

THE ANALYSIS OF FOREST DYNAMICS WITHIN THE CARPATHIANS - THE SUBCARPATHIANS CONTACT AREA BY USING THE HISTORICAL CARTOGRAPHY APPROACH AND OPEN SOURCE GIS SOFTWARE. CASE STUDY: THE LIMPEDEA CATCHMENT (ROMANIA)

Gabriela OSACI-COSTACHE¹, Marian ENE¹

¹ University of Bucharest, Faculty of Geography, e-mail: gabrielaosaci68@yahoo.com

Abstract

The paper is an original contribution based on the diachronic comparison of historical maps from different periods, with the purpose of capturing and mapping the landscape history of the Limpedea catchment (tributary of the Argeș), which stretches almost equally into the strongly man-altered space of the Subcarpathians, as well as into the mountain area. The study highlights the changes undergone by the Arefu - Corbeni Subcarpathian depression and the neighbouring mountain area, paying particular attention to the Carpathian - Subcarpathian interface zone. In order to achieve its goal, the study relied on large scale maps from the 1790-1980 period, which were processed in Open Source GIS (Quantum GIS, GRASS, gvSIG Sextante, MapAnalyst). The interpretation of cartographic information using GIS techniques showed a continuous recession of the forests in the Subcarpathian part of the catchment and their replacement by agricultural lands, which led to a gradual decrease of the naturalness degree. In the 1864-1904 period, the extension of pastures and hay fields to the detriment of the forests was prevalent, whereas in the second half of the 20th century larger and larger areas of pastures and hay fields were turned into orchards or built-up areas.

Keywords: *historical cartography, Open Source GIS, Quantum GIS, GRASS, forest, landscape, land use*

Rezumat

Analiza dinamicii pădurii în zona de contact carpați - subcarpați prin cartografie istorică în mediu SIG open source. Cazul Bazinului Limpedea (România). Lucrarea constituie o contribuție originală, bazată pe compararea diacronică a hărților istorice din diferite perioade, cu scopul surprinderii și cartografierii istoriei peisajului în bazinul hidrografic al pârâului Limpedea (afluent al Argeșului), bazin extins în părți aproximativ egale în spațiul puternic antropizat al Subcarpaților și în zona montană. Studiul surprinde atât modificările din depresiunea subcarpatică Arefu - Corbeni, cât și din zona montană și mai ales din zona de interferență carpatico-subcarpatică. Pentru atingerea scopului propus s-au folosit hărți la scară mare din perioada 1790-1980, care au fost exploatate în mediu GIS Open Source (Quantum GIS, GRASS, gvSIG, Sextante, MapAnalyst). Interpretarea datelor conținute în hărți cu ajutorul tehnicilor GIS a evidențiat o reducere continuă a pădurilor din spațiul subcarpatic al bazinului și înlocuirea acestora cu terenuri agricole, fapt ce a determinat reducerea treptată a gradului de naturalitate. În perioada 1864-1904 a predominat extinderea pășunilor și fânețelor în detrimentul pădurilor, iar în partea a doua a secolului XX, suprafețe tot mai mari de pășuni și fânețe au fost transformate în livezi sau areale construite.

Cuvinte-cheie: *cartografie istorică, GIS Open Source, Quantum GIS, GRASS, pădure, peisaj, utilizarea terenurilor.*

INTRODUCTION

Investigations have proved that over the time, several cultures and economies overlapped on this territory and the result was a real “layering” in time of the landscapes, each of them being in essence a cultural landscape that reflected the identity of the territory. Thus, the landscapes depend on “man’s will and his concrete actions”, which means they are not “a fabrication or a subjective interpretation” (Lorenzi, 2007). In order to capture the landscape history one should turn to historical cartography, because it reveals the landscape features, their

dynamics in various stages and especially their location. This is the reason why the cartographic approach has been tackled widely in the literature (Corna Pellegrini, 2004; Lago, 2004; Longhi, 2004; Robinson, 2004; Rosseli, Paulmier, 2006; Campiani, Garberi, 2008; Osaci-Costache, 2004, 2008, 2009a, 2009b etc.). Therefore, the originality of our contribution consists in the analysis and diachronic comparison of large-scale maps with the purpose of highlighting some aspects concerning the landscape dynamics based on the employment of Open Source GIS software (Quantum GIS, GRASS, gvSIG, Sextante, MapAnalyst).

The study has sought to investigate from a cartographic point of view the changes that occurred in the contact area between the Subcarpathians and the Carpathians, i.e. in the space "invaded" more and more by man in his quest for new resources and new agricultural lands. As study area, we have chosen the catchment of the Limpedeia stream (35.58 sq km), a left-side tributary of the Argeş, which stretches almost equally in the Subcarpathian (18.08 sq km) and Carpathian (17.5 sq km) spaces. In the north, the catchment overlaps the mountain area (maximum elevation of 1621.9 m in the Ghiţu peak), whereas in the south it overlaps the Arefu - Corbeni Subcarpathian depression (with minimum elevation of 592 m at the confluence of the Limpedeia with the Argeş). In the extreme southeast there lies the Chiciura peak (1217.9 m), which is the highest summit in the Romanian Subcarpathians (Fig. 1).

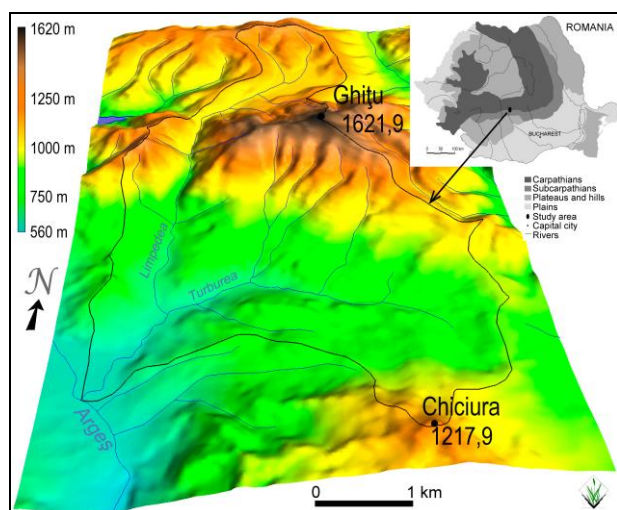


Fig. 1 The study area (3D model obtained in GRASS software by using the "NVIZ" module)

From the administrative point of view, the investigated area belongs to Corbeni Commune, consisting of several villages. One of these is Berindeşti, firstly shown at the beginning of the 18th century on the map drawn by Anton Maria del Chiaro (1718); it appears on the Russian Map of 1835 with 30 families and on the Russian Map of 1853 with 40 families (Osaci-Costache, 2004). The other two are Turburea and Poienari, the latter being shown on the Szathmary Map of 1864. The Subcarpathian catchment of the Limpedeia stream occupies a part of the Arefu - Corbeni subsequent tectonic-erosive depression, lying at the contact between the Subcarpathian and the Carpathian areas. The depression is made up of Paleogene and Miocene sedimentary formations (sandstones, marls, clays and sands), on which landslides,

torrentiality and sheetwash are extremely active (Nedelea, Dorca, 2001). These processes have been encouraged by human actions, which have been responsible not only for the shrinking of forest vegetation, but also for overgrazing and plowing up and down the slopes.

At present, forests are found especially in the mountain area of the catchment (beech forests and mixed beech-coniferous forests, with different features depending on elevation, slope aspect and declivity), as well as on the high Subcarpathian hills (the northern side of the Chiciura Hill).

At the contact between the Subcarpathians and the Carpathians, on the southern slopes of the Ghiţu Massif, on the relatively gently inclined slopes and on the rather flat surfaces of the Gornoviţa erosion level, human settlements and agricultural lands (characteristic for the depression) have gradually climbed to the highest elevations of the mountain area, to the detriment of the forests. Consequently, they have come to occupy the rather steep slopes lying above 800 m of altitude. For the Făgăraş - Iezer Mountains, the mean inner limit of permanent settlements ranges from 600 to 800 m (Mihăilescu, 1936), whereas that of the temporary ones lies above 1300 m (*Geografia României*, III, 1987). Agricultural lands are common in the lower part of the Limpedeia catchment.

A specific feature that has influenced the man-environment relationships within the contact area between the Argeş Subcarpathian Hills (Muşcelele Argeşului) and the Carpathian area is the development of the settlements' estates farther into the mountain area (the Arefu and Nucşoara communes etc.). This feature, together with the favourable pedoclimatic conditions and the high percentage of low declivity surfaces, has encouraged the gradual rising of the temporary settlements' line, north of the investigated area, as high as 2,035 m (at Bălea Lake).

SOURCES AND METHODS

In order to reach the settled objective, we have proceeded to the overlapping and diachronic comparison of several large-scale historical maps, which cover a period of 190 years. These are the Specht Map (1790-1791, scale 1:57,600), "Charta României Meridionale" or the Szathmary Map (1864, scale 1:57,600), the Lambert's projection topographic plan (1904, scale 1:20,000) and the Gauss-Krüger topographic map (1980, scale 1:25,000). All these cartographic documents have been processed using the GIS Free and Open Source softwares under Windows Vista: Quantum GIS

(<http://qgis.org/>), known as QGIS, (versions 1.0.2. – Kore, and 1.3.0. – Mimas), as well as “gvSIG”, version 1.1.2. (www.gvsig.gva.es).

The research has been conducted in several stages: (a) map scanning; (b) map georeferencing to a common reference system, which was done in Quantum GIS; (c) producing of vector layers in ESRI *Shapefile* format and creation of a database in Quantum GIS; (d) quantitative and qualitative analysis of geographical data using GRASS (integrated in QGIS; <http://grass.osgeo.org/>) and Sextante (integrated in gvSIG; <http://www.sextantegis.org>) softwares; (e) elaboration of synthesis maps in QGIS. Some final processing was accomplished with the Open Source “GIMP” (<http://www.gimp.org/>) and “Inkscape” (<http://www.inkscape.org/>) softwares.

Because of their significant distortions, the maps dating back to the 18th and 19th centuries have been georeferenced on the basis of the control points corresponding to those also existing on the map of 1980. These have been chosen by the “MapAnalyst” free software, so that the standard deviation values be minimum (Fig. 2).

The employment of a common reference system (WGS84/UTM Zone 5N) and the good overlapping of the chosen maps have allowed us to compare the land use between 1864 and 1980, both from a quantitative and a qualitative point of view.

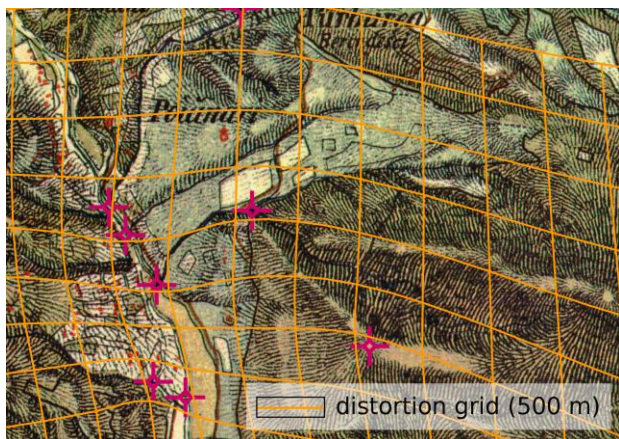


Fig. 2 Distortion analysis of the Szathmary map (1864) through Helmert transformation by using MapAnalyst software

MAIN RESULTS AND DISCUSSIONS

The present analysis has started from the situation mirrored by the Specht Map for the end of the 18th century (1790-1791), when the study catchment was highly forested, even though it was lying in the immediate vicinity of an important road connecting Wallachia and Transylvania. The road followed the Argeș valley, passing through Curtea

de Argeș, Corbeni, Arefu and Sălătruc, finally reaching Căineni (Năstase, 1972; Osaci-Costache, 2004, 2010). The map verifies the existence of Berindesk (Berindești) village, surrounded at that time by forests. Because of the large distortions, the Specht Map has only been used for a reconstruction of the areas covered by forest at the end of the 18th century (Fig. 3), but not at all for other kind of investigations.

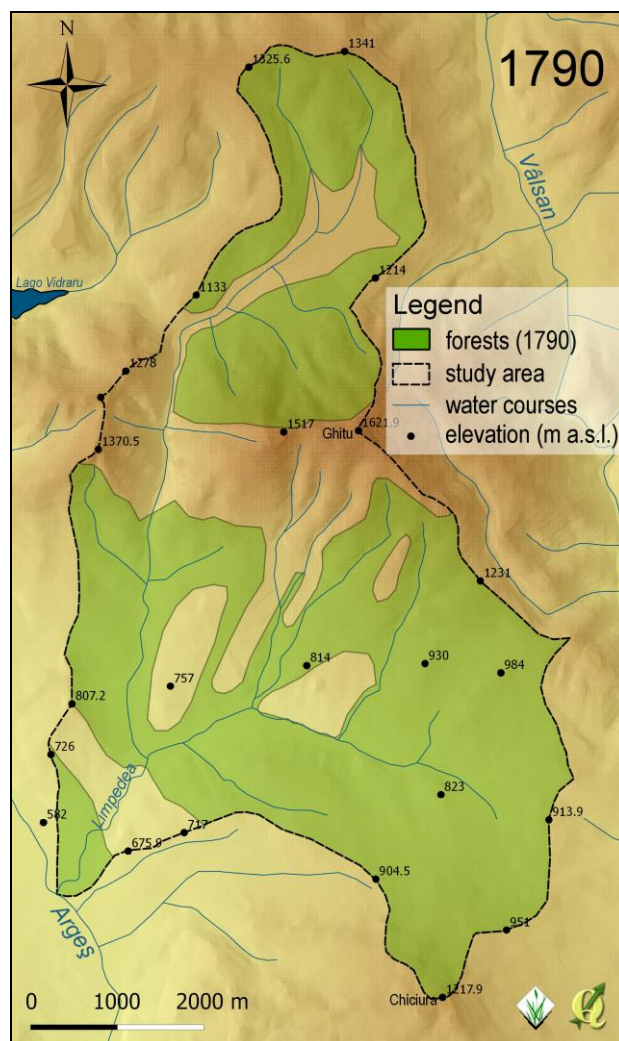


Fig. 3 Reconstitution of the forest extent on Specht Map (1790-1791) in Quantum GIS

Starting from the second half of the 19th century, diachronic comparison of maps has revealed a recession of wooded areas (3,158 ha in 1864, 2,682 ha in 1904 and 2,092 ha in 1980). At the same time, it has highlighted the fact that between 1864 and 1904 deforestations were mainly done on the Limpedeș-Argeș interfluvium, whereas later (1904-1980) they affected also the hearth of the depression, the strip of land situated along the Tulburea stream and the mountain area. The diminution of the forest areas was accompanied by

a rising of the lower tree line (from 594 m in 1864 to 635 m in 1904 and 680 m in 1980), whereas the upper tree line continued to remain at about 1,620 m (Fig. 4). Thus, between 1864 and 1904, the lower tree line rose 41 m and between 1904 and 1980 it rose again by 45 m, which

means a total of 86 m in 116 years (1864-1980). The phenomenon can be explained by anthropogenic interventions, which were stronger on the bottom of the depression (on lower and gently inclined surfaces), where wooded areas were turned into agricultural lands.

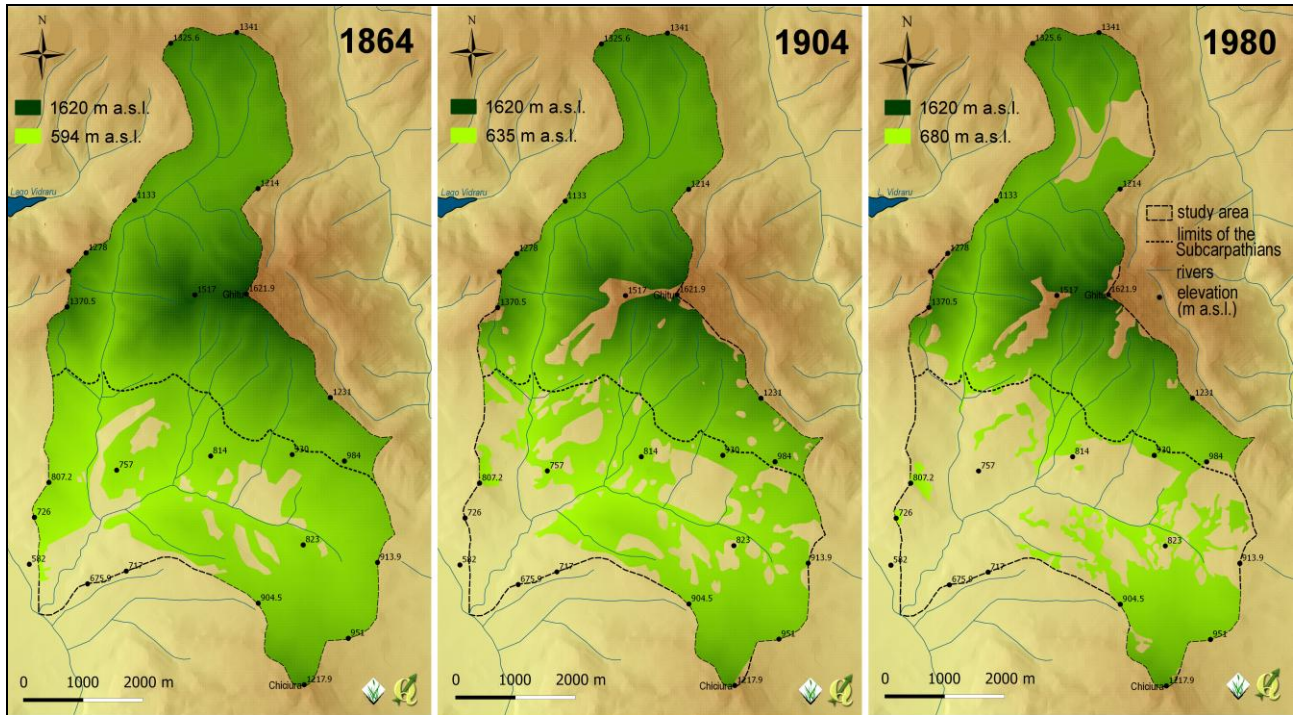


Fig. 4 Forest distribution in relation to altitude. Reconstitution in Quantum GIS – GRASS based on cartographic information

The general view of the deforestations that affected the Limpedea catchment highlights a marked recession of the wooded area in the Subcarpathian space in comparison with the mountain region. At the same time, the analysis of historical maps reveals several stages of anthropogenic intervention and points out the fact

that the human pressure was very strong during the 20th century (Fig. 5). The deforestations affected the wooded areas owned by the state, especially at the beginning of the period, as it has resulted from the overlapping of a cartographic document issued in 1900 by the State Forest Service (the *Forest map on categories of ownership*, scale 1:200,000).

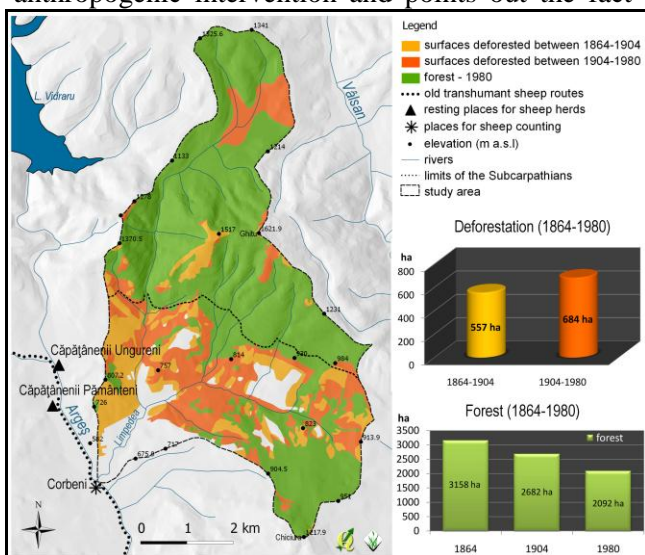


Fig. 5 Reconstitution in Open Source GIS of the deforested areas during the 1864-1980 period

The diminishing of wooded lands determined a continuous lowering of the naturality degree, expressed as percentage of the forest in the total area (Ionescu et al., 1989). It must be mentioned, however, that we have computed the index relying on the information provided by historical maps (Fig. 6), while being aware of the fact that man was not entirely responsible for the recession of wooded areas. Although, on the whole, the values slightly decreased (88.76 percent in 1864, 75.38 percent in 1904 and 58.80 percent in 1980), thus allowing us to include the Limpedeia catchment into the category of intensely forested lands, a detailed analysis conducted separately for the

Carpathian and the Subcarpathian areas has shown a different situation. Thus, because deforestation affected primarily the Subcarpathian space, the naturality degree of this area dropped, reaching a value of 32.4 percent in 1980 (according to the specialists, a value of less than 50 percent leads to negative ecological interactions; Ionescu et al., 1989). The differences are big: most of the mountain sector has currently values higher than 60 percent (often 100 percent), while in the Subcarpathian region there are large areas with values of the naturality degree below 11 percent (with a minimum value of 0 percent at the confluence with the Argeș).

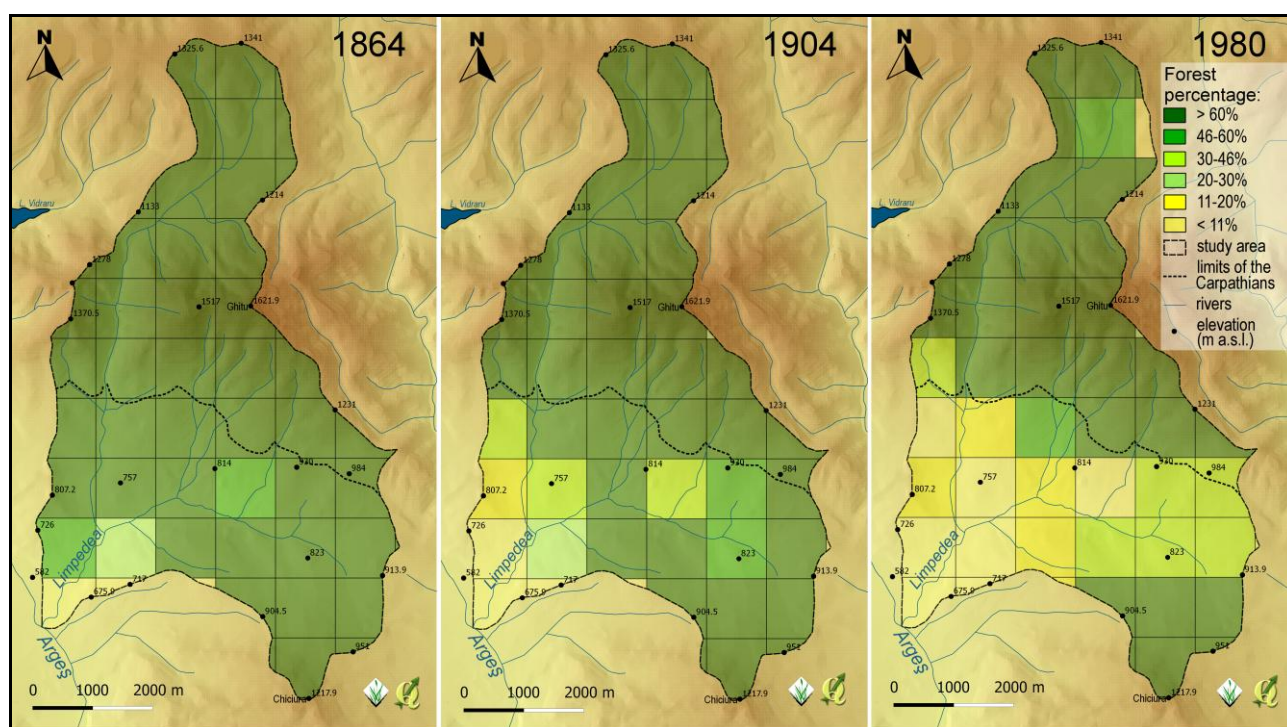


Fig. 6 The evolution of naturality degree computed based on the information provided by historical maps

Deforestation, the most conspicuous anthropogenic intervention on the landscape did not remain without response in the toponymy of the area. Under these circumstances, the old and present maps turn to be important sources for getting in touch with the toponyms, especially with those belonging to the past centuries. Most of the toponyms extracted from the maps we used for this investigation are connected to the deforestation: Secături (roughly Cleared lands), Poiana Vișinului (The Cherry Tree Glade) etc. Other remind of the pastures and hay fields specific for the 19th century: Izlazul Berindești (The Berindești Common),

Izlazul Brădetului (The Brădetului Common). Likewise, there are many toponyms referring to specific tree species (La Sălchioara – At the Dwarf Willow), or to the existence of fruit bearing trees (La Vișini – At the Cherry Trees).

The deforestations were triggered by the new demands of the inhabitants (agricultural lands, building sites etc.) and they were followed by an alteration of the initial land use. Therefore, the land use has been another investigated aspect. Comparing the maps, one can notice not only the deforestation of large areas, but also the fact that over the time the lands had various uses (Fig. 7).

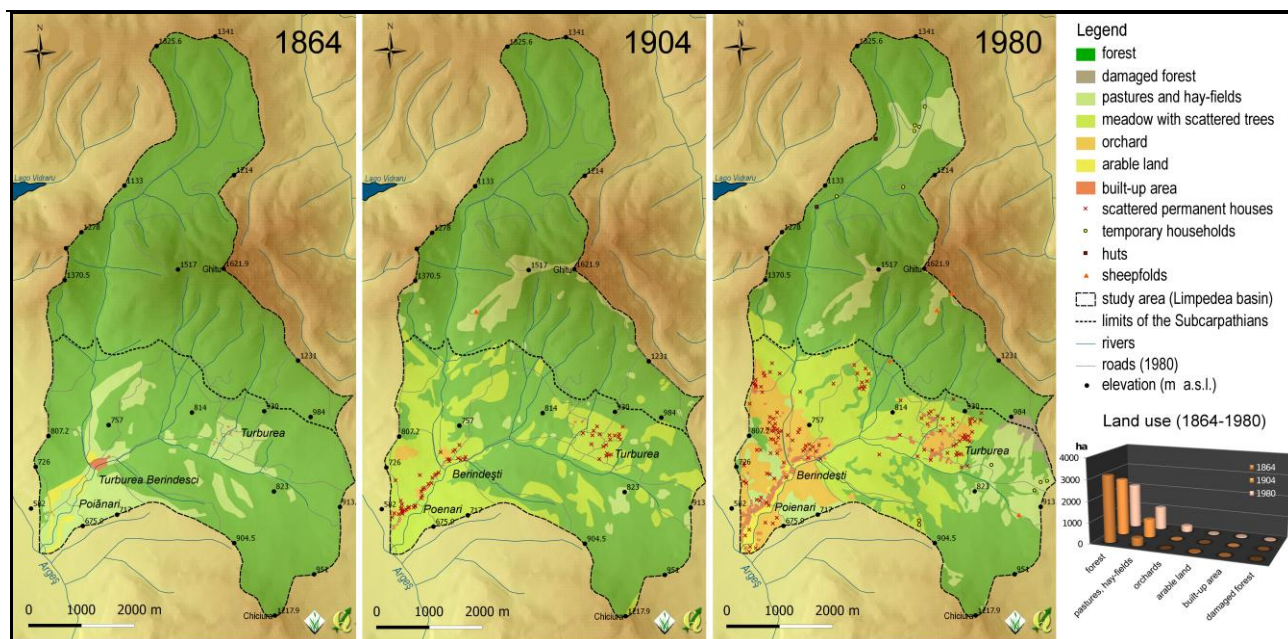


Fig. 7 Land use reconstitution based on historical maps in Open Source GIS (Quantum GIS, GRASS)

A comparison between the Specht Map and the Szathmary Map shows that the dominant phenomenon for the 1790-1864 period was the turning of forests into pastures and hay fields. Cartographic documents (the Szathmary Map) and written sources suggest the main occupation of the inhabitants was stockbreeding, often under the form of transhumance (Osaci-Costache, 2009b). Thus, the spatial extension of pastures was dictated by the necessity to provide food both for the local herds and for those belonging to the Transylvanian shepherds, as the study area was lying near a passing track of transhumant herds. This sheep itinerary was climbing upstream the Argeş River, passing through Corbeni, then reaching Căpățânenii Ungureni (Fig. 5), from where it headed to Arefu and farther away to the Frunți Mountains and the Făgăraş Massif (Popp, 1933). Along this way, Arefu and Corbeni used to be the villages where sheep counting was done (Constantinescu-Mirceşti, 1976), while Arefu, Căpățânenii Ungureni and Căpățânenii Pământeni were resting places for the tired herds (Popp, 1933; Fig. 5).

At the beginning of the 20th century, large areas of pastures and hay fields developed on the site of the former forests. One can also notice an extension of built-up areas and orchards, the latter reaching a large development at the end of the last century (1980). The extension of the orchards after 1960 was encouraged by the socialist legislation, which turned the pastures and the hay fields into socialist plantations (Bold et al., 1960).

The gradual extension of built-up areas within the permanent settlements (29 ha in 1904 and 39 ha

in 1980) was accompanied by an increase in their absolute elevation (Fig. 8). Unlike the forests, which continuously withdrew to higher elevations, the built-up areas stretched both up and down (Fig. 8). Consequently, the amplitude of built-up areas grew from 171 m (1864) to 289 m (1980). Most of the isolated households shown on the topographic plan of 1904 (67.21%) were included in the 20th century in the compact built-up area. At the same time, 32.79 percent of the isolated households kept their position, remaining far away from the compact built-up area, but preserving their potential to become future nuclei for its further expansion, as it happened between 1904 and 1980.

The increasing human pressure was accompanied by the rising of the upper line of temporary settlements. The altitudinal spreading of isolated buildings (chambers, dwellings, huts, isolated houses with or without courtyards) meant both a lowering of the absolute minimum elevation and an increase of the absolute maximum altitude. Looking strictly at the vertical location of sheepfolds one can also ascertain an increase in their absolute altitude (from 1,130 m in 1904 to 1,490 m in 1980), determined by the quest for new pastures, inasmuch as stockbreeding has been a traditional occupation in this area. This also explains the vast lands covered by pastures and hay fields during the former centuries.

Another consequence of the agricultural land expansion to the detriment of the forest was the tillage of highly inclined surfaces (Fig. 9). For instance, if at the beginning of the 20th century the buildings occupied the lands lying at gradients

between 0 and 18°, at the end of the same century they came to seize the slopes with declivities as high as 34° (the highest frequency, however, being specific for the 8-15° interval). With respect to the pastures and hay fields, which represent the dominant land use in the Subcarpathian area of the Limpedeia catchment, one can notice that if in 1980 they recorded a maximum gradient of 37°, in 1980 this value reached 40°. However, in 1980

most of the Subcarpathian pastures and hay fields were found on slopes lying at gradients between 7 and 15°. The same phenomenon is also obvious for the orchards: an increase of the land gradient from a maximum of 15° in 1900 to 37° in 1980. In the mountain area of the catchment, gradients often exceed 50° and, consequently, the slopes are covered by woods (Fig. 9).

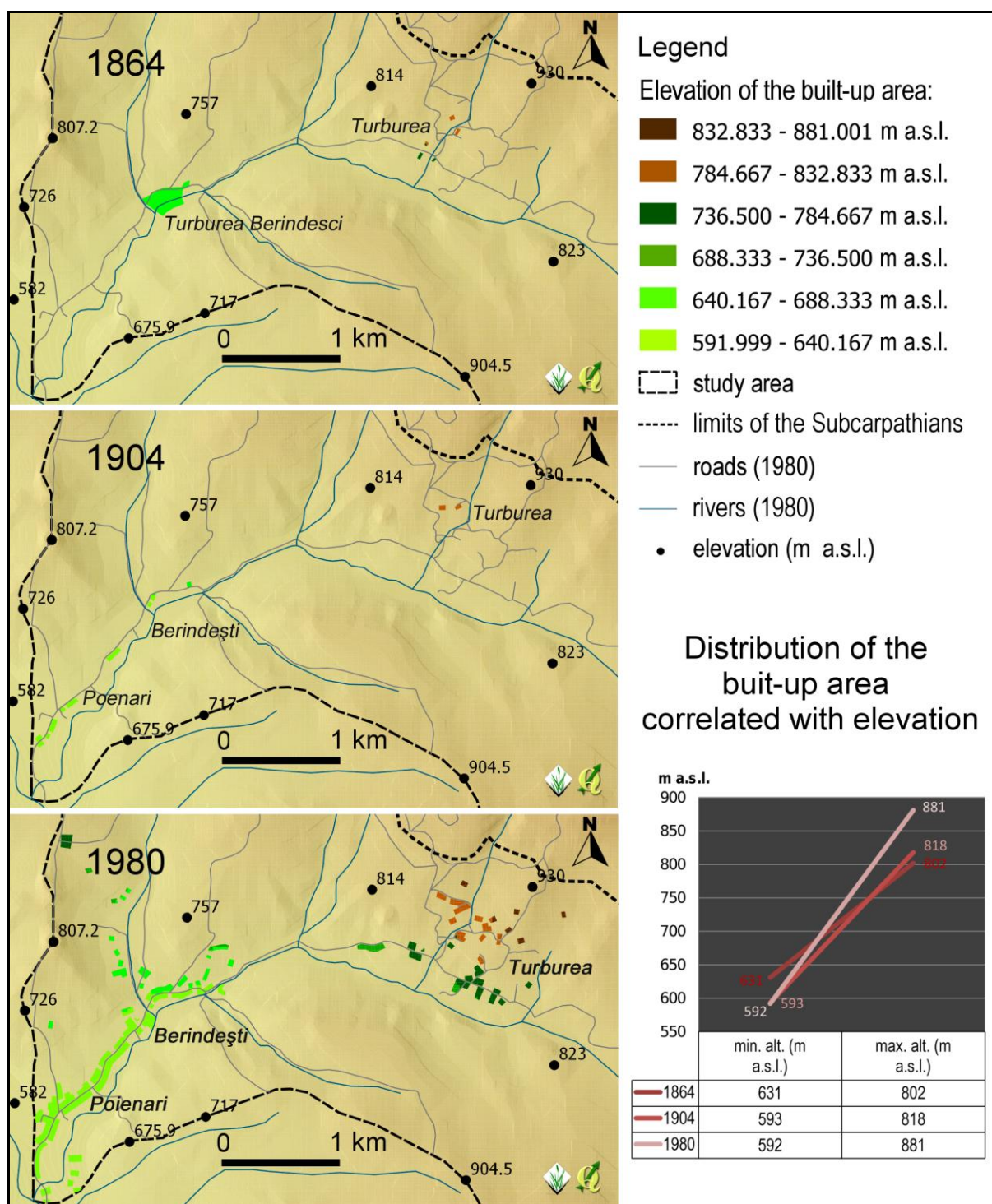


Fig. 8 Correlation between the built-up area and the relief elevation on the basis of cartographic information, in the years 1864, 1904 and 1980

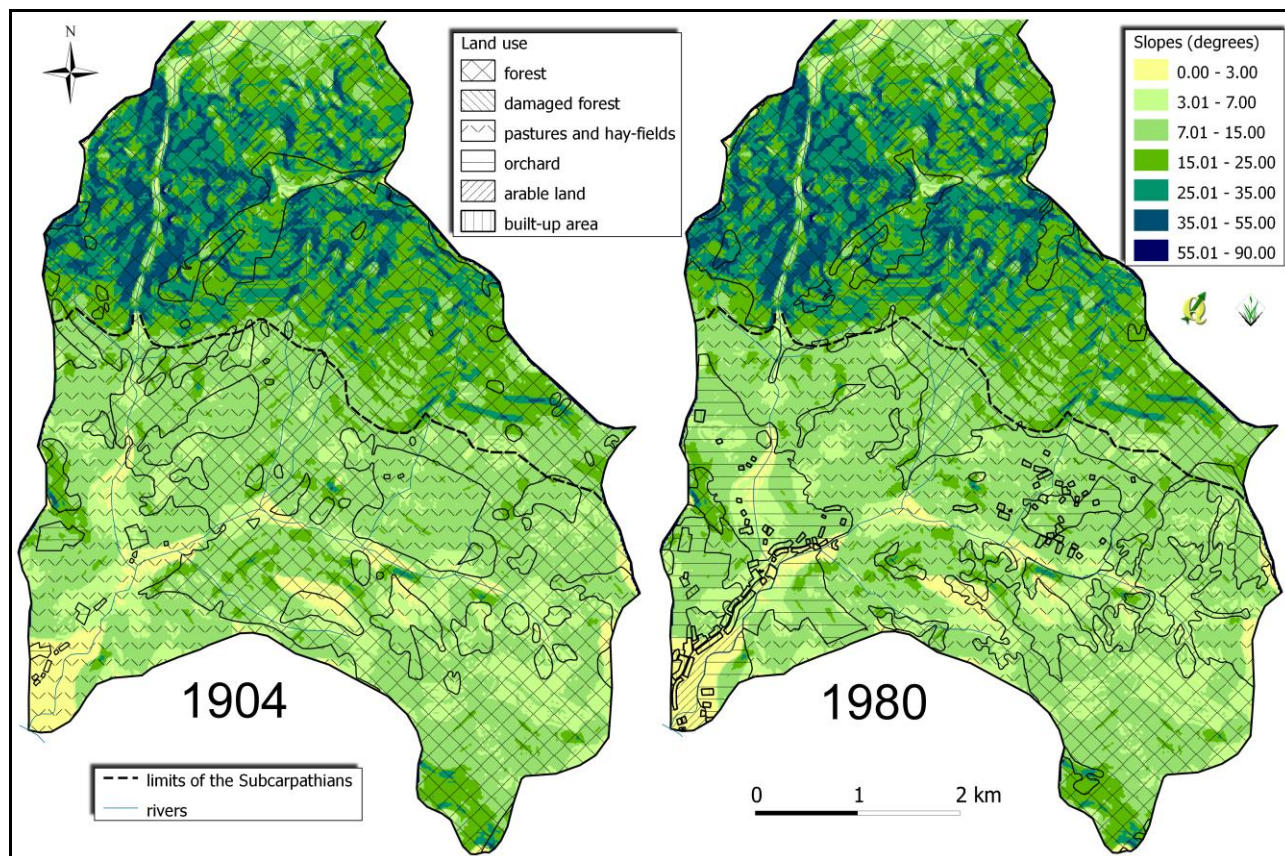


Fig. 9 Correlation based on cartographic data between land use and declivity at the beginning and the end of the 20th century (fragment)

CONCLUSIONS

The large-scale historical maps made in the last 190 years have proved to be the best witnesses of the landscape features. Their analysis and comparison have highlighted a landscape profoundly altered by man. Over the time, the human intervention has had various intensities, but it has particularly influenced the Subcarpathian area and the contact strip between the Subcarpathians and the Carpathians. As far as the mountain space is concerned, it has been affected to a lesser extent. At the end of the 18th century, a big part of the investigated catchment was covered by forests, but the wooded area declined significantly in the following centuries, as a result of their turning into pastures, hay fields, orchards and built-up areas. This phenomenon entailed an increase in human pressure, concomitantly with a lowering of the naturalness index. The dwellings and sheepfolds, which are specific for the local traditional economy, grew numerically and spread to higher elevations in the mountain area.

The use of Open Source GIS software (Quantum GIS, GRASS, gvGIS, Sextante and MapAnalyst) has proved to be very productive for the quantitative

and qualitative analysis of historical maps, as well as for their diachronic comparison, obviously improving the results obtained through classical methods. The overlapping of maps (based on the same reference system) in GIS environment has highlighted the landscape dynamics under the influence of human activities and allowed for its reconstitution in various stages. At the same time, this technique has also allowed for the correlation between the present features of the landscapes and their genesis.

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