MAN-MADE RELIEF: ANTHROPOGENIC IMPACT ON NATURAL EARTH SURFACE

Vanya Stamenova, Stefan Stamenov
Space Research and Technology Institute –BAS, Sofia, Bulgaria

ABSTRACT

People change and transform the Earth surface during the whole human history with different intensity, as the most evident are the changes on the relief. They can be caused by a wide range of human activities, but most important are mining activities, road and railway construction, urban construction, etc. To study the anthropogenic changes of the relief and the variety of anthropogenic landforms, scientists have presented different classifications of the anthropogenic landforms over the years. The current paper makes a brief review of the anthropogenic relief studies and classifications of anthropogenic landforms and discusses the study of the anthropogenic relief in Bulgaria by presenting some case studies.

Keywords: DEM, anthropogenic relief, anthropogenic landforms, GIS, remote sensing

INTRODUCTION

Humans change their environment. This fact today is so obvious and routine that we have stopped even to notice it. The changes of the environment are various and varies in origin and scale. They affect atmosphere, the oceans and inland waters, and the land. Perhaps, the most visible changes at all are the changes of the land. But we are so accustomed to them that even the changes at large scale are accepted by us as almost natural processes, especially if these changes have been made in the past and the nature have had the time to recover the effects. And yet they are artificial man-made changes related to different human activities. May be the most suitable way to detect and define the changes, and describe them is by defining them as changes in the relief. According to the Encyclopedia of Geomorphology, for example, the relief is defined as "topography itself or elevation differences between the highest and lowest points within a certain area" [1]. The results of all human according to this definition leading to reshaping the Earth's surface are considered changes in the relief.

BRIEF REVIEW OF ANTHROPOGENIC RELIEF STUDIES AND CLASSIFICATIONS

During the whole human history people have influenced the natural environment and transformed Earth's surface, particularly relief. One of the first works to emphasize the influence of man on nature, including the relief, is Marsh's book "Man and Nature" (1864) [2]. The importance of human activity as a relief-forming agent is described in the works of Sherlock [3], Fels [4], Nir [5], Demek [6], Goudie [7], Hooke [8], Lihacheva, Timofhey [9], Goudie [10], Rózsa [11], Szabó et al. [12] and others. The artificial changes of the Earth's surface and relief are subject to study of anthropogenic geomorphology. The anthropogenic geomorphology has a definition that slightly varies in the works of the different authors [4], [12], [13], but in general it may be described as study of the human influence on the relief and the anthropogenic landforms created by the various human activities, and the changes in the course of natural geomorphological processes.

The study of anthropogenic relief and human impact on the transformation and change of the earth's surface requires the whole variety of anthropogenic forms to be covered by selecting appropriate criteria for their classification and study. Several works propose classification of the anthropogenic landforms as well as anthropogenic grounds created as a result of the human actions using different classification criteria [12], [14], [15], [16], [17]. In the 70-ties has appeared Brown's classification of human impact on relief and geomorphological processes, which is considered to be one of the influential. It specifies three classes – direct purposeful action, direct action with incidental consequences and indirect influences as a result of modification and diversion of geomorphological processes [14].

Another classification scheme with emphasis of the artificial ground and deposits has been proposed by the British scientists and adopted by the British Geological Society (BGS) [15]. Their classification is based on the genetic approach defining the origin of the deposits, classifying the artificial (man-made) ground as made, worked, infilled, disturbed and landscaped ground. The artificial ground of United Kingdom and the human impact on Earth surface has been well-studied [3], [16] and the mapping of the artificial ground has been elaborated using the BGS classification [16].
The Hungarian scientists have been developed another classification of the anthropogenic landforms based on the genetic principle and the used criteria is the type of the anthropogenic activity which has been lead to changes of the relief and topographic surface [12]. The classification they proposed consists of 8 types: montanogenic, industrogenic, urbanogenic, traffic, water management, agrogenic, warfare and tourism, sports, each of which is further divided into three types, depending on the type of geomorphological processes.
In their research Peloggia at al. [17] outline the conceptual framework for proposing new classification of the landforms produced by the human geological actions and defining them as technogenic relief. They define the term technogenic relief as landforms created as a result of the transformation of the physical configuration of the Earth's surface by human activities [17]. They propose a classification of the artificial ground, formed as a result of the direct and indirect human action, including four main categories of the technogenic ground – aggraded, degraded, modified and mixed ground [17], [18].
To understand the extent and spatial distribution of the anthropogenic relief changes the human traces on the relief need to be mapped. Latocha in her paper discusses the use of detailed geomorphological maps as a tool for assessment of human impact on landforms and the need of development of new set of symbols for the geomorphological legend of the maps representing the anthropogenic activities [19]. The remote sensing data and the geoinformation technologies provides for the provision of reliable and regular data about the Earth surface and the necessary tools which facilitates the mapping and study of large areas. Several works demonstrate applications of remote sensing technologies and geographic information systems for mapping and analyzing anthropogenic relief [20], [21], [22], but this topic which is still underdeveloped is very topical.

CASE STUDIES OF THE ANTHROPOGENIC RELIEF IN BULGARIA

In Bulgarian science the topic about the anthropogenic activity on the relief is almost intact. A pioneering study in this topic is the project for study of the anthropogenic relief and the human impact in an area near Sofia city (Fig. 1). The region of Novi Iskur, part of Sofia municipality was chosen because of its proximity to the capital city and the active anthropogenic activity carried out there in the recent past. In this region there is an early industrialization at the first half of 20th century because of the development of the railway transport, which continues during the socialism period and there are also developed mining activity. The study area is near village of Kutina (Fig. 1) affected by the mining of low quality lignite coals during the socialist period and cause some ecological problems and land use conflicts.
In this study, remote sensing and geographic information systems for human activity monitoring and its influence on relief and its change are applied for the first time. The accent of this research and the related publications have been placed on tracing the changes in relief and land cover in time for a more than 60-year period, and analysis and assessment of the consequences for surrounding environment and the nearby natural landmark "Kutina pyramids" [23], [24], [25]. The study aims to identify, map and analyze the consequences as a result of human anthropogenic activity, particularly coal mining and afforestation of bare slopes and the occurrence of different geomorphologic processes and landforms – landslides, self-burning lignite coals, erosion, etc. (Fig. 2) [26], [27], [28]. This research completed in a PhD thesis of Vanya Stamenova for development of geographic

information system for remote sensing and ground-based monitoring of anthropogenic impact in the drainage basin of the Kutinska River.

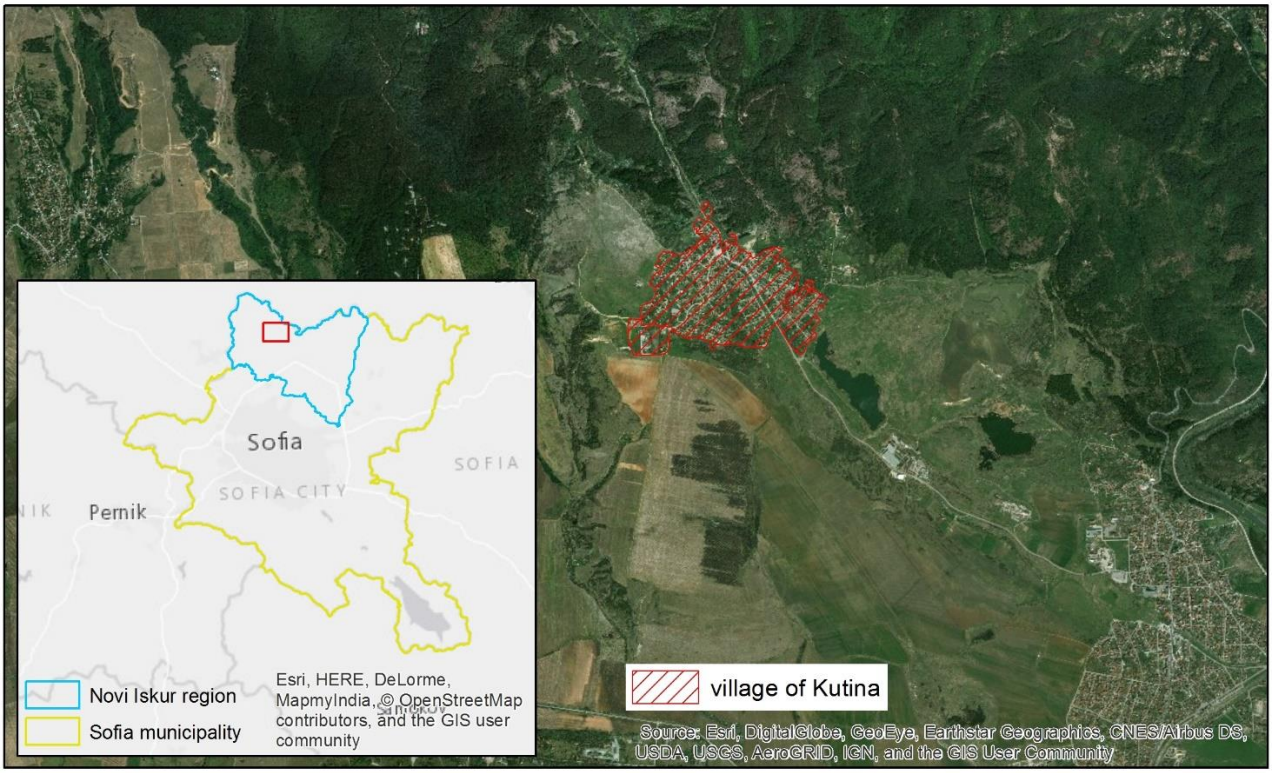

Fig. 1. Location of the village of Kutina, Novi Iskur region, Sofia Municipality

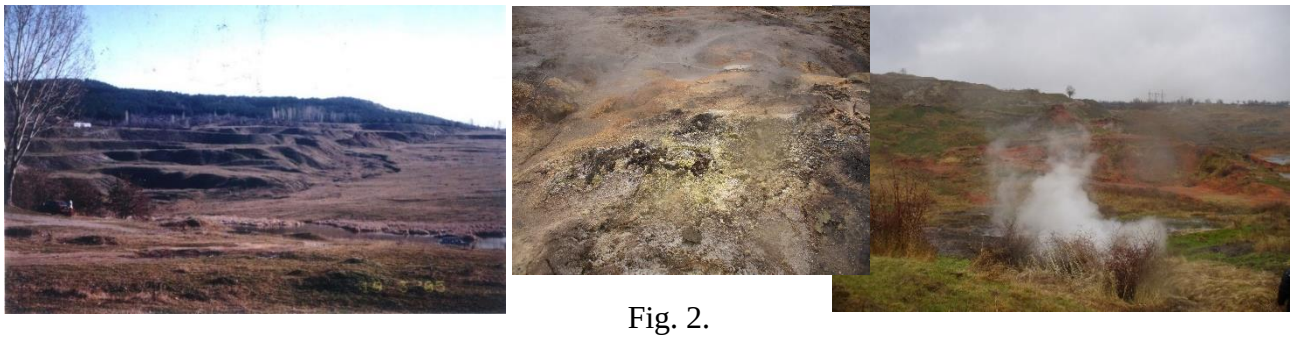

Fig. 2.
Photos of technogenic slopes with active denudation / accumulation processes and self-burning coals

Human activity in the past has also been changed the relief and this process of relief change and transformation has been going through all of human history with different intensity. Other two research projects related to the human impact on the relief in the medieval period and focused on non-destructive survey in archaeology have been conducted during the last six years [30], [31]. Two of the most important medieval archaeological sites in Bulgaria – First Bulgarian capital Pliska and historical and archaeological reserve Kabiyuk were investigated [32], [33], [34], [35], and [36]. It was a pioneering research with applying remote sensing and GIS technologies for mapping, documenting and conservation of two significant archaeological sites. In addition to the purely archaeological topic, the positive archaeological remains and micro topography of the terrain also testify to the human influence on the relief and are evidence of the anthropogenic (man-made) landforms created in the

Middle Ages. The anthropogenic changes in the relief which we studied are mainly traces of fortification facilities and artificial mounds (Fig. 2).

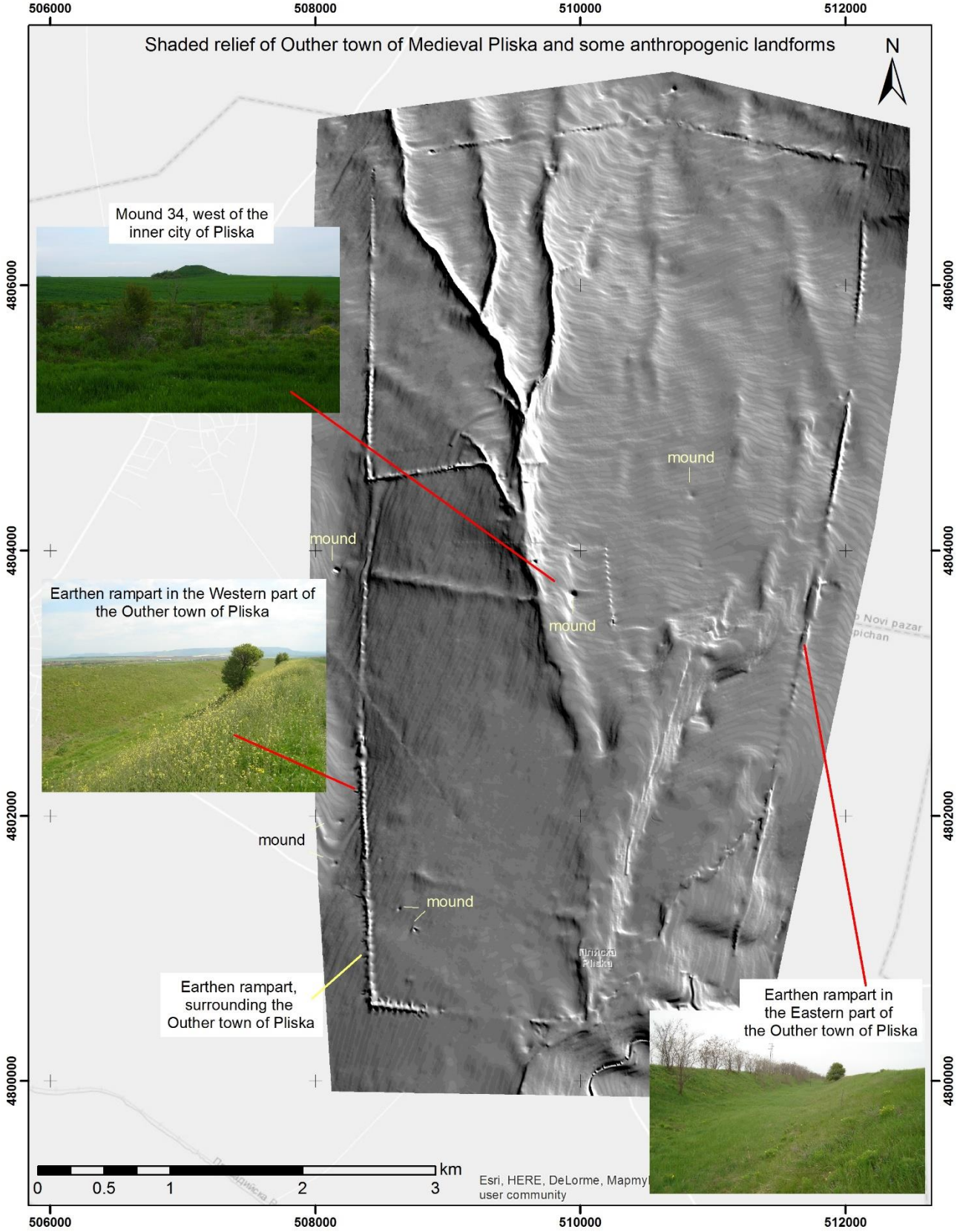

Fig. 2. Shaded relief of the Outer town of Medieval Pliska and some anthropogenic landforms

The latest project, part of which is the current publication, is the research project for study, mapping and spatial modeling of anthropogenic changes of the relief using aerospace and terrestrial data [37]. It aims to perform digital processing and interpretation of aerospace data with different resolution for mapping and spatial modeling of anthropogenic relief changes. The research is aimed at studying and analyzing of anthropogenic changes of the Earth's surface, made in the past and present. A conceptual scheme for the classification of anthropogenic relief forms has been developed as part of the concept of mapping anthropogenic changes of relief and landscape using remote sensing methods and GIS analysis (Fig. 3).

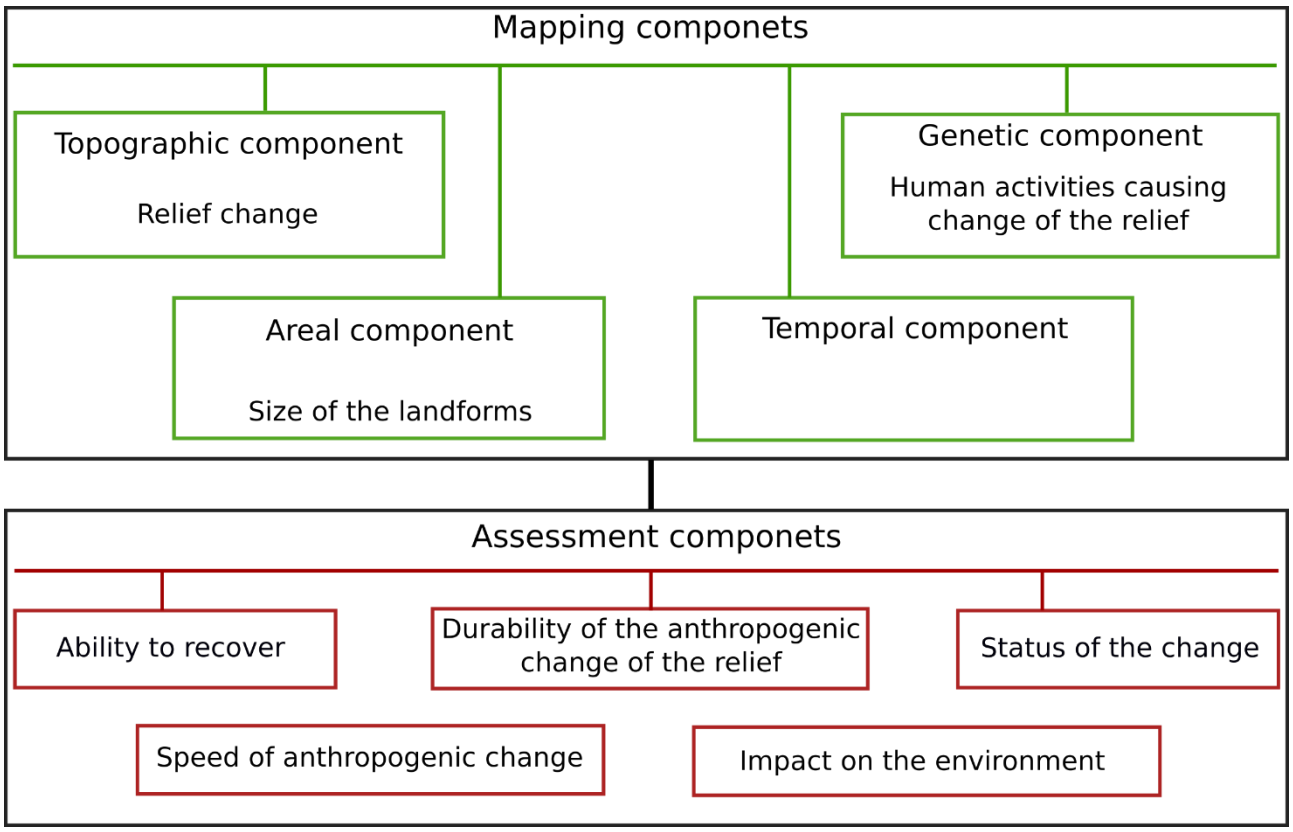

Fig. 3. Conceptual scheme for the classification of anthropogenic relief forms

The proposed scheme includes mapping components and assessment components. The mapping segment includes four major components – *topographic*, related with the change of the relief and landforms formed as a results of negative (denudation) and positive (accumulation) processes; *genetic*, based on the human activities causing change of the relief; *areal*, connected with the size of the landforms; and temporal component depending on whether the anthropogenic changes are contemporary or ancient. The assessment components include the speed of the anthropogenic changes, the status of the change, the durability of the anthropogenic change of the relief, the ability to recover and the impact on the environment.

REFERENCES

1. Goudie, A.S., 2004. Encyclopedia of Geomorphology.
2. Marsh, G.P., 1864. Man and Nature. Scribner, New York

3. Sherlock R.L. (1922) Man as a Geological Agent: An Account of His Actions on Inanimate Nature. London: HF and G Witherby, 372 p.
4. Fels, E. (1934): Der Mensch als Gestalter der Erdoberfläche. – Petermanns Geographische Mitteilungen (in German).
5. Nir, D. (1983): Man, a geomorphological agent. An introduction to Anthropic geomorphology. – Keter Publishing House, 165 p., Jerusalem, Boston, London.
6. Demek, J. (1984): Obecná geomorfologie III. - Vyd. UJEP Brno. Demek, J.(1984): Obecná geomorfologie III. (General geomorphology III.). – Praha: UJEP v Státní pedagogické nakladatelství Praha, 139 p. (in Czech)
7. Goudie, A., 1993. Human influence in geomorphology. Geomorphology 7, 37–59.
8. Hooke, R. L. On the history of human as geomorphic agent. *Geology* 2000, *28*, 843–846.
9. Лихачева, Э., Д. Тимофеев, 2002. Рельеф среды жизни человека. М.: Медиа-Пресс, 640 с.
10. Goudie, A. S. (2006): The Human Impact on the Natural Environment: Past, Present, and Future. – 6th ed.: 357 p., Blackwell Publishing.
11. Rózsa, P. (2007): Attempts at qualitative and quantitative assessment of human impact on the landscape. Geografia Fisica e dinamica quaternaria. 30 (2): 223–238.
12. Szabó, J., Dávid, L. & Lóczy, D. (eds.) (2010): Anthropogenic Geomorphology. A Guide to Man-Made Landforms. Springer, 298 p. ISBN 9789048130573
13. Kirchner, K., I. Smolova. Základy antropogenní geomorfologie**.** (Basics of anthropogenic geomorphology). Olomouc: Univerzita Palackého Olomouc, 2010. 287 s. (in Czech).
14. Brown E. 1970. Man shapes the Earth. The Geographical Journal 136 (1): 74-85
15. Rosenbaum, M., McMillan, A., Powell, J., Cooper, A., Culshaw, M., Northmore, K., 2003. Classification of artificial (man-made) ground. Engineering Geology 69, 399–409.
16. Price S. J., Ford J. R., Cooper A. H. and Neal C. Humans as major geological and geomorphological agents in the Anthropocene: the significance of artificial ground in Great Britain. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, v. 369, issue 1938.
17. Peloggia, A. U. G.; Silva, É. C. N.; Nunes, J. O. R. Technogenic landforms: conceptual framework and application to geomorphologic mapping of artificial ground and landscape as transformes by human geological action. *Quat. Environ. Geosci.* 2014, *5*, 67–81.
18. Peloggia, A., Oliveira, A., Oliveira, A., Silva, E., Nunes, J. Technogenic geodiversity : a proposal on the classification of artificial ground artificiais. 2014, *05*, 28–40.
19. Latocha, A. The geomorphological map as a tool for assessing human impact on landforms. *J. Maps* 2009, *5*, 103–107, doi:10.4113/jom.2009.1047.
20. Nawaz F, Hamidullah F and Fayaz A 2004 The effect of mining on geomorphology; detection of changes by using remote sensing techniques; In: *Proceedings of the ISRPS 2004 Annual Conference, July 19–23*, Istanbul, Turkey.
21. Ursu, A.; Chelaru, D.-A.; Mihai, F.-C.; Iordache, I. Anthropogenic landform modeling using GIS techniques case study: Vrancea region. *Geogr. Tech.* 2011, 91–100.
22. Sofia, Giulia, Francesco Marinello, and Paolo Tarolli. 2015. Metrics for quantifying anthropogenic impacts on geomorphology: road networks. *Earth Surf. Process. Landforms*. Wiley-Blackwell
23. Kanev. G., V. Naydenova, E. Roumenina, R. Nedkov. Local Geomorphologic Analysis of the Relief Dynamics of The Kutina Pyramids Natural Landmark Area. Annual of the St. Kliment Ohridski University of Sofia, Faculty of Geography and Geology, book 2 Geography, vol. 101 стр. 43-58. (in Bulg.)

24. Kanev, G., V. Naydenova, E. Roumenina, R. Nedkov. 2006. Methods for Monitoring the Katina Pyramids Natural Landmark Using Geoinformation Technology. Ecological Engineering and Environment Protection. № 3-4. EEEP, Sofia, pp 26-34. (in Bulg.)
25. Naydenova, V. 2012. The Kutina Pyramids natural landmark – its degradation and disappearance. Proceedings of the First European SCGIS conference "Best practices: Application of GIS technologies for conservation of natural and cultural heritage sites", Sofia, Bulgaria, pp. 23-30. ISSN 1314-7749.
26. Naydenova V., E. Roumenina. 2009. Monitoring the Mining Effect at Drainage Level Using Geoinformation Technologies. Central European Journal of Geosciences. Vol. 1, Number 3, September 2009. Publisher Versita, Warsaw, pp 318-339. ISSN 1896-1517
27. Naydenova, V., E. Roumenina, G. Kanev, L. Filchev, K. Stefanov. 2007. Investigating the Stream Network Changes and Landslide Processes in Open Coal Mining Areas Using Remote Sensing Methods. Proceedings of Third International Conference on Recent Advances in Space Technologies "Space for a More Secure World", 14-16 June 2007, Istanbul, Turkey. Published by IEEE, pp. 242-246. ISBN: 978-1-4244-3628-6.
28. Naydenova, V. Visual interpretation and mapping of landslides on satellite data with very high spatial resolution. 7th Scientific Conference with international participation Space, Ecology and Safety – SES 2011, Sofia, Bulgaria, pp. 222-228, ISSN 1313-3888.
29. Naydenova, V., S. Stamenov. 2013. Landform classification using ASTER GDEM and optical high resolution satellite images of Sofia City District. Aerospace Research in Bulgaria, 25, SRTI-BAS, pp. 183-193.
30. Development of primary geodatabase and GIS of the Outer town of the Medieval Bulgarian capital Pliska. Contract No.453/ 11.06.2010 between the NAIM-BAS and SSTRI-BAS
31. "NHAR „Kabiuk": Complex interdisciplinary study of one of the non-capital royal residences (Aul) of the First Bulgarian Kingdom" Contract № DFNI-K01/5/2012 between NIAM-BAS, SRTI-BAS, BND Ltd, funded by Scientific Research Fund - Ministry of Education and Science.
32. Stamenov, S. V. Stamenova**.** Geodatabase of the Outer Town of the Medieval Bulgarian Capital Pliska. Archaeological map of Pliska. Sofia, NIAM-BAS, 2013, pp. 134-151 ISBN 978-954-9472-23-3 (in Bulgarian)
33. Stamenov, S., V. Naydenova, A. Aladjov. 2012. GIS-based concept for conservation of the archaeological site of Pliska. Proceedings of the First European SCGIS conference "Best practices: Application of GIS technologies for conservation of natural and cultural heritage sites". Sofia, Bulgaria, pp. 63-71. ISSN 1314-7749.
34. Stamenov, S. 2012. Modern land cover and land use of the outer town of the medieval Bulgarian capital Pliska using satellite images with high spatial resolution. 7th Scientific Conference with international participation Space, Ecology and Safety / SES 2011, Sofia, Bulgaria, pp. 236-240.
35. Stamenov, S., V. Naydenova, 2013. GNSS role in planning and conductance of terrain archaeological survey: Technical aspects and methodology. 2013 Digital Heritage International Congress (DigitalHeritage), pp. 235–238.
36. Stamenov, S., V. Naydenova. 2014. Storing, processing and visualization of archaeological information using GIS: a case study - Kabiyuk archaeological site. Proceedings of the 2nd European SCGIS conference "Conservation of Natural and Cultural Heritage for Sustainable Development: GIS-Based Approach". Sofia, Bulgaria, pp.62-68.
37. Survey, mapping and spatial modeling of the anthropogenic terrain changes using aerospace and ground-based data. Research project of SRTI-BAS, 2015-2017.