion of the Technical Norms for the exploitation and marketing of natural mineral waters, approved by Government Decision no. 1,020/2005. Published in Official Gazette No. 400 of June 16, 2010, https://legislatie.just.ro/Public/DetaliiDocument/119587 (accessed January 21, 2022).

423. **Government Decision no. 852 of August 13, 2008** for the approval of the norms and criteria for the certification of tourist resorts. Published in the Official Gazette no. 613 of August 20, 2008, https://legislatie.just.ro/public/DetaliiDocument/96733 (accessed March 15, 2022).

424. **Government Decision no. 887 of October 22, 2020** for the approval of the certification of some localities or parts of localities as tourist resorts of national or local interest (tourist area of Borș, Știei commune) and for the amendment of Annex no. 5 to Government Decision no. 852/2008 for the approval of the norms and criteria for the certification of tourist resorts. Published in the Official Gazette no. 985 of October 26, 2020, https://legislatie.just.ro/Public/DetaliiDocument/257607 (accessed December 16, 2022).

425. **Government Decision No. 910 of July 13, 2022** for the approval of the certification of some localities as tourist resorts of national and local interest, respectively, and regarding the amendment of Annex no. 5 to Government Decision no. 852/2008 for the approval of the

norms and criteria for the certification of tourist resorts. Published in the Official Gazette no. 718 of July 18, 2022, https://legislatie.just.ro/Public/DetaliiDocumentAfis/257598 (accessed December 16, 2022).

426. **Government Decision No. 898 of July 13, 2022** for amending Government Decision no. 1,016/2011 on granting the status of spa and balneoclimatic resort to some localities and areas that have natural healing factors Published in the Official Gazette no. 715 of July 15, 2022, https://legislatie.just.ro/Public/DetaliiDocument/257580 (accessed December 16, 2022).

427. **Government Decision no. 1073 of 2020,** regarding the approval of the certification of some localities as tourist resorts of local interest and for the amendment of Annex no. 5 to Government Decision no. 852/2008 for the approval of the norms and criteria for the certification of tourist resorts. Published in the Official Gazette no. 1288 of December 24, 2020, https://legislatie.just.ro/Public/DetaliiDocumentAfis/235613 (accessed December 16, 2022).

428. **Government Decision no. 1580 of December 28, 2022** for the approval of the certification of some localities or parts of localities as tourist resorts of local interest, as well as regarding the amendment of art. 2 and annex no. 5 to Government Decision no. 852/2008 for the approval of the norms and criteria for the certification of tourist resorts, https://legislatie.just.ro/Public/DetaliiDocumentAfis/263633 (accessed April 16, 2022).

429. **Government Decision no. 377 of May 7, 2020** approving the certification of some localities or parts of localities as tourist resorts of national and local interest and amending Annexes no. 1 and 5 to Government Decision no. 852/2008 approving the norms and criteria for certification of tourist resorts. Published in the Official Gazette no. 384 of May 13, 2020, https://legislatie.just.ro/Public/DetaliiDocumentAfis/225539 (accessed December 16, 2022).

430. **Explanatory note to Government Decision no. 1580/2022** for the approval of the certification of some localities or parts of localities as tourist resorts of local interest, as well as for the amendment of art. 2 and annex no. 5 to Government Decision no. 852/2008 for the approval of the norms and criteria for the certification of tourist resorts, https://gov.ro/ro/guvernul/procesul-legislativ/note-de-fundamentare/nota-de-fundamentare-hg-nr-1580-28-12-2022&page=6 (accessed on April 29, 2022).

431. **Explanatory note to Government Decision no. 910 of July 13, 2022** for the approval of the certification of some localities as tourist resorts of national and local interest, respectively, and regarding the amendment of Annex no. 5 to Government Decision no. 852/2008 for the approval of the norms and criteria for the certification of tourist resorts, https://gov.ro/ro/guvernul/procesul-legislativ/note-de-fundamentare/nota-de-fundamentare-hg-nr-910-13-07-2022&page=61 (accessed March 1, 2022).

432. **Explanatory note to Government Decision no. 343 of March 19, 2021** for the approval of the certification of some localities or parts of localities as tourist resorts of local interest and for the amendment of Annex no. 5 to Government Decision no. 852/2008 for the approval of the norms and criteria for the certification of tourist resorts, https://gov.ro/ro/guvernul/procesullegislativ/note-de-fundamentare/nota-de-fundamentare-hg-nr-343-19-03-2021&page=111 (accessed March 1, 2022).

433. **Explanatory note to Government Decision no. 377/2020** for the approval of the certification of some localities or parts of localities as tourist resorts of national and local interest and for the amendment of annexes no. 1 and 5 to Government Decision no. 852/2008 for the approval of the norms and criteria for the certification of tourist resorts, https://gov.ro/ro/guvernul/procesullegislativ/note-de-fundamentare/nota-de-fundamentare-hg-nr-377-07-05-2020&page=55 (accessed on April 19, 2022).

434. **Explanatory note to Government Decision no. 887 of October 22, 2020** for the approval of the certification of some localities or parts of localities as tourist resorts of national or local

interest and for the amendment of Annex no. 5 to Government Decision no. 852/2008 for the approval of the norms and criteria for the certification of tourist resorts, https://gov.ro/ro/guvernul/procesullegislativ/note-de-fundamentare/nota-de-fundamentare-hg-nr-887-22-10-2020&page=9 (accessed March 15, 2022).

435. **Explanatory note to Government Decision no. 1,073 of December 11, 2020** regarding the approval of the certification of some localities as tourist resorts of local interest and for the amendment of Annex no. 5 to Government Decision no. 852/2008 for the approval of the norms and criteria for the certification of tourist resorts, https://gov.ro/ro/guvernul/procesullegislativ/note-de-fundamentare/nota-de-fundamentare-hg-nr-1073-11-12-2020&page=18 (accessed March 15, 2022).

436. **Explanatory note to Government Decision no. 1580/2022** for the approval of the certification of some localities or parts of localities as tourist resorts of local interest, as well as for the amendment of art. 2 and annex no. 5 to Government Decision no. 852/2008 for the approval of the norms and criteria for the certification of tourist resorts, https://gov.ro/ro/guvernul/procesul-legislativ/note-de-fundamentare/nota-de-fundamentare-hg-nr-1580-28-12-2022&page=6 (accessed on April 29, 2022).

Ministerial order

437. **Order No. 87 of May 20, 2008** for the approval of the Technical Instructions on the classification and evaluation of resources/reserves of natural mineral water, therapeutic mineral water, geothermal water, and the gases that accompany them and non - combustible gases. Published in the Official Gazette no. 403 of 29 May 2008, https://www.namr.ro/wp-content/uploads/2013/02/ ordin87.pdf (accessed 18 May 2022).

STAS, codes, agreements

438. STAS 4621-69, Surface water, groundwater and wastewater. Determination of residues. Romanian Standardization Association: (Romanian Standardization Association): Bucharest, Romania, 1984.

439. SR EN ISO 19458/2007 Quality water. Sampling for analysis microbiological. Standardization Association from Romania, Bucharest (Mohr Method).

440. Agreement no. 85/07.07.2021- Ethics Committee of the Băile Tinca Resort.

Webography

441. www.alesd-bihor.ro (accessed on May 15, 2022).

442. www.anpm.ro (accessed on June 28, 2021).

443. www.antena3.ro (accessed on February 2, 2023).

444. www.arenaconstruct.ro (accessed on April 7, 2025).

445. www.bailetinca.ro (accessed on October 15, 2021).

446. www.beyuscosmetics.com (accessed on March 1, 2023).

447. www.cherechiu.ro (accessed on April 2022).

448. www.comunabalc.ro (accessed on January 2022).

449. www.consiliulconcurentei.ro (accessed on May 15, 2021).

450. www.ebihoreanul.ro (accessed on April 4, 2021).

451. www.eea.europa.eu /en/ datahub (accessed on January 23, 2025).
452. www.fao.org (accessed 19 January 2025)
453. www.geomorphologyonline.com (accessed on January 15, 2025).
454. www.icpa.ro (accessed on May 15, 2021).
455. www.istorielocala.ro (accessed on June 6, 2020).
456. www.kmnp.hu (accessed on July 5, 2021).
457. www.merckgroup.com (accessed May 5, 2022).
458. www.meteomanz.com (accessed 25 May 2021).
459. www.mmediu.ro (accessed July 8, 2021).
460. www.municipiulbeius.ro (accessed on May 15, 2021).
461. www.namr.ro (accessed on June 1, 2021).
462. www.oradea.ro (accessed on May 15, 2021).
463. www.parcapuseni.ro (accessed on May 15, 2021).
464. www.primariabors.ro (accessed on May 15, 2021).
465. www.primariamarghita.ro (accessed on May 15, 2021).
466. www.primariasantandrei.ro (accessed on May 15, 2021).
467. www.rowater.ro (accessed on January 6, 2025).
468. www.sacueni.ro (accessed on June 6, 2020).
469. www.synergytherm.com (accessed on May 5, 2022).
470. www.tbrcm.ro / tratament.php (accessed on June 6, 2020).
471. www.turism.gov.ro (accessed on April 18, 2021).
472. www.urban.ro (accessed on September 15, 2021).
473. www.uvvg.ro (accessed on June 6, 2020).
474. www.wwf.ro (accessed on December 6, 2019).

Synthesis of author's research contribution to thesis development

The thesis research activity was carried out over a period of five years (2020-2024), aimed at outlining the balneoclimatic potential, as well as its exploitation for therapeutic, prophylactic and recreational purposes in the Bihor County area.

The important personal contributions in the thesis are presented in the order of succession in the thesis:

I identified and inventoried all the thermomineral sources in Bihor County through field documentation. This process involved approaching and reviewing each location and administrative entity by physically visiting the site, an effort that I carried out over a span of four years. I conducted interviews with administrative representatives of the balneary sources (mayors, private administrators, local residents) and completed the Hydro-Mineral Resource Location Sheet for each site I visited. In this way, I analyzed the actual situation of the balneary resources in Bihor County.

I assessed the balneary and tourist infrastructure of the balneary resorts and of the small rural and urban localities that exploit thermomineral water throughout the studied area.

I created a database on the physicochemical properties of thermal resources based on testing reports and specialized literature, regardless of the period in which they were produced. This centralized information includes 20 localities with hydro-mineral sources, some of which are not included in the national tourism circuit. These properties provide different degrees of adaptability for pathologies that require balneary therapeutic procedures.

I identified development prospects for the balneary resources in rural and small urban localities, with potential for immediate balneary exploitation due to the similarity in the characteristics of geothermal resources, which are dependent on the connection between aquifers. This could transform a locality with geothermal potential into a balneary destination that should be integrated into the national and potentially even the international tourism circuit.

I collected mineral water samples during two sampling sessions, following established protocols, to conduct chemical analyses of three cold mineral water sources in order to determine their chemical composition and microbiological load. The samples came from three mineral water sources (Pădurea Neagră, Sântimreu, Tămășeu). The analyses were carried out by the Bihor Public Health Directorate.

I carried out the climatic characterization of Bihor County by analyzing a long series of meteorological data (1961-2020) from nine meteorological stations. The climate data included monthly air temperature (°C), wind speed (m/s), atmospheric pressure (mm/Hg), and relative

humidity (%), which were used to determine the particularities of the thermal regime, air humidity characteristics, pluviometric regime, and wind regime.

I applied two sets of questionnaires, in separate studies. One study included clinical evaluation, tracking various parameters in patients with knee osteoarthritis to assess the effects of balneotherapy. The other set of questionnaires targeted public perception regarding the quality and health effects of cold mineral waters from three sources in the county (Pădurea Neagră, Tămășeu, Sântimreu).

I conducted a pilot study aimed at demonstrating whether two weeks of balneotherapy is superior to conventional physiotherapy for patients with knee osteoarthritis. This was carried out at Băile Tinca and at the Fizio Help Med Salonta medical recovery clinic. The study involved evaluating a sample of 102 patients (49 in the experimental group and 52 in the control group) before and after treatment, revealing the efficacy of balneotherapy with mineral water in patients with gonarthrosis.

I performed statistical analysis of data centralized from patient registries from 2010 to 2020 and the annual summary registry for 2020 from the Treatment and Work Capacity Recovery Society (Hotel Ceres) in Băile 1 Mai. This analysis led to a classification of patient profiles and the types of pathologies for which balneotherapy was prescribed.

I analyzed the bioclimatic potential of Bihor County with the aim of identifying the variation in bioclimatic characteristics by processing relevant bioclimatic indices for balneotherapy and balneary tourism. These indices were calculated using mathematical formulas based on variables such as temperature, humidity, wind speed, and atmospheric pressure, taken from nine meteorological stations located within and around Bihor County, for the period 1961-2020. The 60-year period was divided into two 30-year intervals to allow a comparative analysis of the bioclimatic indices and the bioclimatic classification of localities with hydro-mineral resources.

I conducted a socio-economic analysis of hydro-mineral resources, which led to the identification of several aspects regarding the classification of administrative management forms of balneary resources. I identified alternative ways of utilizing thermal water in rural localities and in the new tourist resorts of Bihor County. I noted the sustainability risk of exploiting balneary resources in rural areas and classified localities based on their current stage of resource exposure.

I analyzed the current exploitation of hydro-mineral resources and the tourist and balneary infrastructure in balneary and tourist resorts, as well as in localities with balneary resources.

I identified localities with immediate balneary exploitation potential, based on the physicochemical properties, type, flow rate, and temperature of the hydrothermal resource.

Valorization of research activity

The research results were materialized through participation in various scientific events, where the study's contributions were presented and published:

Articles published in ISI-listed or BDI-indexed scientific journals:

Borze, Theodora Florica; Pallag, Anamaria; Ciobanu, Doriana; Kalman, Klara; **Ciurba, Anca-Paula;** Suciu, Ramona; Mureșan, Mariana și Nistor-Cseppento, Carmen Delia (2025), *The Influence of Rehabilitation Programs on the Mental State and Quality of Life in Patients with Fibromyalgia: A Comparative Cohort Study from Romania*. International Journal of Environmental Research and Public Health. 2025; 22(10):1553 (*ISI, IF = 4,6).*

Ciurba, Anca-Paula; Aur, Cristina; Linc, Ribana (2025), *Balneo physio ginecology în Bihor County,* Roumanian Journal of Physical Therapy, 31(54), 14–19, *(BDI: ERIH PLUS, INDEX COPERNICUS, DOAJ, EBSCO, Crossref, Academic Journals Database, WorldCat, EuroPub, Scipio, ROAD).*

Ciurba (Pastor) Anca-Paula., Haidu Ionel, Sîrbu Elena, Gavril Gavriliu Adrian, Marcu Florin, Motofelea Adrian, Boca Ioan-Cosmin, Ianc Dorina (2023), *The Impact of Mineral Water Balneotherapy on Pain and Physical Function in Patients with Knee Osteoarthritis: A Pilot Study*, Balneo and Prm Research Journal, vol.14 (4): 597 DOI 10.12680/balneo.2023.597**,** *(ISI, IF = 0,7).*

Linc Ribana, Pantea Emilia, Șerban Eugenia, **Ciurba (Pastor) Anca-Paula,** Șerban Georgeta (2023), *Hydrochemical and Microbiological Investigations and the Therapeutic Potential of Some Mineral Waters from Bihor County, Romania*, Sustainability, DOI: 10.3390/su152115640 *(ISI, IF = 3,3).*

Haidu Ionel, **Ciurba (Pastor) Anca-Paula**, Ianc Dorina, Gaceu Ovidiu Răzvan (2023), *75 localities with geothermal water in Bihor County (Romania) and the potential for the sustainability of balneology,* Present Environment and Sustainable Development, vol 17 (2): DOI: 10.47743/pesd2023172013, *(ISI, IF = 0,5).*

Ciurba Anca-Paula, Haidu Ionel, Ianc Dorina (2023), *Administrative Aspects Regarding the Valorisation of Geothermal Waters for Balneological Purposes in Bihor County*, *Romania*, Sustainability, vol.15(13):10320. DOI 10.3390/su151310320, *(ISI, IF = 3,3).*

Ciurba (Pastor) Anca-Paula, Haidu Ionel, Gaceu Ovidiu, Aur Cristina (2023), *Therapeutic valorisation of thermal waters from rural locations of Bihor County*, the 15th edition of the International Conference Air and Water-Components of the Environment, Cluj-Napoca, 200-212, DOI: 10.24193/AWC2023_20, *(BDI: DOAJ, Google scholar, Ulrichsweb, ProQuest).*

Ciurba (Pastor) Anca-Paula., Haidu Ionel, Gaceu Ovidiu, Biriș (Matei) Mihaela, Meșter Cosmin, Ianc Dorina (2022), *The Thermal Water in Bihor County and its Benefits for Treating Arthritis. a Case Study: Băile 1 Mai Resort*, the 14th edition of the International Conference Air and Water-Components of the Environment, Cluj-Napoca *(BDI: DOAJ, Google scholar, Ulrichsweb, ProQuest).*

Studies presented at national and international conferences and world congress:

Ciurba A-P., Haidu I., Linc R., Gaceu O. (2024), *Localities with geothermal water in bihor county and the sustainability potential of balneology. Case study: locality with balneary function - Sarcău,* The Conference Atmosphere and Hydrosphere, 31 oct-3 nov, 6 th edition, Vatra Dornei.

Linc R., Pantea E., Șerban E., **Ciurba A.**, Șerban G. (2024), *Therapeutic Potential, Hydro-chemical and Microbiological Investigations of Certain Mineral Waters from Bihor County,* The annual international scientific paper presentations session of geography students "60 years of geographic academic education at the University of Oradea", 3-6 oct, Stâna de Vale.

Ciurba A-P, Aur C, Linc R**.** (2024), *Balneo-physio-gynecology in Bihor County*, The international scientific conference Physical Education, Sports and Physiotherapy in The Benefit of Health, 25-26 oct, Oradea, România.

Ciurba A-P. (2024), *Balneary and recreation aspects of new tourist resorts in bihor county. Tourist resources and infrastructure,* Spring Dialogues, Green and blue infrastructure: pathways to urban sustainability, Cycle of international meeting swith experts, 1st edition, 23 May, Italy.

Ciurba A- P, Ianc D., Avram C., Drăgoi R.G., Sîrbu E. (2023), *The effect of thermal mineral bathing and joint mobilization techniques on patients with knee osteoarthritis*, World Congress on Osteoporosis, Osteoarthritis and Musculoskeletal Diseases, Barcelona 4-7 May *(published summary).*

Ciurba (Pastor) A-P, Haidu I., Gaceu O., Aur C. (2023), *Therapeutic valorisation of thermal waters from rural locations of Bihor County*, the 15th edition of the International Conference Air and Water-Components of the Environment, May 22-23, Faculty of Geography and Air and Water Association, Babeș-Bolyai University.

Ciurba (Pastor) A-P, Linc R., Gaceu O. (2022), *The spa-based and leisure profile of the tourist resorts in Bihor County, An inventory of tourist resources and infrastructures*. The Conference-with international participation Atmosphere and Hydrosphere, Vatra Dornei, 06-09 October.

Ciurba A-P (2022), with the paper *The Evolution of the „balneary phenomenon" in Bihor County*. Anniversary session of scientific communications of geography students, Stâna de Vale, July 21-23.

Ciurba Anca-Paula, Gavril Adrian Gavriliu, Berdie Daniela, Ianc Dorina (2022), *The effectiveness of hot mineral water and physiotherapy for increasing sleep quality and decreasing pain intensity in patients with knee osteoarthritis*, International Conference on Physiotherapy, Physical Activity and Health, The 44th Edition, University of Oradea, Romania, 14-15 October.

Abstract

This thesis represents an in-depth interdisciplinary and transdisciplinary study of the balneoclimatic potential of Bihor County, highlighting its strategic role for socio-economic development, public health, and balneal tourism. The research is based on a solid theoretical foundation, demonstrating the richness and diversity of the county's hydromineral resources, as well as a favorable bioclimatic environment. The paper emphasizes the geological and geographical conditions that support the existence of thermal and mineral waters in 81 localities, predominantly concentrated in plain areas. The historical and scientific evolution of balneology and bioclimatology is also presented, linking ancient practices with modern research. The adopted methodology was rigorous and complex, combining bibliographic research with extensive fieldwork over a five-year period. This included infrastructure inventory, observations, interviews, and the application of quantitative methods (clinical studies, laboratory analyses, questionnaires) and qualitative methods, as well as digital mapping using GIS. A comprehensive database was created regarding the physico-chemical properties of thermomineral waters, and the infrastructure of balneal and tourist resorts was evaluated. The analysis confirmed the therapeutic potential of mineral waters through microbiological and chemical analyses. A pilot study in Băile Tinca, on 102 patients with knee osteoarthritis, demonstrated significant improvements in pain reduction and joint mobility through balneotherapy. The thesis also analyzed meteorological data over 60 years (1961-2020) to identify the county's bioclimatic particularities, revealing a warming trend and an extension of thermal discomfort. A socio-economic analysis of hydromineral resources focused on administrative practices, alternative uses of thermal waters (heating, agriculture, cosmetics), and exploitation sustainability. Risks such as lack of investment and rural depopulation were identified, emphasizing the importance of obtaining tourist resort status for access to funds. The research identified 16 localities with intensive exploitation of balneal resources and another 15 localities with immediate valorization potential. Strategies are proposed for their integration into national and international tourist circuits, including public-private partnerships. In conclusion, Bihor County possesses a rich and underexploited balneoclimatic potential. Its sustainable management can become a key factor in regional development and public health promotion, provided that investments in infrastructure and services continue, especially in rural areas, and a strategic balance is maintained between intensive resource exploitation and their long-term protection.

Keywords: balneoclimatic, therapeutic, Romania

Résumé

Cette thèse représente une étude interdisciplinaire et transdisciplinaire approfondie du potentiel balnéoclimatique du comté de Bihor, mettant en évidence son rôle stratégique pour le développement socio-économique, la santé publique et le tourisme balnéaire. La recherche est fondée sur une base théorique solide, démontrant la richesse et la diversité des ressources hydrominérales du comté, ainsi qu'un bioclimat favorable. Le travail souligne les conditions géologiques et géographiques qui soutiennent l'existence des eaux thermales et minérales dans 81 localités, concentrées majoritairement dans les zones de plaine. L'évolution historique et scientifique de la balnéologie et de la bioclimatologie est également présentée, établissant un lien entre les pratiques empiriques de l'Antiquité et les recherches cliniques et climatologiques modernes. La méthodologie adoptée a été rigoureuse et complexe, combinant la recherche bibliographique avec une activité de terrain étendue menée sur une période de cinq ans. Cela a inclus l'inventaire de l'infrastructure, des observations, des entretiens et l'application de méthodes quantitatives (études cliniques, analyses de laboratoire, questionnaires) et qualitatives, ainsi que la cartographie numérique utilisant le SIG. Une base de données complète a été créée concernant les propriétés physico-chimiques des eaux thermominérales et l'infrastructure des stations balnéaires et touristiques a été évaluée. L'analyse a confirmé le potentiel thérapeutique des eaux minérales par des analyses microbiologiques et chimiques. Une étude pilote menée à Băile Tinca, sur 102 patients atteints d'arthrose du genou, a démontré des améliorations significatives dans la réduction de la douleur et la mobilité articulaire grâce à la balnéothérapie. La thèse a également analysé des données météorologiques sur 60 ans (1961-2020) pour identifier les particularités bioclimatiques du comté, révélant une tendance au réchauffement et à l'extension du disconfort thermique. Une analyse socio-économique des ressources hydrominérales s'est concentrée sur les pratiques administratives, les utilisations alternatives des eaux thermales (par exemple, pour le chauffage, l'agriculture, les cosmétiques) et la durabilité de leur exploitation. Des risques tels que le manque d'investissements et la dépopulation rurale ont été identifiés, soulignant l'importance d'obtenir le statut de station touristique pour l'accès aux fonds. La recherche a identifié 16 localités avec une exploitation intensive des ressources balnéaires et 15 autres localités avec un potentiel de valorisation immédiate. Des stratégies sont proposées pour leur intégration dans les circuits touristiques nationaux et internationaux, y compris des partenariats public-privé. En conclusion, le comté de Bihor possède un potentiel balnéoclimatique riche et sous-exploité. Sa gestion durable peut devenir un facteur clé du développement régional et de la promotion de la santé publique, à condition de poursuivre les investissements dans la modernisation des infrastructures et des services, en particulier dans les zones rurales, et de maintenir un équilibre stratégique entre l'exploitation intensive des ressources et leur protection à long terme.

Mots clés: balnéoclimatique, thérapeutique, Roumanie

UNIVERSITY OF ORADEA
Doctoral School of Geography,
Sports Science and Physiotherapy

UNIVERSITÉ DE LORRAINE
École doctorale Humanités Nouvelles - Fernand
Braudel, Laboratoire LOTERR

Résumé

Le potentiel balnéoclimatique du département de Bihor (Roumanie)

et sa valorisation thérapeutique

Cotutelle thesis

Coordinators:

Professor PhD **Ionel HAIDU**, Université de Lorraine, LOTERR - France
Professor PhD **Ovidiu-Răzvan GACEU**, Université d'Oradea - Roumanie

Doctorante**: Anca-Paula PASTOR (CIURBA)**

Cette thèse représente une étude interdisciplinaire et transdisciplinaire qui investigue de manière systématique le potentiel balnéoclimatique du comté de Bihor, mettant en évidence sa valeur stratégique pour le développement socio-économique, l'amélioration de la santé et le tourisme balnéaire. J'ai fondé ma recherche sur un cadre théorique et contextuel solide, démontrant que le comté de Bihor se distingue par l'abondance et la diversité de ses ressources hydrominérales, ainsi que par un bioclimat favorable. J'ai souligné les conditions géologiques et géographiques qui soutiennent l'existence des eaux thermales et minérales, réparties dans 81 localités, avec des concentrations significatives dans les zones de plaine. J'ai présenté l'évolution historique et scientifique de la balnéologie et de la bioclimatologie, établissant un lien entre les pratiques empiriques de l'Antiquité et les recherches cliniques et climatologiques modernes. J'ai choisi une méthodologie rigoureuse et complexe, qui a combiné la recherche bibliographique avec une activité de terrain étendue menée sur une période de cinq ans. J'ai inventorié et évalué la situation réelle des ressources balnéaires par le biais de documentations de terrain, d'entretiens et d'observations structurées. J'ai appliqué des méthodes quantitatives et qualitatives, y compris des études cliniques, des analyses de laboratoire, des questionnaires et une cartographie numérique à l'aide d'un SIG. J'ai créé une base de données complète sur les propriétés physico-chimiques des eaux thermominérales et j'ai évalué l'infrastructure des stations balnéaires et touristiques. J'ai analysé le potentiel thérapeutique des eaux minérales, confirmé par des analyses microbiologiques et chimiques. L'étude pilote réalisée à Băile Tinca, sur un échantillon de 102 patients atteints d'arthrose du genou, a démontré que la balnéothérapie a conduit à des améliorations significatives de la réduction de la douleur et de la mobilité articulaire, par rapport à la physiothérapie conventionnelle. J'ai analysé des données météorologiques à long terme (1961-2020) afin d'identifier les particularités bioclimatiques du comté de Bihor, par analyse des indices bioclimatiques pertinents pour la balnéothérapie et le tourisme balnéaire. De plus, j'ai effectué une analyse socio-économique des ressources hydrominérales, en me concentrant sur les pratiques administratives, les utilisations alternatives des eaux thermales (par exemple, pour le chauffage, l'agriculture, les cosmétiques) et la durabilité de leur exploitation. J'ai identifié des risques tels que le manque d'investissements, la dépopulation des zones rurales et le manque d'infrastructures. J'ai souligné l'importance d'obtenir le statut de station touristique, ce qui facilite l'accès aux fonds nationaux et européens. Ma recherche a identifié 16 localités où les ressources balnéaires sont intensivement exploitées et 15 autres localités avec un potentiel de valorisation balnéaire immédiate. J'ai proposé des stratégies pour leur intégration dans les circuits touristiques nationaux et internationaux, y compris des partenariats avec des institutions publiques. La thèse conclut que le comté de Bihor possède un potentiel balnéoclimatique riche et sous-exploité qui, s'il est géré de manière durable, peut devenir un facteur clé du développement régional et de la promotion de la santé publique.

Les caractéristiques des chapitres

Les chapitres 1 et 2 de la thèse offrent une base théorique et contextuelle solide à la recherche, en soulignant clairement l'importance du sujet abordé. Le chapitre introductif met en évidence le fait que le département de Bihor se distingue par un potentiel balnéoclimatique riche, soutenu par la diversité et l'abondance des facteurs balnéaires, tels que les ressources hydrominérales et un bioclimate favorable. Les ressources en eau géothermale du département proviennent de quatre grands gisements: Oradea - Băile Felix - Băile 1 Mai, Salonta - Ciumeghiu - Tinca, Răbăgani - Beiuș et Săcueni - Marghita - Balc, interceptés dans 75 localités, ainsi que sept sites d'eau minérale froide. L'eau géothermale a de multiples usages: en balnéothérapie, dans des activités récréatives, pour le chauffage urbain, l'agriculture (maraîchage), l'industrie dermo-cosmétique et la

pisciculture. La majorité des localités disposant de ressources balnéaires se trouvent en zone de plaine (57 localités), suivies des zones de collines (11) et des dépressions intramontagnardes (10), tandis qu'en zone montagneuse, seules 3 localités disposent de sources minérales froides – Stâna de Vale, Budureasa et Pădurea Neagră. La répartition géographique de ces ressources est donc concentrée principalement dans les zones de plaine et de collines.

Le deuxième chapitre offre un aperçu de l'évolution de la recherche dans le domaine de la balnéologie et de la bioclimatologie, depuis les utilisations empiriques de l'Antiquité jusqu'à la consécration scientifique moderne, en soulignant les contributions de personnalités et d'institutions qui ont façonné le développement de ce domaine. La tradition balnéaire bien établie du département de Bihor, ainsi que le progrès des recherches bioclimatiques, justifient le choix du sujet et soutiennent l'approche interdisciplinaire adoptée dans le travail. Depuis les observations empiriques de l'époque d'Hippocrate jusqu'aux recherches modernes menées à l'Institut de Balnéologie de Bucarest, le bioclimate a été de plus en plus reconnu comme un facteur sanogène essentiel dans la thérapie et la prophylaxie de certaines pathologies. Ensemble, ces chapitres tracent les grandes lignes de l'étude, fournissent des arguments convaincants pour la nécessité de la recherche et constituent la base théorique des étapes applicatives à suivre. Ils offrent ainsi une base solide pour la compréhension du potentiel balnéoclimatique du département de Bihor et du parcours scientifique des recherches dans ce domaine.

Le chapitre 3 est consacré à la méthodologie, qui a été complexe, rigoureuse et systématique, représentant un élément essentiel dans la structure de la thèse, offrant la base scientifique sur laquelle repose l'ensemble de la démarche de recherche. En définissant les étapes méthodologiques, la sélection rigoureuse des sources de données, la description des outils utilisés et la justification du choix des méthodes appliquées, ce chapitre assure la transparence, la reproductibilité et la validité de la recherche. La méthodologie appliquée a été structurée en étapes bien définies, intégrant à la fois des composantes théoriques et applicatives, contribuant ainsi à la validation objective des résultats. Une documentation bibliographique approfondie a fourni un cadre solide de fondement théorique, tandis que les recherches de terrain menées sur une période de cinq ans ont permis d'obtenir des données réelles, actualisées et pertinentes, incluant l'inventaire des infrastructures existantes (touristiques et balnéaires), les installations de loisirs, ainsi que le remplissage de fiches d'observation pour chaque site, contribuant à une meilleure compréhension de l'état actuel de valorisation des ressources balnéaires. La recherche a combiné des méthodes quantitatives et qualitatives, y compris des évaluations cliniques, des analyses de laboratoire, des questionnaires et des entretiens, réussissant ainsi à saisir non seulement les aspects physiques des ressources, mais aussi la perception des communautés locales. Par l'application de méthodes statistiques avancées, telles que le modèle ANOVA et l'analyse de Kaplan-Meier, des conclusions significatives ont été obtenues concernant l'efficacité des traitements balnéaires, tandis que la cartographie numérique à l'aide du SIG a contribué à une représentation spatiale claire des ressources et des indices bioclimatiques. Un autre point important a été l'implication des spécialistes et des autorités locales, ce qui a ajouté un caractère réaliste et applicable à la recherche.

Les résultats ont été valorisés par des participations à des manifestations scientifiques et par des publications dans des revues spécialisées, confirmant la pertinence et la contribution du travail au progrès des connaissances dans le domaine. Ainsi, la méthodologie adoptée a assuré une image complète et fidèle du potentiel balnéoclimatique du département de Bihor, identifiant à la fois les ressources bioclimatiques et les défis administratifs, infrastructurels et thérapeutiques pouvant influencer le développement durable de la balnéothérapie et du tourisme balnéaire dans cette région.

Le chapitre 4 prépare le contenu de la thèse en présentant les caractéristiques connues et fondamentales, car elles établissent la base géographique et géologique, facteur déterminant pour l'existence et la répartition des ressources balnéaires. Ainsi, il fournit le contexte indispensable et les arguments scientifiques nécessaires à la compréhension et à l'évaluation du potentiel balnéoclimatique. Le département de Bihor, situé dans le nord-ouest de la Roumanie, se distingue par un cadre naturel extrêmement diversifié, résultant de l'interaction entre une structure géologique complexe, un relief varié et des conditions climatiques modérées. Son territoire couvre une superficie de 7 544 km² et est bordé à l'ouest par la Hongrie, et à l'est par les départements roumains de Satu Mare, Sălaj, Cluj, Alba et Arad. Le relief est organisé en trois grandes unités: les Monts Apuseni (y compris les massifs de Bihor, Vlădeasa et Plopiș), les collines de Criș et la plaine des Crișuri, chacune avec des traits morphologiques et une genèse spécifiques. Du point de vue géologique, le département se trouve à l'intersection de trois grandes unités: les Monts Apuseni du Nord, les bassins néogènes et la dépression pannonienne. Cette position engendre une structure lithologique variée, comprenant des roches cristallines, calcaires, magmatiques, ainsi que des sédiments néogènes et quaternaires, favorisant l'apparition de reliefs karstiques, de gorges et de dépressions tectoniques. Le climat est de type tempéré-continental de transition, influencé par les masses d'air occidentales et par la barrière orographique des Apuseni. Les températures moyennes annuelles varient de plus de 10,5°C en plaine à moins de 5°C en zone montagneuse, tandis que les précipitations augmentent avec l'altitude, dépassant 1600 mm à Stâna de Vale. Cette diversité climatique influence directement la flore, la faune et les conditions de vie. Sur ce fond naturel, le département de Bihor dispose d'importantes ressources hydrominérales et balnéoclimatiques, qu'elles soient exploitées ou non. L'interaction harmonieuse entre les facteurs naturels confère à la région un potentiel sanogène élevé, avec de multiples opportunités pour un développement balnéaire durable et pour le tourisme de santé.

Le chapitre 5 met en évidence, de manière complexe et documentée, le rôle essentiel des ressources balnéaires du département de Bihor dans la constitution d'un potentiel balnéoclimatique remarquable, avec des implications significatives dans les domaines de la médecine balnéaire et du tourisme balnéaire. L'analyse a démontré que la valorisation thérapeutique des eaux minérales ne relève pas seulement d'une tradition ancienne dans la région, mais repose également sur des bases scientifiques solides, étayées par des recherches cliniques et hydrochimiques récentes. Ce chapitre souligne à quel point les caractéristiques du cadre naturel sont fondamentales pour l'existence et la valorisation des ressources balnéoclimatiques, notamment celles liées aux eaux minérales et au bioclimat. La balnéoclimatologie est définie à la fois comme une spécialité médicale importante, qui améliore la santé par des influences prophylactiques et thérapeutiques, et comme une branche essentielle du tourisme. La balnéologie étudie l'application des facteurs naturels tels que les eaux thermominérales, les gaz thérapeutiques, les boues et le bioclimat dans la pratique médicale. La balnéothérapie, grâce à ses effets prophylactiques et thérapeutiques, est considérée comme un remède ancien mais pertinent pour la santé contemporaine. Elle est reconnue au niveau international comme une approche non pharmacologique efficace pour le traitement de diverses pathologies. La valeur thérapeutique de la balnéothérapie résulte d'une combinaison d'effets mécaniques (pression hydrostatique), thermiques (température de l'eau thermominérale) et chimiques (composition chimique de l'eau ou de la boue). La pression hydrostatique et la flottabilité accrue, associées à la chaleur, induisent des modifications physiologiques bénéfiques, telles que la stimulation de la diurèse, l'amélioration du tonus musculaire, la réduction de la douleur et l'augmentation de la mobilité articulaire. La chaleur peut également influencer la sécrétion hormonale (ACTH, cortisol, prolactine, hormone de croissance). La communauté

scientifique a accumulé de nombreuses preuves attestant de l'efficacité de la balnéothérapie dans la gestion des symptômes d'un large éventail d'affections: rhumatismales, neurologiques, post-traumatiques, cardiovasculaires, gynécologiques, dermatologiques, respiratoires, métaboliques, endocriniennes et musculosquelettiques. La formation des eaux géothermales dans le Bassin Pannonien, y compris dans la Plaine de l'Ouest roumaine, est le résultat d'événements géologiques complexes, comme l'antagonisme évolutif entre la microplaque pannonienne et l'orogène des Carpates. Le chapitre présente également des analyses hydrochimiques et microbiologiques des eaux minérales froides de Tămășeu, Sântimreu et Pădurea Neagră, confirmant leur pureté microbiologique, l'absence de micro-organismes pathogènes, ainsi que leurs profils hydrochimiques spécifiques. Ces eaux sont considérées comme des sources accessibles de minéraux essentiels (calcium, magnésium, sodium, fer, bicarbonate, sulfates), efficaces dans la prophylaxie et le traitement de diverses pathologies. Plusieurs études cliniques sont présentées, démontrant l'efficacité de la balnéothérapie dans le traitement de maladies rhumatismales (polyarthrite rhumatoïde, arthrose, fibromyalgie), neurologiques (maladie de Parkinson, séquelles post-AVC) et douleurs musculosquelettiques. Une étude pilote réalisée à Băile Tinca montre des améliorations significatives en termes de réduction de la douleur, d'amélioration de la fonction articulaire, de diminution de l'inflammation et de la qualité de vie des patients atteints d'arthrose du genou. Au total, 81 localités disposant de ressources hydrominérales ont été identifiées dans le département de Bihor, dont 7 avec des eaux minérales et 75 avec des ressources géothermales, la majorité étant situées en zone de plaine. Une localité (Tămășeu) possède à la fois une source d'eau thermale et une source d'eau minérale. Les eaux thermales sont définies comme des eaux souterraines ayant une température supérieure à 20°C, porteuses d'énergie géothermique. Les termes „eau géothermale" et „eau thermominérale" sont utilisés en parallèle, le premier étant plus courant dans les domaines technico-industriels, le second dans le tourisme balnéaire. L'énergie géothermique peut être utilisée pour produire de l'énergie électrique et thermique, mais aussi dans l'agriculture, l'industrie, la balnéologie et pour les consommateurs résidentiels. L'exploitation des ressources hydrominérales dans le département de Bihor est strictement encadrée par la législation nationale et européenne, garantissant non seulement la protection des sources, mais aussi la qualité de la balnéothérapie. La loi sur les mines et les normes techniques d'exploitation et d'étiquetage des eaux minérales définissent un cadre juridique nécessaire à une valorisation durable.

Ce chapitre présente également les particularités bioclimatiques du département de Bihor, une composante essentielle de l'inventaire des ressources balnéoclimatiques. L'analyse bioclimatique est importante pour comprendre l'impact des conditions climatiques sur la santé humaine. La relation entre les éléments climatiques et le corps humain est illustrée par la caractérisation bioclimatique. Une dynamique notable des particularités bioclimatiques dans le département de Bihor est mise en évidence, marquée par une tendance au réchauffement et à l'extension de l'inconfort thermique au cours des 30 dernières années. L'identification des spécificités bioclimatiques, fondée sur les valeurs moyennes mensuelles pluriannuelles des indices bioclimatiques, permet de classifier bioclimatiquement les localités à potentiel balnéaire. La tendance générale observée indique une supériorité thermique de la période 1991–2020 par rapport à 1961–1990, se manifestant par une augmentation de la fréquence des dépassements des températures maximales et une réduction des non-dépassements des minimales. L'analyse des particularités bioclimatiques et des tendances de variation des indices pertinents pour la balnéothérapie et le tourisme de santé met en lumière une dynamique bioclimatique significative ayant des implications directes sur le potentiel balnéoclimatique et touristique de la région. En

général, on observe une extension des périodes d'inconfort thermique et une réduction des périodes de confort.

Le chapitre 6 présente une analyse approfondie de la manière dont les ressources balnéaires du département de Bihor peuvent devenir de véritables vecteurs de développement socio-économique durable. Selon cette étude, la valorisation efficace de ces ressources dépend essentiellement de l'implication de l'administration, de l'existence de politiques bien définies et d'une infrastructure adaptée aux exigences actuelles du tourisme de santé. Dans le contexte des changements structurels survenus en Roumanie après 1989, le passage d'un système socialiste à un système capitaliste a profondément affecté les formes de gestion des ressources balnéaires. Les privatisations rapides, le manque d'investissements et l'absence d'une stratégie cohérente de l'État ont conduit, dans de nombreux cas, à l'abandon de bases balnéaire précieuses. L'analyse met en lumière comment les formes d'administration influencent directement la fonctionnalité et la rentabilité des ressources. Ainsi, les localités où l'administration locale ou la privatisation ont été responsables et orientées vers le développement (par exemple Sarcău, Sânnicolau de Munte, Săcueni, Beiuș) ont connu des modernisations et sont devenues des points d'attraction touristique locale. En revanche, les localités marquées par un manque d'intérêt ou de fonds (par exemple Cadea, Balc, Mihai Bravu, Valea lui Mihai, Răbăgani) ont vu leurs ressources balnéaires laissées à l'abandon. Un point important du chapitre réside dans la classification des localités selon leur niveau actuel de valorisation des ressources : des localités dotées de bassins simples construits avant 1989, à celles qui exploitent actuellement les ressources à des fins de loisirs, de traitement ou d'activités connexes (chauffage urbain, pisciculture, agriculture), jusqu'aux nouvelles stations touristiques certifiées entre 2020 et 2024, bénéficiant de projets pour le développement futur du tourisme balnéaire dans la région de Bihor. Parmi les exemples les plus notables de développement figurent: Oradea, devenu un modèle national grâce à l'utilisation de l'eau géothermale pour le chauffage urbain et les loisirs, via des projets public-privé comme l'Aquapark Nymphaea et le futur Jardin Thermal Ioșia; Beiuș, seule ville de Roumanie à utiliser exclusivement l'eau géothermale pour le chauffage, tout en la valorisant dans l'industrie dermo-cosmétique et les loisirs; Marghita et Ștei, qui ont mis en œuvre des projets de réhabilitation de leurs bases balnéaires et de construction de centres modernes; Săcueni et Mădăras, localités rurales récemment reconnues comme stations touristiques grâce à l'implication administrative et au développement des infrastructures. Par ailleurs, l'eau géothermale est également exploitée par d'autres moyens alternatifs: dans l'agriculture (Livada de Bihor), la pisciculture (Sântandrei), l'industrie dermato-cosmétique (Synergy Therm – Băile Felix, Beyus – Beiuș), et dans le secteur wellness & spa dans plusieurs localités urbaines et rurales. Cependant, le risque d'insoutenabilité est élevé dans les zones où les investissements sont absents et où les administrations locales ne priorisent pas le tourisme balnéaire face à d'autres besoins (canalisation, routes, approvisionnement en eau). D'autres risques majeurs identifiés comprennent: la dépopulation des zones rurales, l'augmentation des tarifs sans amélioration correspondante des services, et la dégradation des infrastructures existantes. Le chapitre souligne l'importance de l'obtention du statut de station touristique, qui facilite l'accès à des fonds nationaux et européens. Entre 2020 et 2024, huit localités dotées de ressources balnéaires ont été officiellement reconnues comme stations touristiques (par exemple Oradea, Beiuș, Ștei, Marghita, Borș, Săcueni), ouvrant ainsi de nouvelles perspectives pour une valorisation durable des ressources géothermiques dans le département.

Le chapitre 7 de la thèse aborde les orientations essentielles et les contributions personnelles concernant la valorisation du potentiel balnéoclimatique du département de Bihor. Ce département s'est déjà imposé comme un pôle majeur du tourisme balnéaire, tant au niveau national

qu'international, grâce à l'exploitation de ses ressources thermominérales dans des stations balnéaires bien connues telles que Băile Felix – Băile 1 Mai et Băile Tinca, ainsi que dans d'autres localités ayant obtenu le statut de station touristique entre 2020 et 2023 (Oradea, Beiuș, Mădăras, Săcueni, Marghita, Ștei). La destination Băile Felix – Băile 1 Mai se distingue comme la station balnéaire la plus importante de Roumanie fonctionnant en permanence. Elle propose une infrastructure d'hébergement étendue (plus de 7 800 places à Băile Felix), des bases de traitement complètes (y compris des équipements de pointe comme des thérapies robotisées et en réalité virtuelle) et une large gamme d'activités récréatives. D'importants investissements dans la modernisation de l'infrastructure routière via des fonds européens ont encore renforcé leur attractivité. Par ailleurs, certaines localités comme Aleșd, Sarcău, Sânnicolau de Munte, Tămășeu et Chișlaz disposent depuis longtemps de ressources balnéaire valorisées, mais n'ont pas encore obtenu de certification officielle en tant que stations touristiques. Stâna de Vale est une station balnéoclimatique réputée, connue pour son eau minérale oligominérale, ferrugineuse et hypotonique, embouteillée sous le nom d'Izvorul Minunilor. Parmi les 16 localités valorisant actuellement des ressources balnéaire, seules six possèdent des bases spécifiques de traitement, y compris au sein des départements de balnéologie des hôpitaux (à Marghita et Ștei). L'analyse a également porté sur les localités du département de Bihor disposant de ressources hydrominérales présentant un potentiel de valorisation balnéaire immédiate, en mettant en évidence leurs caractéristiques physico-chimiques. 15 localités ont été identifiées comme ayant ce potentiel. Pour transformer ces localités en destinations balnéaire actives, une collaboration étroite est nécessaire entre les autorités publiques, les investisseurs privés et les institutions spécialisées, ainsi que la mise en œuvre d'une législation cohérente garantissant à la fois la protection de l'environnement et les bénéfices économiques et sociaux pour les communautés locales. Une autre mesure importante consiste à instaurer des accords entre la Caisse nationale de retraites, la CNAS (Caisse nationale d'assurance santé) et les nouvelles stations ou centres thermaux, afin de proposer des subventions ou des tickets de traitement gratuits, ce qui favoriserait leur intégration dans le réseau balnéo-touristique national. La valorisation durable de ces ressources implique un suivi attentif des trois dimensions essentielles du développement durable: écologique, économique et sociale. L'extraction incontrôlée de l'eau, un déversement inadéquat ou une pollution accidentelle peuvent compromettre la qualité de l'environnement et la viabilité à long terme des systèmes hydrogéologiques. Il est nécessaire d'instaurer des réglementations strictes en matière d'exploitation, ainsi que des projets autorisés et planifiés par étapes, intégrant des études de faisabilité, des analyses physico-chimiques et des évaluations d'impact environnemental. Enfin, le chapitre attire l'attention sur les limites existantes: les risques administratifs (changements de maires ou manque d'intérêt des autorités), l'absence d'infrastructures, les dangers écologiques et le manque de projets cohérents de valorisation peuvent retarder ou compromettre l'exploitation durable de ces ressources. Parmi les 81 localités recensées comme disposant de ressources dans le département, 45 disposent de forages déjà réalisés mais non exploités, ce qui rend impératif l'élaboration d'une stratégie de valorisation.

L'étude interdisciplinaire et transdisciplinaire du potentiel balnéoclimatique du département de Bihor démontre que celui-ci constitue une ressource fondamentale pour le développement socio-économique de la région, ayant un impact significatif sur l'attraction des investissements, le développement du tourisme balnéaire et l'amélioration de la qualité de vie. Le département de Bihor se distingue par une richesse et une diversité remarquables de ressources balnéaires, incluant des eaux thermales et minérales de différents types (bicarbonatées, calciques, chlorosodiques, alcalines, ferrugineuses, sulfatées, iodées, hypotoniques), des boues thérapeutiques et un bioclimat

favorable. Cette abondance est principalement due à sa situation géographique et à sa structure géologique complexe, caractérisée par des formations sédimentaires et des failles tectoniques qui facilitent l'ascension des eaux géothermales et leur enrichissement en minéraux dissous. 81 localités disposant de ressources hydrominérales ont été identifiées, dont 16 sont déjà intensément valorisées, et 15 autres présentent un potentiel immédiat de développement. L'infrastructure de traitement dans le département est complexe et moderne, comme en témoignent les bases de traitement de Băile Felix, dotées d'équipements de pointe tels que la thérapie robotisée et la réalité virtuelle. Ces procédures, associées à la crénothérapie, contribuent de manière significative à l'amélioration de nombreuses affections (rhumatismales, neurologiques, gynécologiques, métaboliques, digestives), avec des effets physiologiques scientifiquement validés et certifiés par des institutions nationales.

L'analyse détaillée des données climatiques sur une période de 60 ans a permis de caractériser le bioclimat du département, en mettant en évidence les particularités thermiques et pluviométriques selon les différents niveaux d'altitude. L'étude a révélé une tendance à l'augmentation des températures, avec un impact direct sur les zones de disconfort bioclimatique, soulignant l'importance d'un suivi constant de ces évolutions.

Le développement du „phénomène balnéaire" dans le Bihor a été fortement influencé par le facteur administratif et par l'environnement politique. Une gestion performante et adaptée est cruciale pour une valorisation durable des ressources et pour renforcer la position du département en tant que pôle du tourisme de santé. Bien que la période post-révolutionnaire ait apporté des avancées notables grâce à des initiatives privées et des investissements (ex: Sarcău, Sânnicolau de Munte et Beiuș), des cas d'abandon ou de démolition de bains thermaux ont également été observés, mettant en évidence des risques d'insoutenabilité en l'absence d'une approche intégrée.

Le potentiel balnéoclimatique du département de Bihor constitue une ressource précieuse et dynamique, avec une longue tradition dans l'exploitation des eaux géothermales. Pour consolider sa position comme destination balnéaire de référence aux niveaux national et international, il est essentiel de poursuivre les investissements dans la modernisation des infrastructures et des services, notamment dans les zones rurales où les bains thermaux représentent souvent la seule attraction touristique. Il est également impératif d'instaurer un équilibre stratégique entre l'exploitation intensive des ressources et leur protection à long terme, à travers une approche intégrée prenant en compte à la fois le potentiel naturel et les réalités socio-économiques.