ANTHROPOGENIC CHANGES ON LANDFORMS IN THE UPPER AND MIDDLE SECTORS OF STREI BASIN

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Modifications anthropiques sur le relief dans le bassin supérieur et moyen du Strei. Les interventions anthropiques sur les formes de relief sont variées et, plus souvent, se sont prouvées nécessaires, résultant d'une évaluation équitable de chaque partie du territoire et une utilisation en conformité avec le contexte historique, culturel, socio-économique et technologique. L'évaluation efficace des interventions anthropiques sur les formes de relief est obtenue dans une étude systématique en tenant compte du contexte socio-économique, l'instabilité géomorphologique créée ou existante et les mesures d'améliorations prises. Pour illustrer les types d'intervention anthropique sur les formes de relief des cartes avec les formes de relief anthropiques ont été dresées pour deux périodes distinctes, qui ont permis également une évaluation de l'extension et de la durabilité des formes anthropiques.

1. INTRODUCTION

In the international literature, man's intervention on the environment, and consequently on the relief, has been analysed by several authors, such as: Pecsi 1974; Nir 1983; Verstappen 1983; Toy and Hardey 1989; Piacente 1996 in Panizza 1996; Billi and Rinaldi 1997; Goudie 2001, etc. In Romania, Bălteanu 1984; Armaş 1993; Dinu 1997; Grecu *et al.* 2001; Rădoane *et al*. 2007; Urdea *et al.* 2009; Voiculescu 2009; etc. were preoccupied by this subject.

To create certain conditions, man has changed the environment over time by cutting forests, cultivating the land, irrigating, exploiting the resources etc. Through his very complex actions, he has become an *active agent*, who transforms, directly or indirectly, the reality. On the other hand, he is a *passive morphological agent*, who assists, reacts and adapts himself to the conditions created by the natural environment. Under certain circumstances, man has proved to be a strong geomorphological agent, even more efficient than the natural processes in modelling the landforms (Billi and Rinaldi 1997). Most of his actions are unavoidable, while others are necessary. Whatever their nature, they result in the degradation of the environment (Toy and Hardey 1989), and, consequently, of the relief. However, we cannot neglect the positive aspects of these interventions.

2. METHODOLOGY

Anthropogenic changes vary in time and space that is why it is difficult to establish the intensity with which they have occurred. The questions that must be answered in such an investigation are: "*What has man done/does man do*?", "*Why*?", "*When*?", "*How*?" and "*How long*?" In this context, a systematic study should be carried out by addressing the historical aspects of the changes, the socio-economic context when they occurred, the geomorphological processes caused and the measures

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undertaken to improve the situation (Nir 1983; Neboit 1984; Piacente 1996 in Panizza 1996; Latocha 2009 etc.).

To answer the above questions, we aim:

- to use various sources of information to gain a clear picture of man-induced changes;

The sources of information used in this study are: *cartographic materials from different periods of time,* such as: Austrian maps, scale 1:28.800 (1806–1868), Austrian maps, scale: 1:200.000 (1895–1906), topographical maps, scale: 1:25.000 (1963), hydrological maps, scale 1:200.000 (1991), topographical maps, scale 1:100.000 (1996), orthophotographs (0.5 m resolution, 2005); *agro-pedological studies* (1976, 1983 and 2007), *environmental reports* (2006–2008), *bibliography* and *field work* conducted between 2005 and 2010. On this basis, we obtained information from the following areas: agriculture (agricultural roads, land reclamation works, buildings), forestry (forest roads, buildings), infrastructure, settlements (extending built surfaces, types of buildings), anti-erosion works, resources exploitation, hydropower facilities (canals, offtakes, culverts, dams, reservoirs, hydroelectric plants) etc.

- to establish the demographic, socio-economic, cultural and technological context when they occurred;

In this respect, the data regarding the evolution of the population and the population density suggest the pace of the changes.

- to identify the extension and the sustainability of the man-induced changes;
- to identify the geomorphological consequences and the improvement measures that were adopted.

1. RESULTS AND DISSCUTIONS

The upper and middle river basin of the Strei valley falls almost entirely within the area of the Southern Carpathians. Having a general form of a triangle, bordered to the south by the Retezat-Godeanu-Ţarcu Mountains, to the west by the Poiana Ruscăi Mountains and to the north-west by the Şureanu Mountains, and with an area of 1,559 sq. km, it imposes itself as a natural entity well individualised.

The landforms from here have fallen under the incidence of the anthropogenic factor since ancient times, as it has been proved by the archaeological discoveries. These man-induced changes are diverse and we are going to analyse them taking into consideration the activities that claimed them.

Anthropogenic changes on the landforms due to human habitat expanding intensified in the communist period, when pedological, forestry, hydrological and underground resources were exploited. We should not ignore the fact that the upper and middle river basin of the Strei valley overlaps two highly humanised areas since ancient times: the Şureanu Mountains, with the Dacian and Roman traces, and the Haţegului Depression, with the former capital of the Roman colony. That is why it is necessary to stage the changes, as it follows:

1. **anthropogenic changes from ancient and medieval period**: represented by: Dacian traces, Roman traces and Medieval traces (Fig. 1);

2. **anthropogenic changes from the modern and contemporary period**: military fortifications from WWI; on the landforms with altitudes of 285–900 m, houses and buildings responding to agricultural, forestry, industrial and tourist needs, as well as infrastructure (Fig. 2). Currently, most of them have received another destination, or have been abandoned, almost disappearing from the landscape. As a result of grazing practice since ancient times, the geomorphological landscape of the studied area stores consequences of the summer grazing (*e.g.* Şureanu Mts).

Anthropogenic changes on landforms through land reclamation works. Land reclamation works were carried out in the communist period and aimed at fighting against soil erosion, restoring moisture deficit (irrigation) and preventing or eliminating the moisture excess from soil (course regulation, draining works).

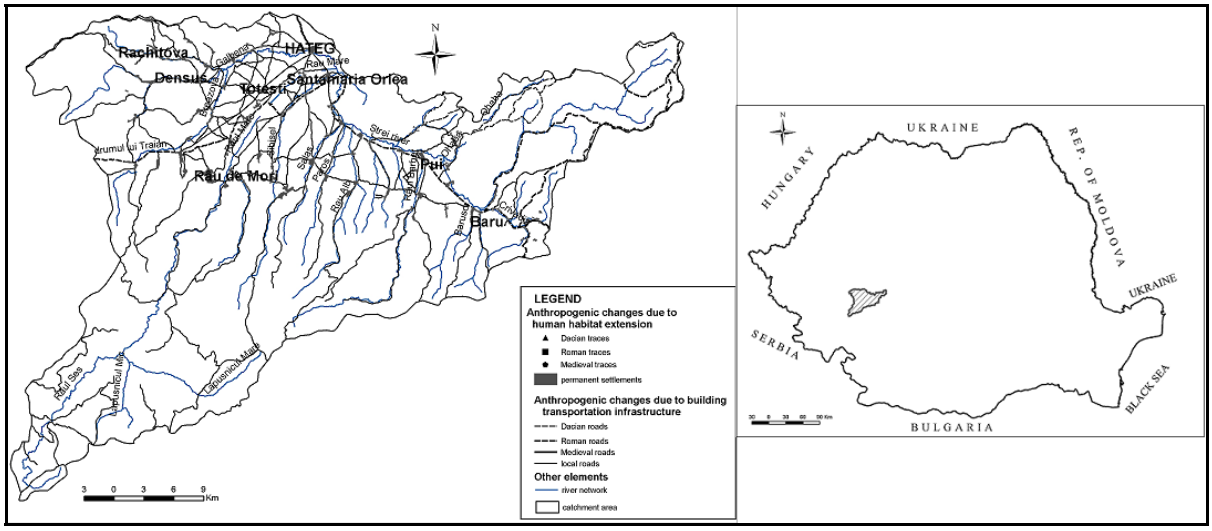

Fig. 1 – Anthropogenic landforms (up to the beginning of the 20th century).

Local irrigation systems, which extended over an area of 4,253 ha, were built between Râul de Mori, Sântămărie Orlea, Pui and Baru. *Draining works* were carried out over an area of 6,720 ha. Of this, 4,536 ha were included in the irrigation systems.

After 1991, when Law no. 18/1991 was applied, the new owners did not use the pipes or they stole them, that is why they are inexistent at present. Draining and irrigation ditches were clogged or occupied by vegetation. Floods affecting the households are more common because those ditches also had the role to collect the water from precipitation.

The most important *anti-erosion works* were performed before 1989 between Clopotiva – Sarmizegetusa – Zeicani, on the right side of the Râul Mare, on the left side of the Breazova and on the right side of the Strei (Fig. 2). These works aimed to stabilize the slopes, to prevent erosion processes, to remove water excess from microdepressional areas, to return the areas affected by landslides, pseudogleisation, erosion etc. to agricultural use.

After 1991, the anti-erosion works became unfunctional. Currently, such works are carried out by owners, depending on the financial possibilities available to them, or by land-owners associations which possess those areas and receive funds to maintain the grasslands. Among the most common anti-erosion works found on the field stand: black locust plantations, bed lining with vegetable remains resulted form cleaning pastures (Glămeia Hill, Livadia village, Baru commune), fencing the affected areas (left slope of the Râul Bărbat, Hobița village, Pui commune) etc. Unfortunately, we found that in most of the cases, no ameliorative measures are taken, and these bad-lands expand, withdrawing from the agricultural circuit these areas, for the long term.

Anthropogenic changes on the riverbeds due to regulation and embankment works. Regulation and embankment works were started after 1975 to protect settlements against floods. The works undertaken up to date are conservative and they did not disturb the initial course, but they protected it. They have ensured the stability in time of the river course in plan and of the cross section of the main channel. In the case of the sections where there are branches it was intervened with bulldozers, especially after

floods, to give the course a straight path. Also, by blocking the branches, the eyots were removed, restructuring the adjacent land. Most of the time, such works led to the widening of the channel, as a large quantity of sediments was extracted. Currently, a radical rectification should be made on the sections where the river has the tendency to loosen, by piercing meander loops.

The dams and thresholds are in an advanced stage of degradation, so they no longer fit the purpose they were built for. The most important complex regulation works were carried out on the Râul Mare. Also, regulations were made on the Strei and its tributaries.

Anthropogenic changes on the relief due to the hydropower engineering on the Râul Mare. The works on the Râul Mare, started in 1975, had as objectives: to turn to good account the hydropower potential, to regulate channels, to remove the branches developed by the Râul Mare at its entrance in the Haţegului Depression and up to its confluence with the Strei, to drain the areas with moisture excess, to expend the irrigated areas and to provide drinking and industrial water for the settlements crossed by the Râul Mare.

The relief has been altered both on the surface and in the underground. Dams, reservoirs (Gura Apei, Ostrovu Mic, Păclişa and Haţeg), hydropower plants, two culverts, two offtakes and several tail races were built. On this occasion, it was changed not only the natural flow of the Râul Mare, but also of the Râul Bărbat, Râul Alb, Paroşu, Sălaşu, as well as of some tributaries of the Râul Mare (Sibişel, Râuşor), by capturing the upper courses and directing the water through an underground gallery, which is 34 km long (Fig. 2).

Anthropogenic changes due to building and expanding the transportation and technical-edilitary infrastructure. The relief has been altered both on the surface and in the underground, by building roads, civil structures (bridges, footbridges, viaducts, retaining walls, dams, drains and tunnels), drinking water, gas and electricity distribution networks as well as sewage networks. The changes began in ancient times in the Şureanu Mountains, and were extended in the subsequent periods. Most of the roads built by the Romans are used today. For example, local road 63 overlaps "*Trajan's road*" between Săcel- Balomir (Sântămăria Orlea commune) (Fig. 1). There are all categories of roads, located on the slopes and along valleys (Fig. 2).

In the case of highly fragmented areas, a series of bridges, viaducts and footbridges have been built and the slopes have been stabilised. Most of the civil structures have been made between Baru and Merişor, where the drainage density values are of 3.1–6 km/sq. km (Fig. 2).

During the upgrade works, even if we talk about national, local (communal) or forestry roads, material from the adjacent slopes was cut down and taken, leading to the installation of the morphological instability. The vegetation, which is a layer protection factor, has also been removed. The instability created manifests itself by erosion and mass movement processes. After upgrading the road around Gura Apei reservoir, the materials taken from the slopes moved downslope where they accumulated as debris.

Most of the roads have proved to be economically inefficient, so currently they are not functional (e.g. the railway between Subcetate and Băuţar). From the former forestry railways built in the upper river basin of the Strei for wood transportation (e.g. from the Lola and Prelucile, Tecuri valleys), their cut-and-fills are preserved after ceasing the activity in 1975.

The instability created by infrastructure implementation is manifested by erosion processes affecting in particular the unpaved roads and bare hillsides, and mass movement processes (landslides, on the railway sector between Baru and Merişor, and rock falls). The basement in the urban (Haţeg) and some rural centres (Baru, Pui, Sântămăria Orlea, Sălaşu de Sus) is studded with drinking water distribution and sanitation networks.

Anthropogenic changes on the relief by natural resources exploitation. The exploitation of subsoil resources has created an excavation (quarries and mines) and accumulation (dumps) morphology. These activities have attracted a large number of workers, especially outside the catchment. This is reflected in the evolution number of the inhabitants and the population density (*e.g*. in Răchitova commune, where Boița mine functioned until 1993).

In the case of the bauxite quarry (Comarnic, Federi village, Pui commune), clay and loam sand quarries (Baru, Crivadia village, Bănița commune, Râul de Mori, Galați village, Pui commune) and granite and granodiorite quarry (the Nețișului Valley in the Râul Mare catchment), we speak about an open-cast mining. Some of these quarries were opened when the building activities at the hydropower reservoirs on the Râul Mare started in 1975 (e.g. Galați village, Pui commune, Râul de Mori). Others provided raw materials for local industries (the quarries form Crivadia and Baru for refractory industry from Baru) or other industries in the country (Comarnic quarry → Oradea for aluminium production) (Fig. 2).

In the case of open-cast mining, the slopes have been changed by creating 3 or 4 open-pit benches, by building access roads, staff buildings and tailings storage facilities. The slopes of the open-pit benches, as well as the dumps, are affected by surface and gully erosion and mass movements (landslides, bank failure etc.).

After ceasing the mining activities, no ameliorative works have been taken to reintroduce in the agricultural and forestry circuit these bad-land sites, although some of them are included in the environmental reports (2006–2008) as ecological perimeters (*e.g*. Comarnic quarry, Federi village, Pui commune).

After the polimetalic ore exploitation from Boița-Hațeg, the topography was modified by creating the Parani dump (3.6 ha), the Valea Luponii settling pond, on the Poni's Valley (a valley pond) (2.3 ha), by building access roads, to the coast galleries and to the pond, and the buildings which belonged to the mine.

The roads and the dump are affected by gully erosion. In the areas adjacent to the tailings, the slopes are affected by landslides, rock falls and intense erosion processes. The mine was included in the category of mining perimeters subject to greening. The pond was fenced and fixed with black locust plantations. The access is prohibited; however, the partly grassed areas are used by local people as pastures. The bare surfaces, directly affected by precipitation, are subject to gully erosion. The dump is also fixed with herbaceous and woody vegetation, so that it is barely distinguishable in the landscape.

Anthropogenic changes due to gravel quarrying. This activity takes place in the gravel pits from Baru, Livadia, Ponor, Pui, Ohaba de sub Piatră, Băieşti and Ciopeia (Fig. 2). Near the gravel pits, sorting stations and aggregate deposits are located.

The gravel quarrying is practiced to unsilt, correct and rectify the course. This ensures protection to the thalweg by keeping the maximum depth of extraction at a rate that matches the thalweg of the valley. The quarrying activity is under total or partial immersion with dragline, excavator or bulldozer. Among the consequences of this activity, it is worth mentioning: widening of the minor riverbed, that can reach widths of about 200–300 m, and reducing the size of the floodplain and creating the possibility of breaking through the floodplain terraces; meander piercing and channel straightening; lowering the thalweg; increasing the quantity of sediments from bank erosion; removing the possibility of alluvial terraces formation upstream of the place of the quarrying; mass wasting (bank failure) that affects the banks; radical modification of the initial riverbed morphology by forming pools.

Between 2005–2010, when the fieldwork was carried out, it was found that both along the Strei river and its tributaries, exploitations are not always conducted, but the gravel is taken directly from the riverbed and used for immediate purposes.

To detect the extension and durability of the man-made changes, detailed geomorphological mapping was used, which proves to be a useful tool in such approaches (Latocha 2009). We made two *maps with the anthropogenic landforms* with origins both in the past and present human activity (Fig. 1 and 2).

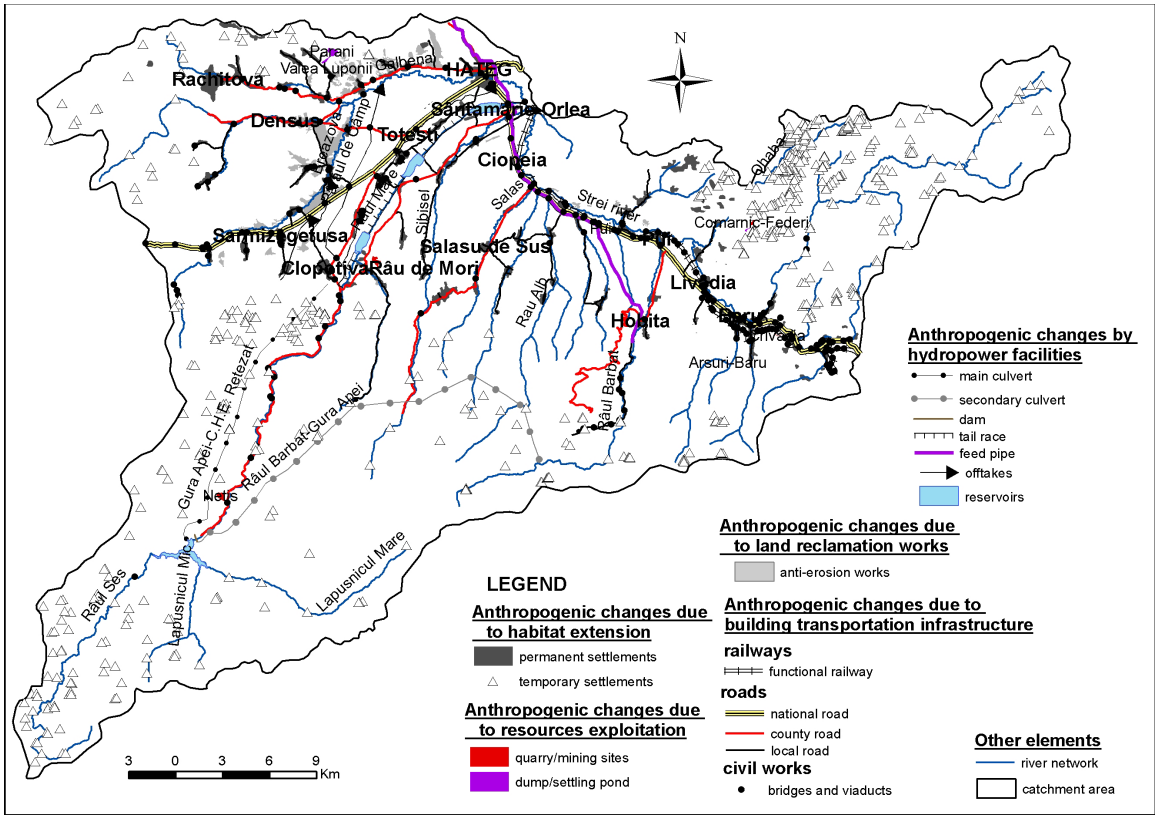

Fig. 2 – Anthropogenic landforms (at present).

4. CONCLUSIONS

By using various sources of information we outlined how the anthropogenic factor modified the landforms, the context when they were done and we detected the extension and durability of the landforms. The fieldwork, combined with the references, allowed the identification of the geomorphological consequences of the interventions, and the comparison of the present day situation with the achievements of the authorities in charge. We also identified the moments when the anthropogenic agent corrected, transformed and modified the natural processes which had affected the landforms, by intensifying or reducing their intensity and causing a rupture of certain equilibrium that nature had tried to reconstruct in different ways.

The anthropogenic changes have affected:

- *floodplains and channels with the modification of the morphology and river drainage system* (regulation and embankment works, gravel quarries, hydropower structures etc.);
- *terraces and treads* (placing the buildings, the roads, industrial activities, technical infrastructure etc.);
- *interfluves* (building roads, location of electric energy distribution network);
- *slopes* (anti-erosion works, building roads, resources exploitation, overgrazing, cattle paths);

The geomorphological processes induced by human activities are:

- *landslides* (the location of the roads and railway on the unstable slopes between Baru and Merişor, undermining the base of slopes by widening forest roads (e.g. upper course of the Strei), slipping of the dumps located in valleys);
- *bank failure* (e.g. the Strei and its tributaries in the middle basin), failure of the dump slopes (the Valea lui Ponii dump, Boiţa, Răchitova) and open-pit benches (quarries form Crivadia, Comarnic, Galaţi, Râul de Mori), of the slopes by widening the forest roads (e.g. the Râul Bărbat valley, the Râul Mare valley etc.);
- *surface erosion* (removal or lack of land cover, in particular, on dumps; overgrazing, tourist routes, cattle paths);
- *gully erosion* (overgrazing, the location of agricultural and forest roads on steep slopes);
- *rockfalls* (limestone quarries form Comarnic, Fizeşti, Pui, Valea Neţişului – granite and granodiorite quarry);

After performing this analysis, we suggest that the following improvement measures be taken in the future:

- course rectification by cutting meander loops and embanking the river banks on the Strei and its tributaries (the Sibişel, the Galbena, the Râul Bărbat, the Râul Alb etc.);
- anti-erosion and soil moisture correction works to reintroduce in the agricultural circuit the areas affected by moisture excess, erosion and landslides (e.g. the slopes around Săcel, Sâmpetru and Bărăştii-Haţegului villages, Sântămăria Orlea commune, Glămeia Hill, Livadia village, Baru commune, the right slope of the Strei between Ponor and Pui etc.);
- special measures implementation to stabilize and reinforce the slopes of the open-pit benches of the quarries and dumps, as they are modeled by external agents (Valea Luponii dump, Comarnic, Râul de Mori, Crivadia quarries etc.)

REFERENCES

Armaş, I. (1991–1992), *Aspects of the anthropic landscapes in Romania and its mapping*, in Analele Univ. Bucureşti, anul **XLI**, 1991-1992, pag. 91-97.

Bălteanu, D. (1984), *Relieful: ieri, azi, mâine*, Edit. Albatros, Bucureşti.

Billi, P., Rinaldi, M. (1997), *Human impact on sediment yield and channel dynamics in the Arno River basin (central Italy)*, Human Impact on Erosion and Sedimentation (Proceedings of Rabat Symposium S6, April 1997), IAHS publ. no. 245.

Campy, M., Macaire, J.J. (1989), *Géologie des formations superficielles*, Editeur Masson, Paris.

Daicoviciu, H., Ferenczi, S., Glodariu, I. (1989), *Cetăţi şi aşezări dacice din sud-vestul Transilvaniei*, Edit. Ştiinţifică şi Enciclopedică, Bucureşti.

Duma, S. (1998), *Studiul geoecologic al exploatărilor miniere din zona sudică a Munţilor Apuseni, Munţii Poiana Ruscă şi Munţii Sebeşului*, Edit. Dacia, Cluj-Napoca.

Goodie, A. (2001), *The human impact on the natural environment*, 5th Edition, Great Britain.

Grumăzescu Cornelia (1975), *Depresiunea Haţegului. Studiu geomorfologic*, Edit. Academiei RSR, Bucureşti.

Ianoş, I. (1997), *Industria, element şi factor de presiune în organizarea spaţiului*, Analele Univ. din Timişoara, vol. **VII**, pag. 139-143.

Ichim, I., Rădoane, M., Bătucă, D., Duma, D. (1989), *Morfologia şi dinamica albiilor de râuri*, Edit. Tehnică, Bucureşti.

Latocha, A. (2009), *The geomorphological map as a tool for assessing human impact on landforms*, Journal of Maps, 103-107.

Migon, Piotr (2000), *Mountain geomorphology of Central Europe under human impact*, IAG 2000, Thematic Conference Monsoon climate, geomorphological processes and human activities, China, abstracts, http://www. geomorph.org/sp/arch/cn00/13 html.

Neboit-Guilhort, R.(1999), *Autour d'un concept d'érosion accélérée: l'homme, le temps et la morphogenèse*, in *Géomorphologie*: *relief, processus, environnement*, no.2, vol.5, 159-172.

Nir, D. (1983), *Man, a geomorphological unit: an introduction to anthropic geomorphology*, Keter Publishing House, Israel.

Panizza, M. (1995), *Geomorphologia*, Bologna, Pitagora Editrice.

Panizza, Mario (1996), *Environmental Geomorphology*, Elsevier Science, Amsterdam, The Netherlands.
Panizza, Mario (2005), *Manuale di geomorphologia applicata*, Franco Angeli, Milano, Italy.
Pecsi, Marton (1974), *Man and environment*, Akademiani Kiado, Budapest.
Popa, N. (1999), *Ţara Haţegului. Potenţialul de dezvoltare al aşezărilor omeneşti. Studiu de geografie rurală*, Edit. Brumar, Timişoara.
Rădoane, M., Radoane, N., Ioniţă, I., Surdeanu, V. (1999), *Ravenele. Forme, Procese, Evoluţie*, Edit. Presa Univ. Clujeană, Cluj-Napoca.
Rădoane, M., Rădoane, N. (2007), *Geomorfologie aplicată*, Edit. Universităţii din Suceava.
Surd, V. (coord.) (2006), *Amenajarea teritoriului şi infrastructuri tehnice*, Edit. Presa Univ. Clujeană, Cluj-Napoca.
Surdeanu, V. (1998), *Geografia terenurilor degradate*, Presa Univ. Clujeană, Cluj-Napoca.
Toy, T.J., Hadley, R.F. (1989), *Geomorphic design and management of disturbed lands,* in *Sediment and the Environment (Proceedings of the Baltimore Symposium, May, 1989*), IAHS, Publ. nr. 184.
Urdea, P., Török-Oance, M., Ardelean, M., Vuia, F., Voiculescu, M. (2009), *Geomorphological Aspects of the Human Impact in the Alpine Area of Southern Carpathians (Romania)*, Hrvatski Geografski Glasnik 71/1, 19-32.
Verstappen, Th.H. (1983), *Applied geomorphology,* Elsevier, Amsterdam.
Vuia, R. (1926), Ţara Haţegului şi Regiunea Pădurenilor, Lucr. Inst. Geogr. Univ. Cluj, vol. **II** (1924-1925).

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