Climatic and Hydrographic Variations in the Dynamics of Geographic Landscapes in North-West Depression of Transylvania

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Abstract

The Depression of Transylvania is the largest depression area within the chain of the Carpathians, and by its associated tectonic, lithological, morpho-climatic, morpho-hydrographic, and bio-pedo-geographic relations it defines the specificity of Transylvanian geographical landscapes. The functionality of Transylvanian geographic landscapes is proved by the heterogeneity of the paleo-media of morphogenesis, and the rate and intensity of contemporary geomorphological processes as apparent in Pleistocene "informational" matrices.

The landscape response to climatic and hydrologic changes was highlighted by: the analysis of climatic and hydrologic conditions, the morpho-dynamics of valleys and slopes, land usage types, and the dynamics of rural and urban settlements. The action of Pleistocene, Holocene, and contemporary modelling factors is apparent in the morphodynamic factors of geomorphological landscapes. Contemporary modelling is inscribed into the Pleistocene matrix, while the processes of linear and regional erosion outline a new dimension of the functions of Transylvanian landscape.

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1. General considerations

The functionality of Transylvanian geographic landscapes is proved by the heterogeneity of the paleo-media of morphogenesis, and the rate and intensity of contemporary geomorphological processes as apparent in Pleistocene "informational" matrices.

The Depression of Transylvania, as a central intra-Carpathian relief unit, is defined as the largest depression area by its spatial relations within the chain of the Carpathians, as well as by its associated tectonic, lithological, morpho-climatic, morpho-hydrographic, and bio-pedo-geographic relations. (Fig. 1.)[1]

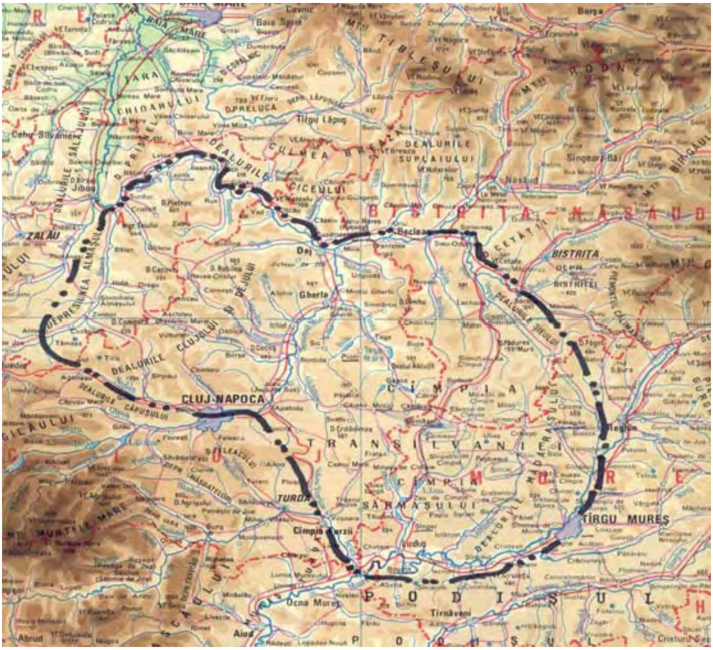

Fig. 1. Geographical position of north-west region of Depression of Transylvania (Someş Plateau and the Transylvanian Plain) (Irimuş, 2003)

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[1] Ioan Aurel Irimuş, *Geografia fizică a României* (Romania's physical geography) (Cluj Napoca: Casa Carții de Stiință, 2003), 66.

The tectonic style of Neogenic molasse deposits was determined by the tectonic of salt and rising mountain chains in the neighbouring area of the Carpathians, which left the mark of a slow gravitational movement on Neogenic sedimentary cover, generating diapiric folds, brachyanticline and domes which impose a specific relief on the molassic sedimentary basin. (Fig. 2.)[1]

Fig. 2. Morpho-tectonic map of the Depression of Transylvania

[1] Ioan Aurel Irimuş, *Relieful pe domuri şi cute diapire în Depresiunea Transilvaniei* (Dome and diapir folds relief in the Depression of Transylvania) (Cluj – Napoca: Presa Universitară Clujeană, 1998), 13.

Neogenic lithology is characterized by the presence of friable rocks (marlstone, clay, sand, limestone, gritstone, volcanic tuff, salt), which alternate in strata of 0.05 m to 150 m.

The morphology of the region is outlined by climatic changes which occurred in the syngenetic Subatlantic – present period, conditioning the modification of the hydrographic network and associated vegetation. Alluvial and colluvial slopes, the steep slopes of the cuesta present an emphatic morpho-dynamics in the Transylvanian Plain and the Someş Plateau controlled by the bases of local erosions, with vertical mobility determined by salt neotectonics, and the alteration of pluviometrically deficient and excessive periods.

Anthropic landscape modification changes the erosion and accumulation rate in the valley-slope geomorphological system, either by the exploitation of construction materials (sand, clay, tuff, limestone, gravel stone), or by agricultural exploitation and fish farming establishments.

The characteristics of contemporary geo-morphological and geographical landscape are outlined by the climatic and hydrologic changes of the last century (1901-2000).

2. Methodology

The landscape response to climatic and hydrologic changes was highlighted by: the analysis of climatic and hydrologic conditions, morpho-dynamics of valleys and slopes, land usage types, and the dynamics of rural and urban settlements.

The climatic regime was investigated by:

- climatic changes in late Glacial – Holocene period, reflected in associated vegetation structure and soil types;
- analysis of pluviometrically deficient periods and aridity and drought phenomena;
- analysis of pluviometrically excessive periods and regional synoptic context.

The methods and procedures used in aridity and drought phenomena assessment have taken into account various criteria based on simple (precipitation, humidity) or complex (aridity indices, climatic diagrams) climatic parameters, hydric, edaphic (water balance in soil), or bio-climatic parameters, etc.

The study of phenomena of aridity and drought was made on the basis of non-periodical variation analysis of precipitations, measured on a monthly basis with the help of standard precipitation deviation and frequency according to Hellmann's criteria applied to annual precipitation quantities, measured at the weather stations of Dej, Cluj-Napoca, Turda, Bistrița, Tg. Mureş, and stations placed in the analyzed region.

The hydrologic regime was assessed by reflecting the pluviometric regime made up of watercourse on slopes, watercourse in riverbed, and also the modifications in the functionality of lake basins (including water surface level).

The morpho-dynamics of riverbeds and slopes, and field usage types are analyzed by means of slope types and their functions, emphasising the convergence of fluvial action with alluvial slope mobility and anthropic impact. The dynamics of rural and urban settlements served as a reference point in assessing climatic and hydrologic changes, and the morpho-dynamics of riverbeds and slopes. The limits of rural and urban development were emphasized due to the intensity of slope process activities, and the limitations of local resources exploitation.

3. Discussion and conclusions

3. 1. Late Glacial – Holocene climatic oscillations as apparent in associated vegetation structure

The interpretation of pollen profiles for establishing vegetal composition for the last 15000 years as a period corresponding to the end of Weichsel (Würn) Glacial Stage, and the Pleistocene – Holocene transition, respectively, were interpreted and achieved by A.M.S. dating.[1]

The totality of pollen and macro plants to be found in sediment deposits of approximately 14700 years BP indicate vegetation without trees, dominated by herbs and shrubs resistant to cold and arid climate. Beginning with late glacial stage, the increase of temperature and humidity determined the rhythmic appearance and expansion of forest vegetation dominated by *Pinus* and *Betula*, and the stabilization of slopes. The reinstallation of a colder climate (14100-13800 years BP), with vegetation dominated by herbs and shrubs, and also the presence of a warm episode (13800-12900 years BP) marked the significant expansion of forests of *Picea* mixed with *Betula*, *Larix*, *Pinus*, and *Alnus*. The expansion of these taxa can be interpreted as a successive process,

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[1] Angelica Feurdean, *Paleoenvironment in North-Western Romania during the last 15000 years,* Thesis in Quaternary Geology, no. 3 (Stockholm University, 2004).

shortly followed by the expansions of taxa *Ulmus* and *Picea*, which survived in favourable habitats, in the neighbourhood of sediment basins. The period of 12950-11500 years BP, characterized by the contraction of forest taxa such as *Ulmus* followed by *Picea*, *Betula*, and *Pinus*, in parallel with the rapid expansion of herbs and shrubs, functions as an indicator of a new cold and slightly humid episode.[1]

The late Glacial – Holocene transition took place approximately 11500 years BP, and the evolution of post-Glacial vegetation was a complex process, resulting from the interference of the following factors: climate, vegetation succession processes, tree migration, inter-specific competition, soils, and anthropic impact.

Nevertheless, the linear expansion of taxa *Betula*, *Larix*, *Pinus*, and *Alnus* 11500 years BP may be interpreted as a successive process during the entire late glacial stage. The expansion of taxa *Ulmus* and *Picea* occurred in the course of a very short period (250 years BP), probably due to the fact that they survived in the favourable habitats of sedimentary areas. The regional appearance of trees with mesotherm foliage *Quercus*, *Tilia*, *Fraxinus*, and *Cotylus* probably occurred approximately 11250 years BP, because local expansion started approximately 10700 years BP, when forest areas became much more diverse and dense.[2]

In addition to the inter-specific competition of taxa already present in the region and new ones, new climatic conditions also played an important role in forest reorganization and the formation of vegetation layers.

Carpinus and *Fagus* appeared in compact forest formations, approximately 5700-4800 years BP, most likely as a result of climate change and soil cover.

Human presence became more obvious during the last 3500-3700 years, in the Bronze Age (Coțofeni culture). Human presence is mostly reflected by the extension of steppes as opposed to forest areas, as a classic evidence of deforestation and diminution of forest diversity and density, as attested by soil types (brown forest soil, argillic-illuvial brown soils, brown luvisols, or preluvisols and luvisols.[3]

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[1] Feurdean, *Paleoenvironment in North-Western Romania.*
[2] Feurdean, *Paleoenvironment in North-Western Romania.*
[3] FAO/UNESCO (1998-1999), Soil Taxonomy II, Handbook, no.18, USDA Washington.

3. 2. Analysis of pluviometrically deficient and excessive periods and aridity and drought phenomena in north-western Transylvania

The analysis of time series offers an overview of the succession of pluviometrically deficient and excessive periods for the analyzed territory and allows the identification of a probable cycle of drought episodes, and the evolution tendency of time series. These conditions were analyzed for a period of 100 years, 1901-2000, by the quantity of precipitations measured at Bistrița, Dej, Târgu-Mureş, and Sibiu weather stations (Fig. 3.), with help from the Standardized Precipitation Index (SPI).[1] (SPI is based on the probability of registering a certain quantity of precipitations, the probabilities are standardized, and the index value is positive for periods of humidity and negative for periods of drought.)

The cumulated SPI values have demonstrated that the 20th century started with a poor precipitation period between 1900 and 1920, for all the stations except Dej, where there were excessive precipitations in the period between 1910 and 1928.

[1] Iulian Holobâcă and Adina Croitoru "Les risques pluviometriques dans la Depression de la Transylvanie", *Publication de l'Asssociation Internationale de Climatologie* 13 (2000): 128 – 135.

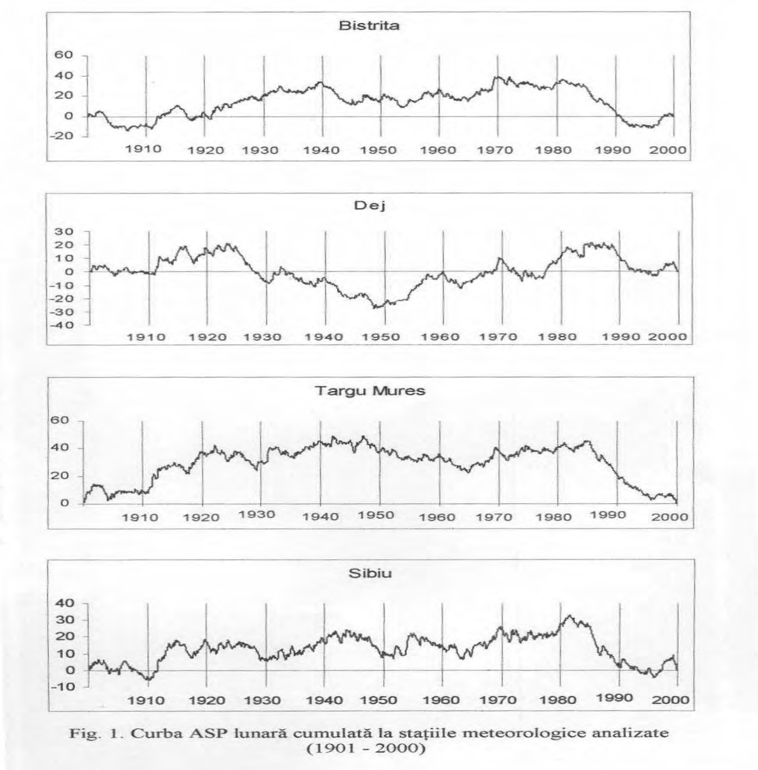


Fig. 3. Monthly SPI curve cumulated at weather stations Bistriţa, Dej, Târgu-Mureş, Sibiu, 1901-2000

Decade 4 and the first half of decade 5 is characterized by the descending course of the cumulated SPI curve, but the second half of decade 5 displays an ascending course, demonstrated by the succession of pluviometrically excessive months at Dej and Bistrița. A new pluviometrically excessive period is visible at the end of decade 6 and the beginning of decade 8 (1969-1970). The tendency continues all along decade 8, the succession of pluviometrically excessive months is interrupted by isolated years of aridity (1971, 1975, 1977).

For the most part, the years of decade 8 and the beginning of decade 9 are characterized by a negative trend in SPI curve evolution, continuing also after the year 2000, with the exception of years 1996 and 1998, with excessive precipitation in north-western Transylvania.

The analysis of pluviometrically deficient periods was made by studying the phenomena of aridity and drought, as measured at weather stations in the region (Turda, Dej, Cluj-Napoca), or bordering on the region (Târgu-Mureş).

The drought occurs depending on the parameters of deficient periods (duration, intensity, time of the year), and anthropic factors. The various manifestations of the drought (atmospheric, pedologic, phreatic, potamologic) and the appearance of these periods in the flow pattern of rivers, the dynamics of mountain slopes, the biotic cycle, or the development of pedogenic processes is highly important in the structure and role of geographic landscapes in Transylvania.

The years of severe drought in the north-west of the Depression of Transylvania were: 1917, 1948, 1961, 1982, 1986, 1990, 1992, and 1994.

The negative deviations of annual medium precipitation quantities were anywhere between 225 mm and 270 mm in the analyzed period of 1891-1997, while they were of 409.1 mm in Dej in 1966 (difference of -225 mm) and 383.9 mm in Bistrița in 1986 (difference of -270 mm). (Fig. 4.)[1]

[1] Ibid.

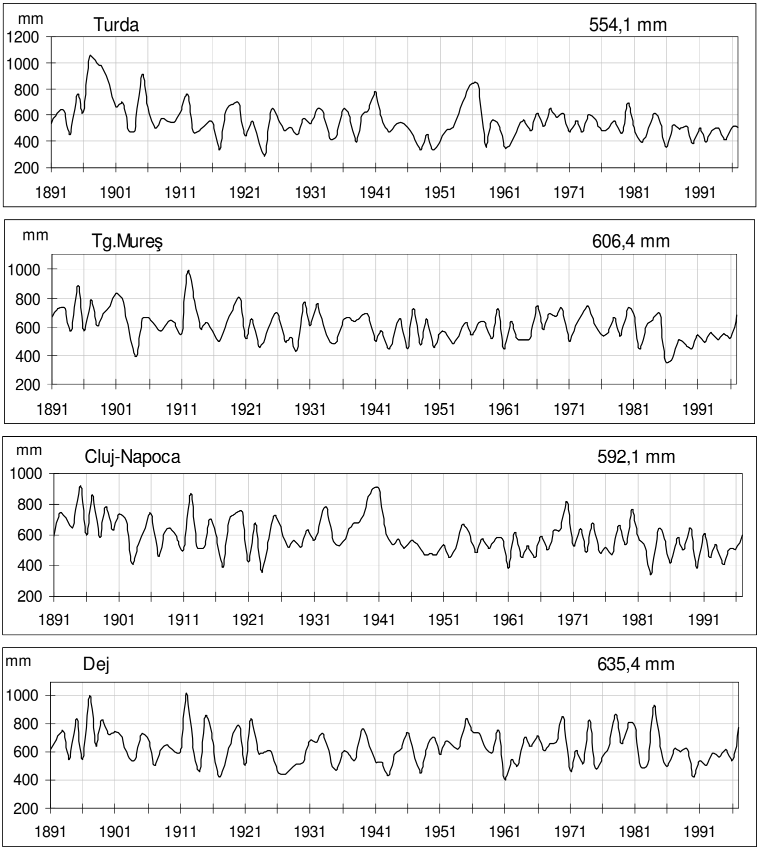
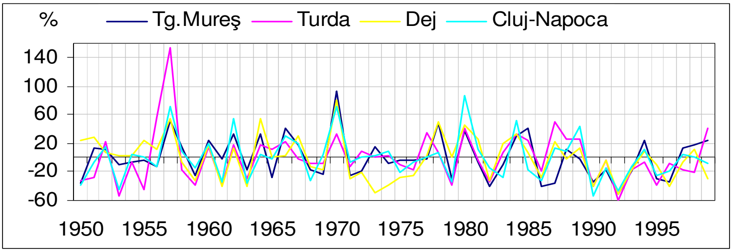


Fig. 4. Non-periodical variations of annual precipitation quantities (1891-1997)

The weather stations of Someş Valley (Cluj-Napoca, Dej, and Bistriţa) displayed the largest number of deficient periods, between 5 and 7 periods, for 2 consecutive years. The drought was felt more intensively here because the quantity of precipitations in this region is far greater than in the central and southern parts of the Depression of Transylvania. According to seasons (Fig. 5.), the largest negative deviation (for all stations) was registered in the autumn (71% - 80%), and to a more reduced degree, in the spring (52% - 61%).[1]

[1] Ibid.



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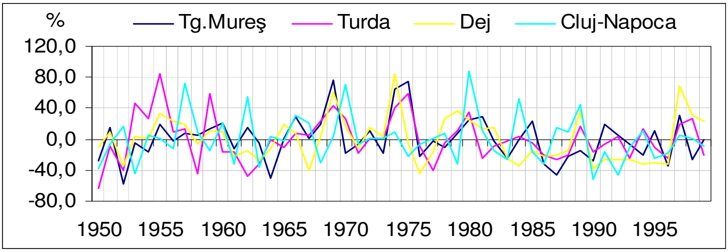

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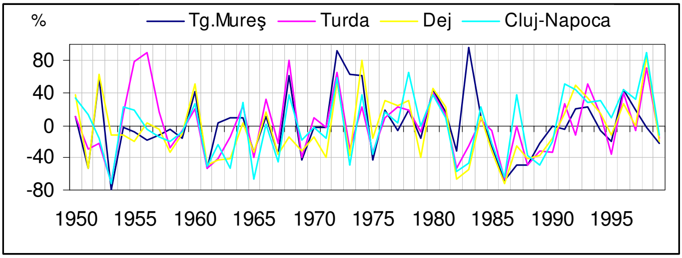

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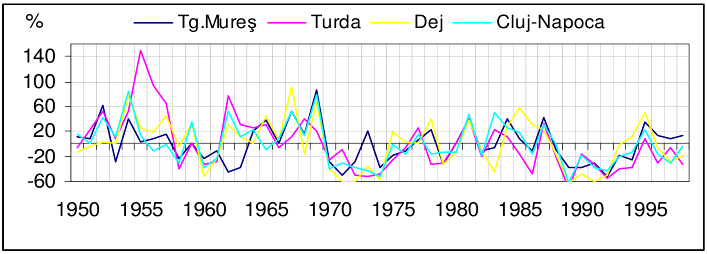
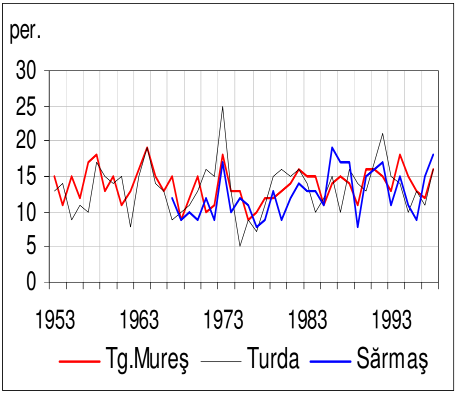


d)

Fig. 5. Relative deviation of seasonal precipitation quantities in relation to multiannual average (a-spring; b-summer; c-autumn; d-winter)

The analysis of the frequency of years deficient in precipitations according to Hellmann's criteria has demonstrated the high frequency of drought periods during excessively arid years. (Fig. 6).[1]



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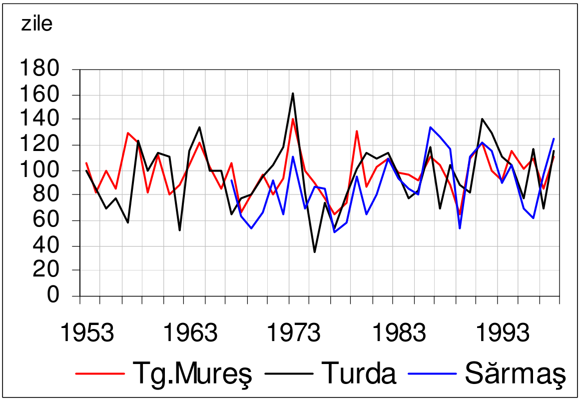

b)

Fig. 6. Evolution of periods (a) and number of days (b) of drought, determined according to Hellmann's criteria

[1] Ibid.

Year 1986 witnessed 19 periods of drought in the Transylvanian Plain, at Sărmaş, and year 1995 witnessed 5 periods of drought at Turda, in the Arieş Valley.

3. 3. Changes in hydrology and spatial dynamics of lakes in the north-west of the Depression of Transylvania

The configuration of the contemporary hydrographic network is determined by modifications due to the convergence of tectonic, climatic, and anthropic factors in the last 15000 years. While in the late Pliocene two areas of hydrographic convergence were outlined[1]: the junction of the Someşul Mare and Someşul Mic (at Mica settlement, close to Dej) and the Almaş and Someş (close to Jibou), the situation has considerably changed in the Pleistocene – Holocene as to the convergence and mobility of riverbeds.

Anthropic impact is increasingly perceived in river systems and the dynamics of water surfaces of lakes. The suspended flow of alluvial deposits in the north-western rivers of the Transylvanian basin represents one of the parameters that argue for the correlation lithology – climate – anthropic use of the territory – hydrologic conditions.

The systematic measurement of alluvial flows into the hydrographic basin of the Someş has started since 1960 in 33 hydrometric stations.[2] The specific alluvial flow in the Someşul Mare basin is 5 t/ha/year, and in the Someş basin 2.5 t/ha/year. The Someş River transports over 3.500,000 m^3 of alluvial deposits, of which 1.000,000 m^3 are transported by the Someşul Mare. These values show a high erodibility index, between 3 l/s km^2 (Someş Plateau) and 9 l/s km^2 (Transylvanian Plain), reflecting the high frequency of friable rocks and a low degree of forestation.

The correlation between the potential energy specific to precipitations with a coefficient of erosion resistance demonstrated at 500 m altitude (general altitude of Someş Plateau and the Transylvanian Plain) and raindrop energy of 1000 Mwh/km^2 explains the high values of suspended specific alluvial deposit capacity in the region.

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[1] Alexandru Savu, *Podişul Someşan: Studiu geomorfologic* (The Someş Plateau: A geomorphological study), Lithograph, (Cluj-Napoca: Library of the Faculty of Geography, 1958).

[2] Gavril Pandi, *Concepţia energetică a formării şi transportului aluviunilor în suspensie* (The energetic concept of the formation and transportation of suspended alluvial deposits), (Cluj-Napoca: Ed. Presa Universitară Clujeană, 1997).

The decrease of forest surfaces, the extension of agricultural, especially arable surfaces, the tendency of aridity of the climate, and the large quantity of alluvial deposits in the Someş hydrographic basin are also apparent in the decrease of water surfaces, especially those of lakes. An 1808 Austrian map (Wien bey Artaria und Compagny) takes note of over 78 lakes, of which 69 in the Transylvanian Plain, and 9 in the Someş Plateau. (Fig. 7.)

Fig. 7. Austrian map from 1808 (Wien bey Artaria und Compagny) with lakes in north-western Transylvania

Many of these lakes were used in flax and hemp retting, and their absence today is due to the disappearance of these traditional occupations. Today, there are only 19 such water accumulations for fish farming, called "iaz" (ponds), some of which are: Lacul Cătina, Lacul Geaca, Lacul Ştiucii-Săcălaia, Lacul Ţaga, Lacul Zau, Lacul Tăureni, etc.[1]

[1] Victor Sorocovschi, "Studiul fenomenelor de secetă şi uscăciune în Câmpia Transilvaniei" (The study of drought and aridity in the Plain of Transylvania) In *Geography in Context of Contemporary Development*, vol. 3, (Gheorgheni: Ed.F.&F , 2004).

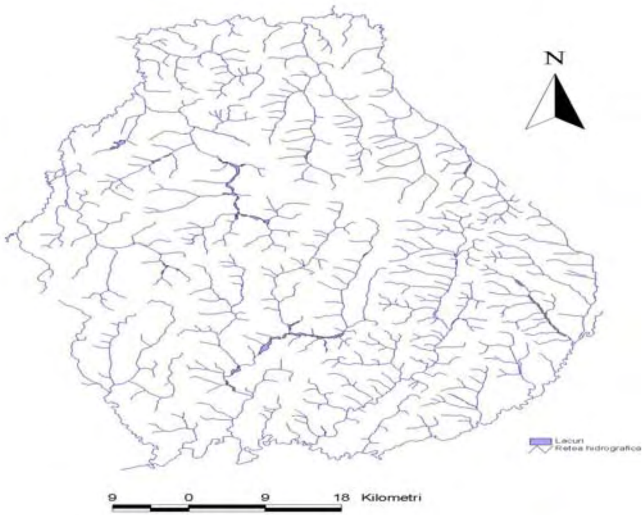

Fig. 8. The hydrographic network of the Transylvanian Plain and the distribution of lakes

3. 4. Climatic and hydrologic variations reflected in the morpho-dynamics of valley-slope systems

The action of Pleistocene, Holocene, and contemporary modelling factors is reflected in the morpho-dynamic characteristics of geo-morphological landscapes in particular and geographic landscapes in general. Contemporary modelling is inscribed into the Pleistocene matrix, while the processes specific to linear and regional erosion outline a new dimension of the function of Transylvanian landscapes. The modelling of minor riverbeds was achieved under the control of climatic changes and hydrologic variations in the first place, but also with the massive participation of humans, at least in the last five decades.

In the morphology of the minor riverbed, the presence of island-type forms of alluvial accumulations signals the large amount of materials flowing from the slopes. The materials mostly resulted from mass movement processes (landslides or mud flows) and linear processes, especially gully erosion.

The more emphatic human impact of the last 5 decades was marked by the extension of arable lands to the disadvantage of spontaneous steppe-type cultures, steppe-forest associations, and forests, which led to the increase of linear and regional erosion. (Fig. 9.)[1]

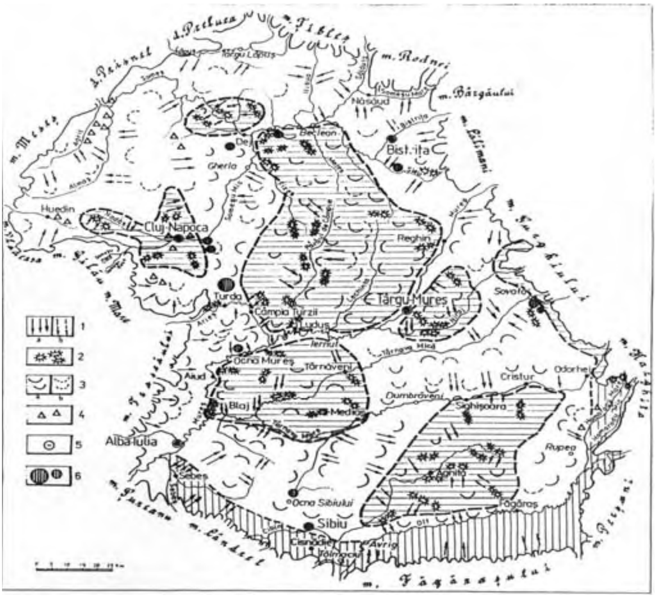

Fig. 9. Map of geomorphological processes
1. Surfaces mainly affected by torrential erosion; 2. Surfaces with glimee-type landslides; 3. Surfaces affected by landslides; 4. Wind-modelled surfaces; 5. Pseudo-karstic and karstic surfaces; 6. Surfaces modelled by salt dissolution

The modifications of the function of certain riverbed-sections (quarry, water retention basin, irrigations, or recreation) by the correction applied to minor riverbeds has generated a new configuration of the hydrographic network and has modified the morphological relation of valley and slope.

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[1] Virgil Surdeanu and Ioan Mac, "Processus de modelage dans la Depression de la Transylvanie", *Analele Universităţii Dimitrie Cantemir Târgu Mureş*, 1998: 505 – 521.

The alternation of pluviometrically deficient and excessive periods was demonstrated by the reactivation of late glacial landslides (glimee-type landslides)[1], and the development of new landslides on other kinds of surfaces (Fig. 10.) These processes were most frequent in the following intervals: 1930-1933; 1956-1957; 1970-1971; 1982-1985.

Fig. 10. Glimee-type landslide at Ocnița (Transylvanian Plain) (Photo by Irimuş, 2006)

The transit of alluvial deposits is reflected in the function of valleys and lakes. The existence of valleys adapted also to the continuous subsidence of the alluvial bed also demonstrates the disfunctions of the valley-slope morphological system, as the riverbed is adjusting to the material *exits* from the slope's geomorphological system.

The modification of lake surfaces happened in the context of maintaining the same morpho-climatic and hydrological parameters, which have brought upon the complete or partial filling up of lakes.

Lakes have special relations with slopes. The oscillation of lake levels in Transylvania continuously moisten the base of slopes and increase their instability, as shown in the territory analyzed: active or partially stabilized landslides (there are inventories of over 500 areas with glimee-type landslides in the Depression of Transylvania, and over 300 fields with landslides in north-western Transylvania), mud flows, swampy surfaces with upper-phreatic waters. (Fig. 11.)

[1] *glimee* – term coined by T. Morariu for profound landslides in Transylvania

Fig. 11. Geomorphological relations in lake-slope systems (Țaga lake) (Photo by Irimuş, 2006)

The changes in climatic and hydrologic conditions appear also on the level of urban and rural settlements, as well as in the way of using and arrangement of the territory.

The anthropic pressure over the territory became apparent in decades 7 – 9 of the previous century by the increase of arable agricultural surfaces to the disadvantage of pastures, meadows, forests, and lakes, syngenetically supporting a policy of rural and urban systematization aiming at the social and economical modernization of the life and architecture of Romanian villages, and approaching rural life standards to the urban medium (communist policy).

Traditional agricultural occupations were substituted by industrial and tourism-related ones, and this trend was increasingly becoming more important after 1990 with rural tourism. Rural settlements witnessed stagnation and regression determined by climatic changes, variations in hydrologic conditions, and wilful anthropic impact.

The floods in the period of May-June 1970 caused the dislocation of 16 villages and the modification of the area of 24 rural settlements. Mass movement processes were recorded, which resulted in removing 16700 ha of land from the agricultural circuit.[1] The effects of the floods determined a new territorial strategy and policy, apparent in the first place in programs and measures for the rehabilitation of forest areas (the program was meant to unfold in the period between 1970-2010), programs of hydrotechnical management of rivers with torrential flow and predominantly pluvial supply (channelling, levees, regulations, drainage), measures of stabilization of slopes and soil erosion, the systematization of rural and urban settlements, etc.

Meadows and terraces were recommended for designing rural settlements and residential districts, as well as road, railroad, and air transportation, while the agricultural use of meadows was recommended to be the cultivation of vegetables.

The slopes were terraced (agricultural terraces), and large orchards of apple trees (Bistrița, Reghin, Dej, Cluj-Apahida-Baciu), cherry trees (Dej-Cireşoaia), and plum trees (Someş Plateau) were planted.

The period between 1976 and 1990 was a very important stage of the reforestation program by enlarging surfaces of *Accacia* and Douglas fir (*Pseudotsuga taxifolia*) plantations. These measures were successful in reducing soil erosion and stabilising the morphodynamics of the slopes of Transylvanian geographical landscapes.

Fig. 12. Abandoned agricultural terraces at Apahida (Photo by Irimuş, 2006)

[1] Ioan Crişan, *Studiu pedologic stațional agroproductiv şi ameliorativ al împrejurimilor Clujului.* (A pedological stational agro-productive and ameliorative study of the Cluj region) Doctoral thesis. (Cluj-Napoca: Library of the University of Agricultural Science and Veterinary Medicine, 1981).

The policy of exploiting the geographical space included new forms of usage after 1990: abandoning of agricultural fields (Fig. 12) as a result of the lack of financial resources for agricultural works, the aging of rural population, as well as the increasing interest in real estate enterprizes. The anthropic impact responded to the climatic and hydrographic modifications by a system of complementary measures to handle the critical situations of pluviometrically deficient or excessive conditions, and alleviate or moderate the intensity of erosion processes in the active parts of slopes. Thus it contributed to the diminution of rhexistasic landscape structures and surfaces, the increase of surfaces assisted by programs of parastasic landscape reconstitution, and the adoption of certain territorial programs and policies to ensure the durable and sustainable development of north-western Transylvania in the new context of European integration.

Translated by Emese G. Czintos