ELABORATING AND IMPLEMENTING AN ALGORITHM FOR LANDSCAPE EVALUATION AND PROGNOSIS

APPLICATIONS FOR THE MOUNTAINOUS AND THE SUBCARPATHIAN SECTORS OF PRAHOVA VALLEY

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1. PROJECT PRESENTATION

ILEANA PĂTRU-STUPARIU

1.1. Scientific results

Among the objectives of the European Landscape Convention there are those of identifying, analysing and evaluating the landscape, following the premises that landscapes, through their aesthetic value, represent a veritable *resourse* that needs to be *capitalized*, *managed* and *valorised*. In addition, through landscape evaluation the vocation of this living framework is identified (territorial vocation). Do we evaluate the landscape in order to emphasis the esthetical dimension and to attribute the protected area status? Do we evaluate the landscape in order to identify those landscape that require planning (touristic planning), thus enhancing its value? Do we identify through evaluation these landscapes which must be sustainably valorised (agricultural evaluation) or reconverted in order to be valorised in territorial planning? At this question an answer can be given through the identification of intermediate solutions between the subjective approach of the landscape and the objective one. This *bridge* can be drawn only through quantification, based on a qualitative analysis, but moreover an adequate qualitative analysis.

The previous questions represented the starting point of the current project *Elaborating and implementing an algorithm for the landscape evaluations and prognosis. Applications in the mountainous and sub-carpathian sectors of Prahova Valley.* The project aimed at using certain landscape analysis methods of quantitative nature which are currently used in specialised international studies, nether less they are seldom integrated in the Romanian research, following, as a final

scope, to connect the Romanian geographic school to the working trajectories that envisage the landscape. Therefore, the project objectives were firstly linked to understanding these methods, to deeply approach certain theoretical aspects, drawing attention to a vast bibliographic reference expanding at international level. We equally aimed at adapting and apply working methods for a distinct area in Romania. As for the case study, we selected the mountainous and subcarpathian sectors of Prahova Valley, a dynamic area, intensely antropised, presenting diverse issues which are relevant from the landscape analysis perspective.

The landscape evaluation integrates both the visual method (*in situ*) and also the non-visual methods. The visual assessment (*in situ*) is mainly based on field observations. On the other hand, for the non-visual evaluation we started from the idea of using and testing various types of cartographic materials (historical maps, topographic maps and orthophotoplans and satellite images). In this regard, we illustrated the different advantages, disadvantages, limitations in using multiple sources and diverse methods. The information gathered from these sources indicated that there are several limitations induced by the projection system, the scale of the materials used in the analysis and that sometimes the models that are produced must be rectified with the field information. The quantum of this information formed the basis of the algorithm for the landscape evaluation, which finalised through the computation of several indicators and indexes, simultaneously with their spatialisation on different types of maps. Explicitly, in the project development we approached three main working directions: *visual and non-visual landscape evaluation (Markov model); landscape metrics*. We mention from the beginning that these working directions were sustained in the project proposal, but subsequent interventions were developed, accordingly to recent research tendencies. As following we detail the themes we approached and the main results we obtained.

1.1.1. Visual and non-visual landscape evaluation

In the last two decades, in order to analysis and evaluate landscapes, there were elaborated different quantitative methods, based

on *non-visual mathematical models* – landscape metrics[1], or *in situ landscape evaluation*[2] grid. The purpose of implementing these methods was that to eliminate the subjectivity and to create the possibility to characterise, classify and compare diverse landscape areas. The results which were summed up from these quantitative methods are used in landscape rehabilitation of certain spaces, just as in adjacent domains (territorial planning, agronomy, ecology, environmental geography, architecture, etc.).

An increasingly accent is placed upon the *in situ* evaluation (or perceptive evaluation type). The *in situ* landscape evaluation visual method is based on both a qualitative assessment and also a quantitative evaluation, determined through the accumulation and mathematical processing of the score attributed in the field. As in the case of any another methodology, we can highlight advantages and disadvantages. The *advantages* connect to the fact that through its application, all the important attributes, that are relevant to associating an area with a landscape value, can be cumulated. Thus we obtain more information regarding the detail degree of the landscape in the field. The *disadvantages* are related to the difficulties that intervene, being interwoven with the perceptive capacity of those who evaluate (experience), the subjectivity degree, the aperture or the obscurity degree (it is considered a radius of 1200 m, starting with an observation point), with the moment when the evaluation is applied (depending on the season, the weather conditions).

At a methodological level, within the present project, we brought an improvement of the mathematic model for visual evaluation, through the *share method*, which has already been published *Forum Geografic* journal (2010) and which enables an enhanced accuracy in quantifying the variables and the landscape attributes. The data that has already been gathered from the previous year were processed using the new mathematic model and were applied in two pilot points. The

[1] Botequilha Leitão, A., Miller, J., Ahern, J., McGarigal, K. (2006) *Measuring landscapes*. Island Press, Washington.

[2] Cañas Guerrero, I., Sanchez Ruiz, M. (2001). Método de valoración del impacto paisajístico. In Fundación Alfonso Martín Escudero (Ed.) *Gestión sostenible del paisaje rural* (pp. 55–75) Editorial Mundi-Prensa, Madrid.

mathematic model was elaborated in order to estimate the visual landscape value: using the network of working points it is generated a triangulation of the target area, which peaks are exactly the point where it was created, in the field, the visual assessment. The landscape value in a arbitrary point is computed in accordance to the triangle vertexes to which this point belongs. Consequently, several assessments were achieved in pilot points.

Within the project different sites were chosen, having a complementary and antipodal character. More exactly, we applied *the sheet of landscape surveying type*[3] for an urban tissue (Sinaia town was selected), mainly highlightening the valences of the cultural landscape with a heritage value and the state of the landscape in Sinaia opposed to the contiguity area of Bucegi Natural Park. At the opposite side we selected a sample of the mountainous and subcarpathian sectors of Prahova Valley were we delineated several elements that indicate the degraded state of the landscape. In the working points that we selected for the two areas, the anticipated value which was determined using the executable developed during the project was compared with the real value identified in the field. We observed greater differences in the points where the topography intervenes as a visual barrier. This fact reveals that an improvement of the mathematic model is necessary, being useful to integrate data referring to the third dimension of the landscape in the visual evaluation method. Thus, we created a triangulation of a digital elevation model, which improves the methods which were already used in this context. The major advantage of the method developed during the project in comparison to the commonly method[4] used is the *continuous* character of the approximation. The second conclusion of the comparative study undertaken in the field envisages the usefulness of producing maps that indicate the visual value of the landscape through the comparison to clearer defined administrative areas (for example neighbourhoods in the case of Sinaia) and geographic (the limit of Cornu locality). As finality, we created the

[3] Pătru-Stupariu, I. (2011) *Peisaj şi gestiunea durabilă a teritoriului.* Edit. Universităţii din Bucureşti.
[4] Jenness, J.S. (2004) *Calculating landscape surface area from digital elevation models.* Wildlife Society Bulletin 32, 829–839.

maps of the visual value for the two areas previously mentioned. The results obtained for Sinaia town are found in the article published in *Forum Geografic* journal (2010) and those for the area located in Cornu are detailed in Chapter 3 of the presented paper, which is dedicated to the field evaluation, *in situ.*

1.1.2. Spatio-temporal landscape dynamics (Markov model)

Another research theme which was approached within the current project referred to the landscape dynamics of a particular area. Analyzing the maps of the same area that were produced at different moments in time, the frequency matrice can be generated and also the transition matrice which offer numerical information regarding the changes between the different types of land cover. Considering this matrice, global indexes can be calculated (binary index, kappa index, kappa conditional indexes) and scenarios referring to the future evolution of the study area can be generated. On the other side, the change phenomena can be spatialised through the creation of a new map: the binary change map, the maps of the land cover/ use changes (change trajectories).

More exactly, within the project, the method was applied for the entire area but also to a reduced scale, that of Sinaia town.

For the entire mountainous and subcarpathian sector of Prahova Valley we took into consideration the maps that were produced in the years 1970, 1989 and 2009, with a particular focus on the recently dated evolution. The main observation resides in the fact that during 1970–1989 there was registered a lower rate of changes into the land cover as compared to the interval 1989–2009. Also, the values that were obtained in relation to different land cover classes highlighted the principal tendencies for the two periods (reforestations, consequently intense urbanisation). The indicators that were computed demonstrate that the anthropical pressure must be controlled and massive deforestations must be avoided. The methodology employed in this study but also the results we obtained are presented in more detail in Chapter 2 of this volume.

The analysis undertaken at the level of Sinaia town was published in the revue *Journal of Maps* (2011). The cartographic support integrated

in this study had a vaster character, covering over 200 years (we used maps dating from the yeas 1790, 1912, 1970, 1990 and 2009), resulting a long-term analysis. The final results strengthened the idea that, at a historical scale, the main phenomena was recorded in the XIXth century, consequently the reforestation one. Moreover, the considered analysis highlighted the intense urban pressure of the present time, due to the expansion of residential areas and mainly because of the development of the touristic infrastructure, revealing the necessity to implement coherent landscape planning and improvement measures.

1.1.3. Landscape metrics. The 3D landscape dimension

A higher accuracy in the assessment of a study area and a better understanding of its dynamics can be obtained through the computation of quantitative indicators that are destined to quantify certain landscape features. In this category are included the *landscape metrics*, which measure two fundamental aspects of a landscape structure: the composition and the configuration. In the last years, at an international level, these indicators proved to be a standard instrument in landscape analysis. In the international research, over 50 such metrics are used. For Romania, in order to analyse the landscape in Transylvanian hilly Depression, a set of four metrics was used[5]. In 2008 we proceeded to a initial study that aimed at using the landscape metrics in an area situated in Prahova Valley, at the contact between the mountainous and subcarpathian sector, where we selected a region covering almost 6 km^2, for which we processed two maps that corresponded to the years 1989 and 2007. We explicitly computed several landscape metrics (Patch Richness, Patch Number, and SHAPE)[6].

In the current project we proposed to diagnose the landscape state, introducing as a new element the integration of these metrics in the context of punctual analysis that are meant to emphasise the fact that the landscape is used as in indicator in the environmental

[5] Schreiber, W. E., Drăguț, L., Man, C. T. (2003) *Analiza peisajelor din partea de vest a Câmpiei Transilvaniei,* Presa Universitară Clujeană, Cluj Napoca.
[6] Pătru-Stupariu, I., Stupariu M. S., Cuculici, R. (2009) Landscape metrics for assessment of mountain landscape using GIS applications. Revista de Geomorfologie, 11, 59–62.

diagnosis, synthesises and prognosis. In addition, the results that we obtained during the metric's computation offer important information that can be used in territorial planning (landscape planning) or in order to enhance the competitive potential of certain regions through capitalisation and valorisation. Another innovative element of this approach envisages integrating the resulting values of these metrics in detailed analysis that indicate the landscape change trajectory. More exactly, in the study, published in *International Journal of Physical Sciences* (2011) we considered and computed *global indexes* through which we highlighted several fundamental landscape irregularities, reflected in its functionality: diversity, fragmentation, complexity and homogeneity. The resulting values of the metrics computed (*PR, SIDI, NP, PD, ED, CONTAG, PAFRAC*) for year 2009 weren't deviant from normal, if we consider the reference to the interval of values for each one. On the other hand, the enquiries undertaken on the field, in the working point that had complementary characteristics (Sinaia area – mountainous), Breaza–Câmpina–Cornu area, in the subcarpathian sector of the valley, correlated to the historical evolution, illustrated two specific phenomena: reforestations in the mountainous area (Sinaia) and the increase in the built-up areas that is associated with the intensification of touristic activities and the conversion of the industrial character of the area. These measures indicate that for a better understanding of the phenomena developing in the target area, it is useful to consider a comparative study of the landscape metrics, through time. Thus we thoroughly considered these landscape metrics that were computed for year 1970. The study's conclusion was that the global indexes that were taken into consideration offer a proper image upon the landscape transformations affecting an area, being interlinked and complementary and thus facilitating a more accurate assessment of the changes that have occurred within the landscape structure and functionality. In addition, these metrics permit the identification of some phenomena, independently from the map analysis or the field study that can be use particularly in landscape analysis and in territorial planning. The first observation is that a certain diversification occurred within the land cover types and the fragmentation degree of the landscape. A very significant change is related to the diminishment of several forest covered areas, complemented only with local

reforestations, which demonstrates the necessity to integrate more efficient measures to control the deforestation. Moreover, new research directions are shaped, which are linked to the influence of the fragmentation phenomena over some ecological processes.

Within the project we published a contribution in the field of the methodology for landscape metrics computation, in the journal *Landscape Online* (2010). Thus, one of the recent tendencies that envisage the improvement of the working methodology with landscape metrics and the expansion of the applicability area of the landscape metrics is related to a more integration of the third landscape dimension. The metrics were inserted in a bi-dimensional model which excludes the vertical distribution of the landscape elements. Recent studies emphasised the necessity to also include information related to topographic aspects of the target area and to adapt the standard landscape metrics. We developed methodologies for the 3D landscape metrics that capture certain characteristics of the terrain rugosity. In the article published in *Landscape Online* a mathematic model was developed in order to facilitate a better quantification of these characteristics. Thus, we created two alternative triangulation methods for an initial terrain, beginning with a digital elevation model of a determined terrain. We start from a grid to which each cell (pixel) is assigned a specific elevation, obtaining a discontinuous approximation of the initial terrain. The idea of the first method we developed (called method T_2) is to associate an elevation to each node in the grid, by determining the arithmetic mean of the adjacent cells elevation. Consequently, each one of the initial squares is replaced with an irregular quadrilateral which is triangulated by using the Delaunay triangulation principle. Finally, each cell of the original grid is replaced with two triangles. The second method (called T_8) concentrates on the working idea to associate each elevation first to each node and secondly to the middle of the edges specific to a cell. In this manner, each square is replaced with a palette formed of eight triangles. These methods are meant to improve a previous method, proposed in 2004 by Jenness, that was already used in 2008 by Hoechstetter, Walz and Thinh in order to develop the 3D landscape metrics. A considerably important advantage of the methods introduced in our study is that it generates a continuous triangulation of the target area, a fact that can be used in subsequent

development of the model. All three methods were implemented in a program, written in C++, using the Microsoft Visual Studio platform. Since one of the fundamental landscape metrics which is affected by the terrain rugosity is AREA metric, more explicit computations were undertaken for two work areas, situated in the mountainous, that and the sub-mountainous valley of Prahova (Sinaia, respectively Cornu), thus the values we obtained reveal the validity of the methods we used, that any method can represent a work alternative for improving the way of determining the values of landscape metrics in a 3D model.

It's worth mentioning that the T8 method and the one proposed by Jenness provide relatively close results, but the T8 method removes two limitations of the Jenness method: it generates continuous approximations of the target area and it provides coherent lengths for the patch boundaries, which do not depend on the selected patch. However, further studies are needed and the also the application of these methods to other areas, in view of their final validation.

The purpose of the present volume is to unitary present the concept of landscape analysis which was developed within the project, being structured into three chapters: the natural environment, methods and techniques used in the development of the landscape evaluation algorithm, *in situ* visual assessment. In the volume were included unpublished scientific results. Thus, the material from this volume complete the articles already published in journals (systematically presented in the second section of the introduction, dedicated to dissemination), resulting in an overview of the research carried out by the whole team.

2.1. Dissemination

2.1.1. New and original results

Within the project were obtained several new results, both at the methodological level and in terms of approach perspective.

– Improving the methodology for calculating the 3D landscape metrics. In the scientific literature is currently used the method introduced by Jenness in 2004 for adjusting the standard landscape metrics in the context of a three-dimensional landscape mosaic (Jenness's article has more than 50 citations, out of which 30 in ISI journals). This model has two shortcomings: the target area is

approximated by a network of triangles that is generally *discontinuous*. In addition, the length of common edges between the patches (particularly important element in modeling ecological phenomena) is not well defined, the length being dependent on the selected patch. In the article "*Geometrical approaches to 3D computing landscape metrics*" is presented an alternative model to adjust the 3D metric, which removes these two limitations of the Jenness model.

– Creating a database of landscape data for the analysed sector, the database was done by collecting geographic information, digital vectorization of the landscape elements on the topographical maps, orthophotoplans and satellite images from 2009; the data processing was completed using ArcGIS 10 software.

– Application of the visual and non-visual assessment methods (used on an international level) to establish the landscape value in the target area.

– Creating the IT support needed in order to establish the visual value of the landscape, the computation of the 3D landscape metrics, processing the matrix data and the indices of temporal development, landscape prognosis, using a program written in C + +, using Microsoft Visual Studio 2005 and the scientific MATLAB software which was developed by MathWorks.

The results were disseminated through publications and also participation in conferences, primarily aiming at a good international visibility.

2.1.2. Publications

Articles which were indexed as ISI

1. Angelstam, P., Axelsson, R., Elbakidze,M., Laestadius, M., Lazdinis L,., Nordberg, M., Pătru-Stupariu, I., Smith, M. (2011) *Knowledge production and learning for sustainable forest management: European regions as a time machine*. Forestry An International Journal of Forest ISI journal with a 1,555 (2011) impact factor and a relative influence score of 1,2 (2011)
2. Abdellaoui A., Pătru-Stupariu, I., Huzui, A. (2011) *Analyzing urban dynamics using multi-temporal satellite images in the case of a mountain area, Sinaia (Romania)*" International Journal of Digital Earth, ISI journal with a 1,453 (2011) impact factor and a relative influence score of 0, 41491 (2011)

3. Pătru-Stupariu, I., Stupariu, M. S., Cuculici, R., Huzui, A. (2011) *Contribution of global indicators to landscape change modeling. Case study: Prahova Valley (Romanian Carpathians and Subcarpathians).* International Journal of the Physical Sciences, 6, 535–539. ISI journal with a 0,540 (2010) impact factor and a relative influence score of 0, 20690 (2010)
4. Pătru-Stupariu, I., Stupariu, M.S., Cuculici, R., Huzui, A. (2011) *The integration of historical maps in landscape reconstruction. Case study: Sinaia, Romania.* Journal of Maps, v2011, 206–220. ISI journal with a 0,623 impact factor (2010) and a relative influence score of 0, 26016 (2010)

Articles which were indexed as BDI

1. Stupariu, M. S., Pătru-Stupariu, I., Cuculici R. (2010) *Geometric approaches in computing 3D landscape metrics.* Landscape Online 24, 1–12. Journal edited by IALE – Germany, indexed in Ulrichsweb and DOAJ databases
2. Pătru-Stupariu, I., Stupariu, M. S., Huzui, A. (2010) *Mathematical models for visual landscape assessment. Case study: Sinaia.* Forum Geografic, 9, 133–138. Journal indexed in EBSCO database
3. Abdellaoui, A., Vişan, L., Pătru-Stupariu I. (2010) *Etude de la viabilite du paysage par analyse de grille dans la region Souscarpatique de la Vallee de Prahova (Roumanie).* Revista de Geomorfologie, 12, 85–94. Journal indexed in EBSCO database
4. Oprea, R., Nedelea, A., Curcan, G. (2010) *The landscape differentiations in the Prahova sector of Bucegi Mountains*, Geographical Forum-Geographical studies and environment protection research, Editura Univertitaria, Craiova, Year IX, No. 9, ISSN 1583-1523, pp. 139–145, Journal indexed in EBSCO HOST
5. Huzui, A., Mire, D., Stoiculescu, R. (2011) *The perception of industrial landscape revitalisation, the case of Belvedere and S.C. Mefin S.A. industrial units*. Romanian Review of Regional Studies, Journal indexed in DOAJ, Ulrichweb and Scipio

2.1.3. Conference participations

International

1. M. Stupariu, I. Pătru-Stupariu, R. Cuculici: *Geometric techniques in quantifying landscape irregularities*. Conferinta IALE, Salzburg, Austria, 2009. Communication included in the proceedings of the Conference, edited by J. Breuste, M. Kozova, M. Finka: European Landscapes in Transformation Challenges for Landscape Ecology and Management, ISBN: 978-80-227-3100-3 [European IALE Conference 2009, Salzburg, Austria, July, 12–16, 2009]. The communication is also presented on the site www.scala-project.at/webseiten/ of the international SCALA project (Scales and Hierarchies in Landform Classification)

2. Pătru-Stupariu, I., Cuculici, R., Huzui, A. *Integrarea hărţilor istorice în reconstrucţia peisajului – studiu de caz oraşul Sinaia*. Mediul actual şi dezvoltarea durabilă, Iaşi, 2009
3. Stupariu, M. S., Pătru-Stupariu, I., Cuculici, R. *On the use of discrete – geometry differential operators in the study of landscapes*, Geobia 2010, Ghent, Belgia.
4. Pătru-Stupariu, I., Stupariu, M. S., Cuculici, R., Huzui, A. *Application of quantitative indexes (binary index, kappa index), in the diachronic analysis of landscape. Case study – Sinaia Town.* The first Romanian–Bulgarean–Hungarean–Serbian conference, Craiova, 2010
5. Vişan, I., Pătru-Stupariu, I., Abdelkader A. *Anthropogenic landscapes through hydrotechnical works in the mountainous sector of the Prahova River (Romania).* The first Romanian–Bulgarean–Hungarean–Serbian conference, Craiova, 2010
6. Pătru-Stupariu, I., Stupariu, M. S., Huzui, A. *Application of landscape metrics to assess the interaction between nature parks and their urban surroundings. Case study: the Bucegi Nature Park – Sinaia city fringe.* Congres IFLA, Zurich, 2011
7. Stupariu, M. S., Pătru-Stupariu, I. *Edge – related effects, land cover change and landscape metrics.* Conferinţă internaţională Environment – Landscape – European Identity, Bucharest, 2011
8. Pătru-Stupariu, I., Huzui, A., Călin, I. *Spatial pattern analyses of landscape using multi-temporal data sources.* The international conference Environment – Landscape – European Identity, Bucharest, 2011

National

1. Pătru-Stupariu, I., Stupariu, M. S., Cuculici, R. *Aportul metricilor peisagistice în evaluarea dinamicii peisajului din sectorul subcarpatic al Văii Prahova.* The annual communication session of the Faculty of Geography, Universtiy of Bucharest, 2009
2. Huzui A., Mirea D., Stoiculescu R. *The perception of the industrial landscape reconversion within the urban structure Case Study–towns Bucarest and Sinaia.* The conference Disparităţi regionale: tipologie, impact, management, Cluj, 2010
3. Vişan, L., Pătru-Stupariu, I. *Landscape management in the process of urbanisation in the Subcarpathian sector of the Prahova Valley.* The conference Disparitati regionale: tipologie, impact, management, Cluj, 2010
4. Vişan, L., Abdelkader A., Pătru-Stupariu, I. *L'indice du bati dans l'analyse du paysage: cas du versant d ouest des Monts Baiu (Roumanie*). The works of the Internation Geographical Seminar Dimitrie Cantemir, Iaşi, 2010.
5. Vişan, L., Pătru-Stupariu, I. *Percepţia peisajului între realitate şi ştiinţă.* The annual communication session of the Faculty of Geography, University of Bucharest, 2010

2. GEOGRAPHIC FRAMEWORK

Răzvan Oprea, Roxana Cuculici

2.1. Geographic location

In the mountainous sector the western boundary of Prahova catchment area, up to Omu, follows the line of the great heights between Prahova and Ialomita. The northwestern, northern and north-eastern limit separates the catchment areas of Ghimbav, Timis and Gârcinu. The eastern limit expands on the watershed between Prahova and Doftana Rivers and it describes a large curve in the Petru-Orjogoaia area in Baiu Mountains. Thus, the general orientation is north-south and changes to east-west, then changing back to the original one (figure 1). This situation can be the result of intense regressive erosion of Doftana`s tributaries (Orjogoaia, Prislopul, Floreiul de Doftana) more developed than those of Prahova.

In the northern part, the limit has a special character, as shown by Vâlsan (1939): "...on the Carpathian`s ridge the limit has lower altitude, going into zigzag over saddles and medium mountains, between 1100 and 1400 m". From Fitifoiu Peak (1292 m) and up to the northern extremity of the basin (about 1 km south from the Piatra Mare peak), Timiş River pushes the limit of the greatest heights to the south at the expense of Prahova catchment (upstream of Azuga) and Limbăşel.

Drawing the boundary between the mountainous and hilly areas is quite difficult, especially on the eastern side of Prahova. This problem was widely discussed in scientific literature (Popp, 1939; Niculescu 1971, 1981; Ielenicz, 1981, etc.).

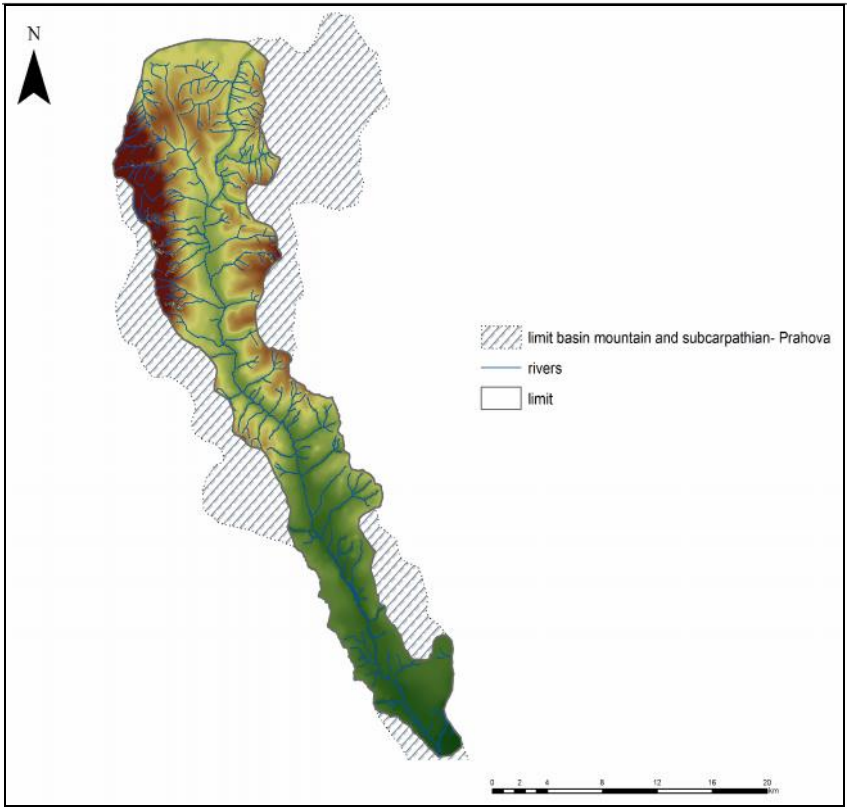


Figure 1. The mountainous and subcarpathian sectors of Prahova Valley. *Geographical positioning, limits* (after the topographic map 1: 25. 000, 1988)

Research related to the Eastern Carpathians and the Curvature Sub-carpathians revealed a contact area west of Slănicul de Buzău Valley, where the delineation between the mountains from the hills is very difficult.

In specifying the area of "*interference*", which is visible up to Prahova Valley (Niculescu, 1971), there were used primarily the geological criteria (the Cretaceous and Paleocene flysch formations which are penetrating in the area of Miocene formations) and geomorphologic, but there were taken into account issues related to land use, habitation degree, etc.

Without going into details, we mention that Niculescu (1971) separates two regions east of Prahova, in the area of contact between the Carpathians and Subcarpathians. The one located on the eastern side of Teleajen he includes into the Subcarpathians and the western one to this valley he includes into the mountains. So in the space between the Prahova and the watershed between it and Doftana, according to Niculescu (1971, 1981), the limit between Baiului Mountains and the Subcarpathians arrives to the north of the villages Şotrile and Plaiul Corbului and then continues parallel to Prahova, up to Comarnic and Posada.

On the other hand, Ielenicz (1981) considered as a contact between the mountains and the hills, the morphostructural corridor of Floreiului Valley, a perspective that we appropriated, including the hilly region Secăria to the Subcarpathians.

Drawing the boundary between the mountains and the hills on the morphostructural corridor alignment which resulted through the widening of Floreiului Valley is supported by: – sudden level difference of 300–500 m, between the southern peaks (south of Floreiului Valley), which only locally overcome 1000 m and Mierlei–Doamnele Tituleni Peak (located at 1400–1600 m) – setting a net difference in the landscape physiognomy (low ridges dominated by petrographic and structural outlier and wider valleys with steep slopes and less fragmented by numerous landslides in the south in comparison to the extend peaks and intensely depend valleys with steep slopes north of the Floreiului valley).

Besides the morphological criteria, the forest distribution (smaller forested areas and more fragmented) and of the permanent settlements reinforce the idea that the region geographically belongs to the Subcarpathians.

The contact between mountains and hills in the area between Dâmboviţa and Prahova is well outlined by an altimetry difference of 200 m and by widening valleys (Popp, 1939). To the south, the landscape presents just a few tips that pass 850–900 m altitude, compared to the first mountain heights that reach 1050 to 1250 m. To the west of the Prahova Valley, the delimitation of the Carpathians and Subcarpathians can be made (primarily using the morphological criteria) on the alignment north to the Comarnic and Talea localities. Prahova Valley becomes wider out of the mountains while the terraces extend.

Thus defined, the Prahova mountain basin includes mountain areas with distinct geographic features (in the north Clăbucetele Predealului, Baiul Mountains in the east, in the west Bucegi Mountains, continued to the south through the Gurguiatu Mountains).

In the subcarpathian sector, the western limit of Prahova catchments focuses on the interfluves of Talea and Proviţa hills, separating Talea basin from the Bizdidel`s one, and continues south, following the watershed between Proviţa and Prahova rivers. The eastern boundary follows the line of the highest altitudes of the Câmpiniţa hills, a line that separates, until it reaches Câmpina Depression, the passageways of Prahova River from its tributary, Doftana, which join courses south of Câmpina city.

South of the previously mentioned hills, Câmpina Depression continues to the east with the large flume passage of Mislea (Geografia României, vol. IV, 1992); also south of the city of Câmpina, the Ploiesti Plain penetrates far inside the hills with a wide "gulf" corresponding to the slightly convex surface of Câmpina terrace on Prahova river; the entrance of Prahova river into the plain is marked by a slight knick (Popp, 1939).

East of the Prahova, the limit has a discontinuous nature which expands in the analysis sector stretching from Băicoi to NV, on the outskirts of Câmpul Urletei up to Băneşti (Niculescu, 2008). West of Prahova the limit can be set north of Floreşti town. Within the mentioned limits of Prahova, the central part of Prahova Subcarpathians are included, also covering the eastern part of Ialomiţa Subcarpathians and the western side of Teleajen Subcarpathians (figure 2).

Through the position that Prahova Valley has, it became over time an important linking corridor between the southern part of the country and Transylvania. Certainly the valley was populated in the Subcarpathians from the XVth century, as shown in the documentary record of some localities (Comarnic in 1510, Breaza in 1431, and Câmpina in 1503).

The Carpathian sector of Prahova Valley, despite its proximity to well-populated regions, crossed by old roads, was later populated (Oprea, 2005). In the east, on Teleajen and in the west, the transcarpathian road of Bran, the *limes cis-alutan* (Vulcanescu & Simionescu, 1974) was known since the roman period. Braşov (documented in 1234) and the neighboring settlements (Bran documented in 1367, Râşnov documented in 1331) were wealthy centers of human activities.

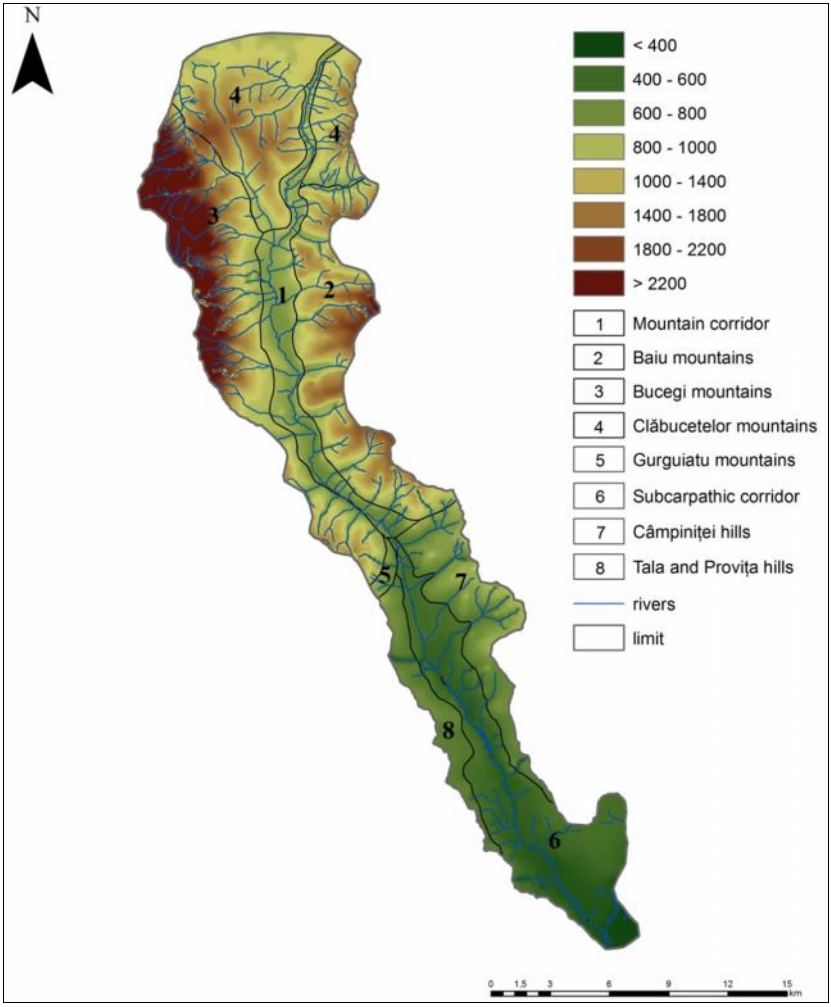


Figure 2. The mountainous and subcarpathian sectors of Prahova Valley. Relief units and levels (after topographic map 1: 25. 000, 1988)

Until the XIXth century, the lower accessibility of Prahova Valley in the mountain sector imposed that the roads between Țara Românească (Walachia) and Transylvania would focus on Dambovita Valley, Teleajen and Buzău (Niculescu, 2008) but after 1849 and

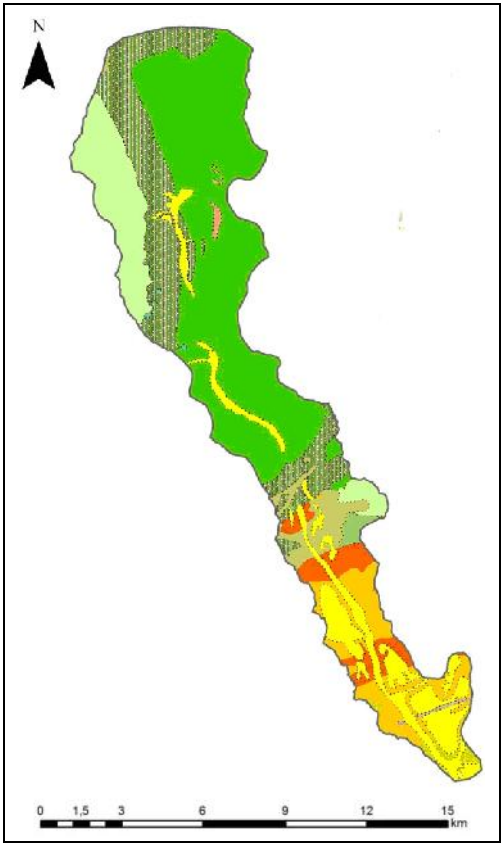
especially after the year 1879, when the railroad was put into use, the mountainous and subcarpathian sectors of Prahova emerged as a major traffic axis (Dobre, 2007), which currently connects major urban centers (Bucharest, Ploieşti, Braşov etc.) along European road E60.

2.2. Landscape differences

We mention that in this chapter the landscape analysis was performed of a naturalist perspective, looking at it as a system of natural and human elements, dynamic over space and time, being interrelated. According to this line, Tudoran (1976) consider the geographical landscape as a comprehensive, synthetic representation of the environment itself. We distinguished the landscape`s role, the landscape structure through its petrographic elements (figure 3), tectonical, structural and morphometric. The layers of Sinaia (flysch of Ceahlău) (Patrulius, 1969) prints a monotonous aspect (Baiului Mountains, Clăbucetelor, Gurguiatu), but favors (the presence of marls and clays) landslides and debris torrents. Conglomerates and gritstones of Bucegi have preserved a remarkably diverse and petrographic relief. Cryo-nival processes (Nedelea et al., 2009) and the fluvio-torrential ones have a fundamental role in shaping detailed forms. In the Subcarpathians, formations which are predominantly Miocene and Pliocene have generated a fragmented relief with slopes affected by landslides and torrential phenomena; in places, erosion outlier maintain on the toughest rocks (conglomerates).

The region's relief energy of about 2200 m generates a variation of the climatic conditions and correlated with these, the morphodynamic processes vertical zonality and the soil cover (luvic soil, cambisoil, spodosoils, humosoils, umbrisoils class) (figure 4) and the vegetation. The slope gradient is also an important morphometric parameter which presents thresholds, depending on which the current geomorphologic processes can be activated. Slope exercise its influence on the pedogenesis and continuity of the soil cover (on the eastern slope of the Bucegi Mountains, the lithosoils from the protosoil class and the visible rocks are defining), thus in the distribution of the plant formations. It also affects land use types.

Figure 3. The mountainous and subcarpathian sectors of Prahova Valley. *Geology* (after geology map 1: 200.000, 1967)



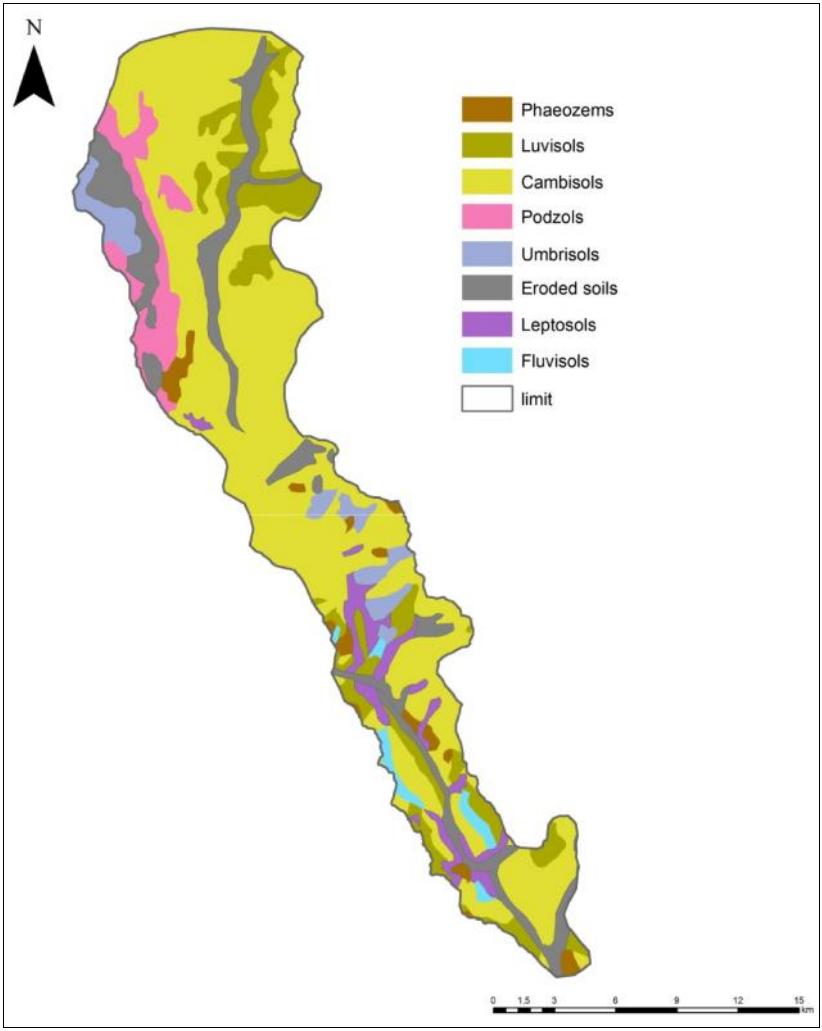


Figure 4. The mountainous and subcarpathian sectors of Prahova Valley. *Soil* (after soil map 1: 200. 000, 1984)

The mountainous and subcarpathian basin of Prahova portrays a variety of landscape elements, but also a plurivalence of human interventions (Oprea & Comănescu, 2008; Vartolomei & Armaş, 2010)

highlighted in the complex land use types (figure 5). Multiple references between them highlight a great landscape variety (Oprea, 2005; Oprea et al., 2010, Geografia României, vol. I, 1983). A model for identifying them is represented by the *Landscape types map* (figure 6) developed by Popova-Cucu (1978).

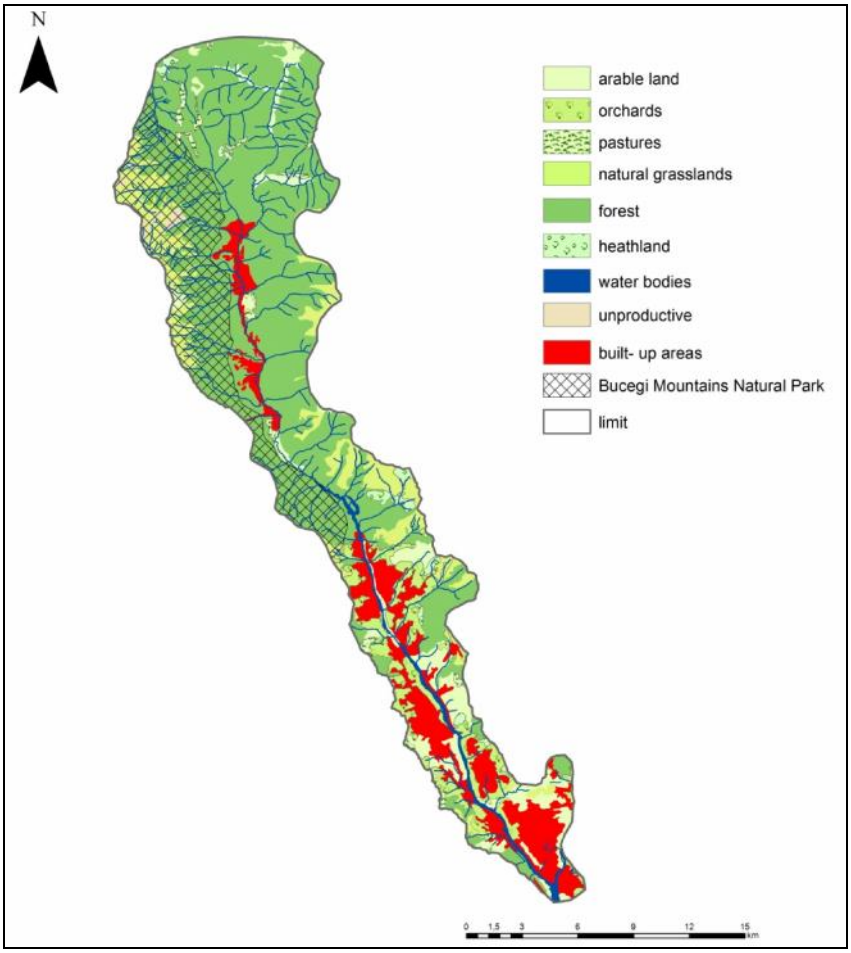


Figure 5. The mountainous and subcarpathian sectors of Prahova Valley. *Land use types* (after Corine Land Cover, 2006)

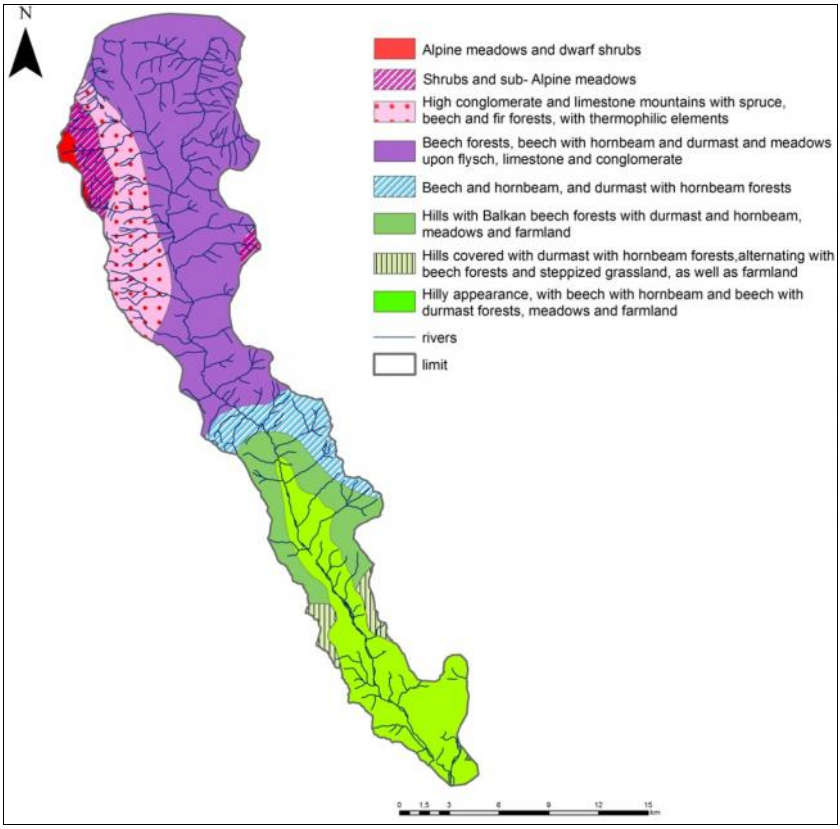


Figure 6. The mountainous and subcarpathian sectors of Prahova Valley. *Landscape types* (after Landscape types map 1: 1.000. 000, Ana Popova Cucu, 1978)

2.2.1. Prahova mountain corridor

There is a diverse morfography (floodplains, terraces, glacis and narrowing areas) and an extension of villa districts, tourist complexes and fuel stations on the European route E60. There are traffic problems related to the oversizing road traffic. Four sectors are highlighted (Geografia României, vol. III, 1987).

Prahova river origin Depression. It is located between the Prahova springs and Malul Ursului narrowing. Predeal platform is

imposing (the eponymous town and the tourist facilities) with the extend peaks and erosion outliers (Geografia României, vol. III, 1987). North of Malul Ursului spur (between Ursoaia Mare and Ursoaia Mică valleys), the valley widens and extends the coluvium-proluvium glacis, slightly sloping towards the river bed (Valsan, 1939). On the left banks of Prahova the glacis is more visible (100–150 m wide) and is occupied by buildings, orchards and meadows. Above the glacis, the slopes are well forested. The main tributaries (Râşnoavei with its tributary, Leuca) also have a wide valley, flanked by hillocks.

Clăbucetelor Gorge. It has two narrow sectors (Grigore, 1989), separated by a widening of the valley. The first, held between the confluences with Ursoaia Mică and the Azuga basin is bordered by Clăbucetul Taurului ridges (in the east) and Clăbucetul Baiului (in the west). At the confluence between Valea Grecului and Prahova Valley, on the alluvian fan, there is a terrace of 30–50 m.

Downstream from Azuga basin and up to the confluence with Valea Cerbului expands a segment of a narrow valley called *La Genune* where Prahova has deepened through a mountain spur stretching through the Cazacu-Orgojoaia mountain ridge to Sorica Mountain and up to Clăbucetul Taurului (Vâlsan, 1939). On the right side of Prahova, on the foot of Clăbucet Mountains stands a step in the rock, with small meadows, small alluvian fans and glacis.

In the confluence basin of Azuga and Prahova (3–4 km long and a maximum width of 1.5 km), Vâlsan (1939), noted the transverse profile which is very elusive and the large meadow (with beaches and islets). At the foot of Clăbucetul Taurului and at the confluence between Azuga and Prahova it was created a level meadow and terraces. Azuga`s center part is on the lower terrace (4–5 m) and the highest (10–20 m) is occupied by villas. The two steps of the terrace extend on Azuga Valley (up to about 3 km upstream) on the glacis located at the foot of Clăbucetul Taurului.

Busteni – Sinaia depression. Is located downstream of the confluence between Cerbului Valley and Prahova Valley up to the confluence with Bogdan Valley, between Buşteni and Sinaia localities. It is the largest sector of the upper sector of Prahova Valley (10 km long, 2–3 km wide). At the foot of Bucegi and the dip slopes of Zamora and Cumpătu peaks (Baiului Mountains) are extended coluvium-proluvium

glacis (at the foot of Baiul Mountains, 5–6 km long and 750–1000 m wide) on which Prahova formed three steps terraces.

The first one is Parcului terrace (the name comes from the Park "Dimitrie Ghica" established in Sinaia in 1881). Its correspondence on the cone of Izvorul Dorului Valley is a step (20–70 m) on which Izvor neighbourhood is placed. Mănăstirea Sinaia step is the second one (40–70 m, respectively 30–50 m on Zamora). The third step, Castelul Peleș (90–120 m) – Cazarmă Sinaia (120–140 m) reaches a relative altitude of 60–70 m in Zamora

The meadow ranges between 100–200 m being very dynamic (islets, beaches, underwater alluvia). Human intervention is intense (Buşteni, Poiana Țapului, Sinaia settlements are built on terraces; the drainage and gravel pits are located in the meadow).

Sinaia–Posada Gorge. From Prahova`s confluence with Valea lui Bogdan brook and outside the mountain, the valley greatly narrows in the inferior side. So, in the gorges cut between Doamnele Mountains and Gurguiatu Mountains, the valley`s width is several tens of meters. The microtectectonic is clearly distinguished on the surface (small faulted anticline and syncline).

Dip slopes are obvious (over 30–400), especially at the lower segment. Here and there are small rock terraces (covered with deluvium) extended beyond the left bank of Prahova (in the wide valley basin of Valea Largă, on both slopes). On Gagului, Doamnele and Bogdan valleys, rapids are forming.

Human intervention is seen through – the railstation and the households in Valea Largă, the national route (DN1) which was built in the late XIXth century on the terrace level in rock, on the left side of Prahova (slopes were consolidated and viaducts were made), the households from Posada; torrential improvements on the valley Valea lui Bogdan, Doamnele; the railway and the consolidation works carried out to protect its banks.

2.2.2. Baiului Mountains

Baiu Mountains west ridge is sinuous (sinuosity coefficient is about 1.16) and in a straight line has a length around 30 km. It can be

distinguished from north to south, three sectors (Ielenicz, 1984): Neamțului, Petru-Orjogoaia and Baiu Mare.

Along Neamțului Peak which is surrounded by the upper valley of Azuga, all peaks present a higher altitude than 1600 m. Towards Azuga there are large slopes. From this ridge branches off others, secondary, that smoothly descend to 1350 m altitude. There are large catchments areas, made up of ravines that reach far to the watershed.

Petru-Orjogoaia ridge is lower, keeping below the altitude of 1600 m. The large bridges are clear in the physiognomic context, from the top being surpassed only by a few tens of meters by high rounded edges.

Baiu Mare peak develops at an altitude of 1500 – 1900 m. The peaks are centred on the toughest rocks and they dominate an upper erosion level, being shaped as islander mountains (round shaped, blunt, conical or truncated cone) separated by saddles (Niculescu, 1981). Towards Prahova and Azuga valleys secondary ridges extend being levelled into steps.

In Baiului Mountains it can be distinguished (Oprea, 2005) primarily a landscape of smooth or rounded ridges and a landscape of slopes.

Smooth or rounded ridges. Ielenicz (1984) identifies three levels of erosion, higher (peaks can be seen in Mierlele–Drăgan ridge, Mount Petru–Vf. lui Petru, Turcului–Țigăilor, Cazacu–Urechea and Ceauşoaia Mountain), middle (highlighted on the secondary peaks – Piciorul Câinelui, Plaiul Tufa, Piciorul Cazacu etc.) and lower (on the rounded mountain spurs that set the trasition to Prahova Corridor).

The main ridge between Doamnele Mountain and Țigăilor Peak has smooth slopes (with the exception of catchments with deep ravines) and aligns a series of peaks, shaped as isolated mountains which are separated by saddles.

For the most part, at altitudes above 1400 m, forests and shrubs were removed and replaced by secondary grassland (sometimes with subalpine elements). Pastoral and tourist trails, cattle paths and sheepfolds are other evidence of human intervention.

The slopes. Straight or convex are preponderant and are generally moderately inclined. Exceptions are represented by origins shaped as

semicircular amphitheaters which are heavily ravened in the torrential basins and by the lower sectors of the narrowing valley areas. The contact with Busteni–Sinaia basin is marked by the Zamora glacis which is unfolded in steps.

Forests account for almost ¾ of the total land (Oprea, 2005). Human pressure has manifested itself especially in their upper limit for increasing the pasture areas. In fact, the lowest upper limit of the forest (± 800 m) identified in Prahova mountain basin is located in Doamnele Mountains (Oprea, 2005). The most extensive fundamental natural forests from Baiului Mountains have been preserved on steep slopes from the river valleys Unghia Mare, Ceauşoaia, Cazacu, Urechia and further west in small torrential basins located on the north side of Sorica Peak.

2.2.3. Bucegi Mountains

Bucegi Mountain`s defining feature of the landscape is the complexity. It Is dictated by the lithological, structural, tectonic and the large altitude extent characteristics. It can be distinguished: the structural plateau landscape, the steep Prahova cliff and the lands located at the foot of Bucegi.

Erosion outlier and structural plateau from the alpine clearing. The peaks located at the top of Bucegi (Bucşoiu, Omu, Bucura Dumbravă, Găvanele, Colţii Obârşiei, Coştila, Caraiman, Jepii Mici, Jepii Mari, Piatra Arsă, Furnica, Vârful cu Dor, Vânturiş etc.) are structural outliers that preserve the sidewall layers from Prahova slope of the Bucegi synclinal. On the Bucegi Plateau detailed forms are represented by gritstones – conglomeration rocks of mushroom rocks, sphinxes (*Babele,* the mushroom rock from Vânturiş, *Sfinxul* etc.).

The upper basin of Izvorul Dorului fully conserves (up to an altitude of approximately 2,200 m) the footprint of human pressure, manifested through tourism (dense and unorganized network of paths) and uncontrolled grazing. The results of human action are: – destruction of the natural vegetation (Oprea, 2005, Michael et al., 2006) and firstly the destruction of dwarf pine shrubs (large visible areas are occupied by Nardus stricta or ruderal plants that are associated with the sheepfolds);

– soil erosion (appearance of the erodisoil and antrisoil class) and a widening network of ditches on numerous mountain roads and trails (Oprea, 2005).

The landscape of erosion outliers and structural plateau with alpine elements (at altitudes greater than 2200–2300 m) has a better degree of conservation, compared to that of the subalpine zone. Imbalances are evident near the Costila lodge and relay and near the weather station at Omu Peak.

Prahova Cliff. The Bucegi Plateau dominates towards Prahova with a cuestic front presenting a bump of over 1000 m and a length of about 15 km in a straight line. The slopes which are located between 1550–1600 and 1950–2000 m are generally the steepest.

From the general line of steep gritstones – conglomerations there are trapezoidal facets that become evident (Coştila mountains, Caraiman, Jepii Mici, Jepii Mari, Piatra Arsă etc.), triangular ones (Moraru Mountain and Bucşoiu Mic), but also jagged ridges (Morarului, Balaurul from Bucşoiu Mic etc.) or shocks (Jepii Mici – Claia Mare and Clăiţa), and between them, imposing steep valleys with mixed function (intermittent drainage, debris torrents or avalanche corridors). In the thalwegs there are knicks, evidenced by falls on some valleys (Caraiman, Vâlcelul Înspumat, Urlătoarelor, Peleş, Zgarbura).

The upper extremity is hemmed in the form of semicircles of nivation cirques and nivation funnels, such as the Coştila Massif: Blidul Uriaşilor (on the southern slope), the nivation cirques from the Coştila valley origins (on the eastern slope), Mălinului, Priponului the previous two are on the northern slope, etc. The detail relief is complex, pointing out structural benches (girdles), bulges, lithological levels, generating the steep of floor physiognomy (Valeria Michalevich Velcea, 1961). Steep walls are fragmented by glacial horns and cracks (the most evident being *Fisura Albastră* the fissure located in the southern wall of Coştia). In the north-east, at the origin of Cerbului and Morarului valleys, separated by Morarului ridge, there are obvious the glacial cirques (between 2100–2450 m altitude and with diameters of 1.5 and 1 km).

Seen from Baiului Mountains, the eastern slope of the Bucegi appear higher to the north and lower to the south part. The sector between Bucşoiu and Piatra Arsă spur is the most impressive and fragmented.

South to Piatra Arsă spur the slope is more homogeneous. The Slopes of Vârful cu Dor – Furnica – Piatra Arsă Mountains are characterized by strong tourist humanization. Here, its clear the deterioration of roads, paths and tracks which are improperly located and unmaintained. North to Piatra Arsă spur the slope of Bucegi maintains natural landscapes in a dynamic equilibrium, where it stands out the limit glade (spruce and larch, sometimes pinus cembra).

Smooth interfluves. On the foot of the steep, through the accumulation of large debris train, resulted in a smooth plateau (rounded interfluves): Plaiul Fânului, Plaiul Coştila, Plaiul Munticelu, Plaiul Văii Seci, Plaiul Bolovanului, Plaiul Stânei, Plaiul Stâna Veche, Plaiul Paltinului, Plaiul Secului, Plaiul Piatra Arsă, Plaiul Peleşului, Plaiul Furnica, Plaiul Zgarburei, Plaiul Colții lui Barbeş.

In their profile there are smooth areas that maintain the erosion levels, related to the limestone rocks from Sf. Ana, those from Poiana Stânei, Piatra Arsă etc. Forests that have a dominant fundamental natural character, occupy the largest area, but there are areas of secondary grassland. Moreover, in areas with limestone, the vegetation installed itself on rendsines (cernisoil class). In some sectors, the anthropogenic pressure generated a degradation processes (e.g. Plaiul Furnicii with complex tourist facilities).

2.2.4. Clăbucetelor Mountains

The most representative Clăbucet types of mountain are located both on the right and left Prahova sides are: Baiul (1582 m), Taurului (1520 m), Azugii (1586 m) and Susai (Cocoşului Peak, 1479 m). It is distinguished by rounded edges, often covered by grassland, which dominates through small level differences the extended ridges, smooth or rounded. The levelled bridges, which are smooth or slightly rounded, occur in three stages (first at over 1400 m, the second between ±1200–1300 m and the third from ±1000 to 1100 m. The valleys between the Clăbucet (mountain crests) are deep, with slopes which are dip enough and with a high degree of forest cover (83%) (Oprea, 2005). Similar to Baiu Mountains, these peaks with secondary grasslands were marked by human pressure, which sometimes led to the appearance of damaged

areas. Clăbucetul Taurului ridge is a good example for the high volume of tourists and herds of cattle (often large cattle).

2.2.5. Gurguiatu Mountains

The lower mountain stage (1200–1400 m) presents physiognomic similarities to Baiu Mountains. Rounded interfluves are prevailing, being separated by torrential valleys with large basins. There are visible some erosion levels, the upper one consists of a succession of rounded edges and a peripheral one of secondary peaks. Valleys of torrential nature present large alluvial fans at the confluence. The lower altitudes, which are well below the potential climatic limit of the forest, determined a high degree of reforestation, over 84% (Oprea, 2005).

2.2.6. The subcarpathian corridor of Prahova Valley

The subcarpathian corridor landscape of Prahova Valley presents several meadows and terraces which are more extensive (in Breaza and Câmpina depressions) or less extensive. Generally, it was appreciated that the subcarpathian terraces of Prahova Valley are 4–5 (Humel, 1927 and Weymuller, 1931 cited by Popp, 1939), but well outlined in the landscape and used with good performance are the lower and middle ones (Geografia României, vol. IV, 1992).

The largest area has Câmpina terrace that decreases in altitude with 10–20 m between Breaza (75 m relative altitude) and Câmpina (55–65 m relative elevation) (Geografia României, vol. IV, 1992) and on which at, the bridge level was located the most important set of human settlements (Comarnic, Breaza, Câmpina).

There are also areas where, in the morphology, are imposed tougher rocks. Popp (1939) shows that Brebu conglomerates are related to some knicks along the Prahova Valley (at 515 m and 460 m elevations) and Niculescu (2008) mentions a small narrowing sector in the Prahova Valley within massive gritstones, near Breaza railstation They can be defined as following:

Comarnic–Gura Beliei Sector. Once out of the mountain sector (about 660 m altitude), south of the Posada, Prahova River valley

widens, extending on the terraces. Thus, between Comarnic and Gura Beliei localities (located at the confluence between Prahova and Belia), the western slopes of Câmpinița hills have traces of terraces and some oiconimes like "pod" ("bridge") suggests the smoothness of the relief – Podul Lung, Podul Corbului, Podul Neagului, Podu Vârtos (Popp, 1939; Niculescu, 2008).

Through the development of Comarnic town (with Ghioşeşti, Podu Lung, Poiana composing localities) humanization intensified, land being used for construction (built-up areas, routes) and agricultural purposes (mainly orchards and meadows). The closure of the cement factory (which began operating in early XX^{th} century) solved the dust pollution issue that resulted from the processing activity. Sizing up the traffic on the European route E60 raises other problems for Comarnic town area.

Breaza şi Câmpina depressions. From Gura Beliei (component locality of Breaza city) Prahova valley becomes very large, with well developed terraces on both banks (Popp, 1939). On Câmpina`s broad bridge of the terrace (Niculescu, 2008) has developed Breaza city, along the route Ploieşti–Braşov (where the mild climate favors the natural cure) that also gave the name of a small depression (Popp, 1939, Niculescu, 2008) that was superimposed over Slănic Synclinal. Along with orchards and pastures built-up areas imposed in the landscape.

Further south, Prahova valley opens up even more in Câmpina Depression which is formed at the confluence between Prahova and Doftana, through the erosion of these rivers and the accumulation of a thick horizon (up to 10 m) of gravel. It is suspended about 50 m above the meadow and it is shaped like a large plain (Câmpina terrace) (Niculescu, 2008). The landscape is strongly humanised, the largest urban centre in Prahova`s subcarpathians being established in Câmpina basin, (Geografia României, vol. IV, 1992).

2.2.7. The subcarpathian hilly massives

Subcarpathian hills are formed in Miocene and Pliocene formations, which are general joined, in some places, by Paleocene formations, Quaternary and even Cretaceous (in the north) (Geografia

României, vol. IV, 1992; Niculescu, 2008). Their variety translates into the interfluve physiognomy and slopes.

Most of the slopes are affected by landslides and torrential phenomena. Land cover is associated with forests, orchards and meadows. It can be distinguished three sectors (which present many similarities), Câmpinița hills, in the eastern part of Prahova, Talea and Provița hills west of this river.

Câmpinița Hills. The eastern sector of the Prahova`s subcarpathian sector, Teleajen Subcarpathians (Geografia României, vol. IV, 1992), is being located between the Prahova and Doftana. In the north is the hilly region of Secăria and in the south-west Câmpina Depression dominates the landscape.

In the analysed sector it is included the western part, inserted into Câmpinița basin (tributary of Prahova river), the limit is represented by the watershed between the two rivers mentioned above. Niculescu (2008) distinguished two main peaks in these hills (Dealul Frumos hill – Cornu and Şotrile) along which there are aligned, largely due to the lithological conditioning, a series of peaks with heights that generally remain between 650–750 m (Străjiştea, Vârfu lui Iordan, Orădia, Voila, Cucuiatu – the highest, with 826 m, centred on *Brebu conglomerates*) and saddles.

These hills are predominantly composed of Miocene deposits that are differently included in the physiognomy of the region: gritstones, conglomerates, clay deposits, marls (which supports erosion landslides and torrential phenomena). Local Paleogene flysch occurs (in the south and north) and Cretaceous one (in the north-west). The forest area was heavily fragmented by various other land uses (built-up areas – Cornu, Şotrile, etc. Plaiul Câmpina, orchards, pastures and meadows).

Talea and Provița hills. The western sector of Prahova`s subcarpathians is called *Ialomița Subcarpathians* (Geografia României, vol. IV, 1992). In the studied area, the limit initially extends in the north, on the watershed between Belia (with its tributary, Talea), a tributary of the Prahova and Bizdidel in the west, respectively the upper Provița (made up of two streams, Ocina and Târsa) in the south. Further to the south, the limit follows the watershed between Provița and Prahova.

The narrow peaks, generally descend from 700–800 m (in north) to 350–400 m (in south), the higher sectors focusing on conglomerates and the lowest (the saddles) on alignments of less resistant rocks to erosion (Ielenicz et al., 2005), which favoured the intense slope processes (torrential phenomena and landslides). Thus, burdigaliene conglomerates called *Brebu conglomerates* sometimes imposed lofty peaks as Gurga peak (741m), as a cuesta, which dominates Breaza de Jos town (Popp, 1939).

In some places, small bumps along the interfluve dominate the remains of levelling surfaces (Talea platform being the most representative in Talea river basin, where the smoothed peak is used by the village's households) (Popp, 1939). Humanization, just like in Câmpinița Hills is intense (built-up areas – Talea, composing localities of Breaza, etc. dwellings related to hay economy, pastures and meadows, orchards), the areas covered with forest are slightly expanded.

2.3. Types of landscape functionality

Summarizing the information above, we present a further delineation of the landscape types (after the typological criterion, function/natural, anthropic); a model that incorporates the landscape features from a specific moment in time. The typology and the spatialisation of the functional landscape types integrate three reference levels: abiotic, biotic and cultural. The abiotic plan is the basic landscape framework (Turner, 2005) and the human footprint refers to the way it intervenes (sometimes positively, sometimes negatively) on the landscape (McDonnell & Pickett, 1997).

In our work site, using the landscape spatialisation and functionality model (Pătru-Stupariu, 2011) we identified the following types of landscapes (figure 7): natural landscape (annex 1.1.) agricultural landscape (annex 1.2), anthropic landscape (annex 1.3.) and transition landscape (annex 1.4). From this spatialisation results a significant share of the natural landscape (forest) and anthropic one (built-up area).

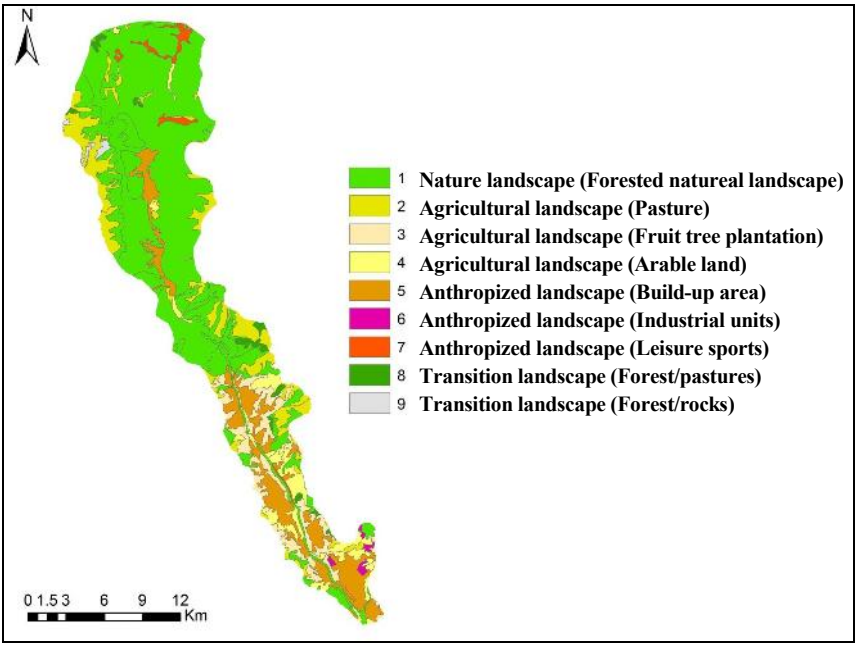


Figure 7. The mountainous and subcarpathian sectors of Prahova Valley. *Functional landscape type* (vector and raster databases processed after: topographic map 1:200.000; soil map 1:200.000; geology map 1:200.000; Corine Land Cover 2006, EEA)

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1. METHODS AND TECHNIQUES USED IN ELABORATING THE ALGORITHM FOR LANDSCAPE EVALUATION

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3.1. Markov Model – component of the landscape evaluation and prognosis algorithm

3.1.1. Introduction

Sustainable landscape management is a priority objective of territorial planning policies in Europe. Implementing the European Landscape Convention (Council of Europe, 2000) includes the landscape analysis, highlighting the need for quantitative indicators in the context of such analysis. In this context, this chapter aims at evaluating the landscape dynamics and to generate scenarios of landscape development for Prahova Valley. Anthropic pressure is becoming more pronounced (due to the development of tourist resorts and because of Bucharest–Brasov highway project) confirming that Prahova Valley is a region where the landscape structure and features are in constant change. Landscape assessment, together with the prognosis development may be relevant to prioritizing human interventions in the region.

Elaborating a landscape evolution prognosis is related to one of the fundamental work directions of landscape analysis (Farina, 2007 for a global perspective): land use and land cover changing. An overview of this topic and other references can be found, for example, in Lambin & Geist (2006), Koomen & Stillwell (2007). Turner et al. (1990); Vitousek (1992) points out that changing land use and land cover types

plays an important role in the current changing phenomena that occur globally. Moreover, changes in land use have a major impact on landscape structure (Forman & Godron, 2006).

From a temporal perspective, land use changes are related to both present, past and future features of the landscape in a target area. The importance of the past is relevant because it is not possible to assess the current conditions of a landscape mosaic without knowing at least the recent history (Pena et al., 2007). On the other hand, only by taking into account the evolution of a landscape can we understand the level of its reaction to various types of disturbances (Moreira et al., 2001). The future is directly linked to sustainable land use, which refers to an efficient use of resources to produce goods and services so that on a long term the base of natural resource would not be compromised and the future needs of human society could be covered (Lambin & Geist, 2006).

For Romania, the studies on land use changes have been carried out by Kuemmerle et al. (2009); Müller et al. (2009), in Arges County focused on the agricultural land abandonment.

At a methodological level, we already demonstrated that domains like geography and mathematics bring an essential contribution to understanding and simulating changes in land use (Koomen & Stillwell, 2007). Thus, one of the models that are widely used in the analysis of landscape changes is Markov chain model (Baker, 1989, Brown et al., 2004). Next we apply this model, interpreting the pixel-level changes as transition probabilities. Despite its limitations, it can provide a first approximation model of the landscape change and it can be used to estimate future trends. This model was chosen to perform the analysis on land use change in the target are.

3.1.2. Material and methods

3.1.2.1. Maps and programs used

In this analysis we used three maps for the years 1970, 1990 and 2009. For the years 1970 and 1990 there were used the maps at 1:50.000 scale, made by ANCPI respectively DTM, scanned with a resolution of 600 dpi. For the year 2009 we used satellite images from Google Earth Pro, scale 1:21.000 (1:50.000 scale transfer) with a

resolution of 1200 dpi. All maps were georeferenced using Image Analysis – ArcGIS, version 10 in Stereo projection 70. The results were analyzed and processed by an application written in C + + using *Microsoft Visual Studio* (Miscrosoft, 2008). Some of the calculations were completed using the facilities of MATLAB (MathWorks, 2008).

3.1.2.2. Mathematic model

Frequency matrix and change matrix

Further are presented some basic theoretical elements related to the theory of Markov chains. A comprehensive overview can be found, for example, in Iosifescu monography (1980). There are also described several indicators related to landscape composition analysis, which can be derived from Markov model (eg Riiters et al., 2009).

Thus, m is the number of different classes of land cover in the study area. The first step is to determine the *frequency matrix* $F = (f_{ij})_{i,j}$ that can be associated with a time interval [t, t '] which is a square matrix of order m (to simplify notations, it will be further eliminated indices *t, t'*, which should appear in the matrix notation). f_{ij} element is placed on line i and j column of the F matrix, indicating the area belonging to land cover class j at t time moment and of i class belonging to t' time moment. Next, for each i class and we will note: $r_i = \sum_{j=1}^{m} f_{ij}$, consequently $c_i = \sum_{j=1}^{m} f_{ji}$ the sum of elements on line i, and on i column of F.

In fact, r_i consequently c_i represents the area belonging to cover class i at *t'* time moment and consequently *t.*

For each index i and j we define: $p_{ij} = \frac{f_{ij}}{c_i}$ if $c_i \neq 0$ and, as a convention, $p_{ij} = \delta_{ij}$ (Kronecker symbol), if $c_i = 0$.

Thus we obtain a new square matrix of order *m,* $P = (p_{ij})_{i,j}$, called *transition matrix,* whose elements represent the proportions of observed transitions used to estimate the transition probabilities.

Thus, the element p_{ij} is the probability that a pixel in the state j at any given time t to be in state i at time moment t'. In particular, an element of p_{ii} on the main diagonal of P is the probability of coverage

for the class *i*. In addition, the sum of items on each column of the matrix *P* is equal to 1, representing a transition matrix that is stochastic on the columns.

May it further be $X_t = (x_1,\ldots x_m)^T$ the sate vector for time moment *t*, representing the column vector containing various fractions of land cover in that moment of time. Thus, x_i is the probability that a pixel belongs to the coverage class *i* and the *t* time moment. The transition matrix and the vectors of state X_t, $X_{t'}$ are linked through $P \cdot X_t = X_{t'}$. equation.

Since matrix *P* is stochastic on the columns, it results that $\alpha_1 = 1$ is a value of *P*. Moreover, if *P* is regular (e.g. there is a power of *P* which has all positive elements), then the vector space corresponding to α_1 has a dimension equal to 1 and there is a unique state vector X^* (hereafter referred to as *asymptotic equilibrium vector*) so that $P \cdot X^* = X^*$. Its components (which sum equal to 1) represent the asymptotic equilibrium distributions of the *m* classes of coverage.

It can also be calculated the *rate of convergence* $\rho = \frac{1}{|\alpha_2|}$: low ρ values indicate a slow convergence in X^*. We noted with α_2 the second value of *P* (values were ordered descending in comparison to their module); in particular its module is subunitary. Another indicator that can be taken in consideration when using Markov chain model is the *normalized entropy of P*, given by the formula:

$$H'(P) = \frac{-\sum_i X_i^* \sum_{j, p_{ij} \neq 0} p_{ij} \log p_{ij}}{\log m}.$$

Normalized entropy is zero when for every column *j* there is exactly one *pij* element equal to 1, and all others are equal to 0, meaning all the pixels in state *j* that change to state *i*. On the other hand, if each element of matrix *P* is equal to 1/*m*, the normalized entropy is equal to 1, which is its maximum value. Values of *H′ (P)* close to 0 indicate a Markov chain closer to a 'deterministic' model while values of *H′ (P)* close to 1 indicates a more "random" Markov chain model (Riiters et al., 2009).

Binary change index and Kappa index

A better understanding of landscape dynamics can be obtained by calculating the global indicators of change, reflecting changes in the period considered in the study area.

The first of these is the *binary change index* (eg. Van Eetvelde & Käykhö, 2009) defined by the relation:

$$BCI = \frac{NCH\% - CH\%}{NCH\% + CH\%},$$

where *NCH%* and *CH%* represent the percentage of surface in the target area that remained unchanged, respectively, which changed its destination in the period under review, between moments of time t and t'. It can be shown that the binary change index can be inferred directly from the matrix F of frequencies. More precisely, the following relation is present:

$$BCI = \frac{2\Delta}{A} - 1,$$

where $\Delta = \sum_{i=1}^{m} f_{ii}$ is the sum of elements the main diagonal of F, and $A = \sum_{i,j=1}^{m} f_{ij}$ is the total surface of the target area.

The Binary change index can be visually illustrated by using the binary change map.

The second quantitative change indicator is *kappa index*, defined by the formula:

$$K = \frac{A\Delta - \sum_{i=1}^{m} r_i c_i}{A^2 - \sum_{i=1}^{m} r_i c_i}.$$

This index is a measure of the degree to which the two maps are similar, one being seen as a whole, actually quantifying the magnitude of changes in the studied period (eg Congalton & Green, 1999; Biondini & Kandus, 2006). Kappa index may be calculated for each land cover classes by introducing the *kappa index* and the *directly conditional kappa index* K_d and the *reversed conditional kappa index*:

$$K_d = \frac{Af_{ii} - r_i c_i}{Ac_1 - r_i c_i};\ K_r = \frac{Af_{ii} - r_i c_i}{Ar_1 - r_i c_i}.$$

The values of all indices defined above are always located in the interval [–1,1]. There are also some differences that are worth mentioning. The binary change index is equal to –1 when for each *i* class the relationship $f_{ii} = 0$ it present, meaning each class of land cover that completely changes the classification. On the other hand, the global *kappa index* is equal to –1 only when $m = 2$ and each pixel changes the state in other possible state, which shows that the kappa index is generally more "sensitive" if radical changes occur in the landscape. Both indexes are equal to 1 when there is no change in terms of land cover in the studied area. For a fixed *i* coverage class and the $K_d = 1$ relation applies when $f_{ii} = c_i$, meaning the whole area covered by type *i* remains unchanged. On the other hand, $K_r = 1$ when $f_{ii} = r_i$, meaning that there is no such $j \neq i$ pixel to change its state in type *i*.

Due to its linearity, we propose a classification of binary change index values into five groups, each of them having a length of 0.4: values between –1 and –0.6 represent radical changes, values between –0.6 and –0.2 represent very substantial changes, values between –0.2 and 0.2 are substantial changes, values between 0.2 and 0.6 represent moderate changes, and values between 0.6 and 1 indicate low changes. For the kappa indexes, the classification includes all five classes, but not with the same length (we consider a longer period for the radical changes due to the sensitivity of kappa index to these changes): values between –1 and 0 indicate radical changes, values between 0 and 0.25 indicate very substantial changes, values between 0.25 and 0.5 are substantial changes, values between 0.5 and 0.75 represent moderate changes and values between 0.75 and 1 indicate low change.

3.1.3. Results and discussions

The analysis was structured based on three fundamental questions. What major changes have occurred in the study area as a whole, and that is the intensity of these change? What are the relevant processes? What will happen in the future? It is a widely accepted fact that the link between spatial features and ecological processes can be better understood through the use of indicators that measure spatial

heterogeneity (Turner, 2005). Thus, possible answers to these three questions raised above can be obtained by calculating the appropriate indicators, derived from frequency matrices (Table 1 and Table 3) and the transition matrices (Table 2 and Table 4), using the mathematical model presented in the methodological section. First, in the section dedicated to the land use dynamics and the transitions that took place, we try to present an overview of the change magnitude which can be obtained based on indicators such as binary change index, index kappa, respectively the conditional kappa index (Table 5). All these indexes were compared for two time periods: 1970–1990 and 1990–2009. We believe that these indexes are important in the analysis of changes that occurred in the land use, because it represents quantitative information of a global nature, indicating the magnitude of changes. Global indexes can provide additional information about the relevance of changes at the landscape elements level. Moreover, they can be easily compared, using the appropriate scale of intensity.

The second subsection (processes the land use level) emphasizes the most important processes that are identified in the analyzed intervals. These processes can be deduced based on the frequency matrices and are reflected by the land cover maps (figure 8) and the binary maps of change (figure 9). The further evolution of the landscape is directly related to the sustainability of the land use (discussed in the third subsection), as spatial development policies are a fundamental component of the environmental sustainability (Council of Europe, 2010). Thus, these policies should be based on understanding the evolution in time and on the current trends (Antrop, 2005). These elements can be derived by applying the Markov model transition matrix.

Table 1

Frequency matrix for Prahova Valley (1970–1990)

Area (km²)	Forest	Pastures/ Meadows	Orchards	Arable	Residential	Industry	Total (1990)
Forest	41,668	6,409	4,914	1,725	0,902	0,293	57,346
Pastures/Meadows	1,952	21,197	2,045	1,327	0,208	0,122	26,901
Orchards	1,051	1,643	18,085	0,989	4,898	0	27,044
Arable	0,287	0,852	1,482	2,988	2,102	0,011	9,301
Residential	0,211	0,176	2,795	0,937	11,811	0,057	16,195
Industry	0	0,052	0,228	1,944	0,696	0,162	3,122
Total (1970)	45,550	30,472	29,921	10,488	20,688	0,741	146,116

Table 2

Transition matrix for Prahova Valley (1970–1990)

Area (km²)	Forest	Pastures/ Meadows	Orchards	Arable	Residential	Industry
Forest	**0,915**	0,210	0,164	0,165	0,044	0,395
Pastures/Meadows	0,043	**0,696**	0,068	0,127	0,010	0,165
Orchards	0,023	0,054	**0,605**	0,094	0,237	0
Arable	0,006	0,028	0,050	**0,285**	0,102	0,015
Residential	0,005	0,006	0,093	0,089	**0,571**	0,077
Industry	0	0,002	0,008	0,185	0,033	**0,218**
Total	1,000	1,000	1,000	1,000	1,000	1,000

Table 3

Frequency matrix for Prahova Valley (1990–2009)

Area (km²)	Forest	Pastures/ Meadows	Orchards	Arable	Residential	Industry	Total (2009)
Forest	41,374	5,805	2,087	0,541	0,313	0,072	50,525
Pastures/Meadows	5,494	13,096	1,745	1,126	0,174	0	21,682
Orchards	3,393	2,456	8,631	0,733	0,794	0,052	16,680
Arable	1,877	4,160	1,977	0,816	0,276	0,432	10,080
Residential	3,298	1,244	12,239	4,493	14,017	2,167	38,200
Industry	0,044	0,006	0,073	0,690	0,320	0,399	1,535
Total (1990)	57,346	26,901	27,044	9,301	16,195	3,122	146,116

Tabel 4

Transition matrix for Prahova Valley (1990–2009)

Area (km²)	Forest	Pastures/ Meadows	Orchards	Arable	Residential	Industry
Forest	**0,721**	0,216	0,077	0,058	0,019	0,023
Forest	0,096	**0,487**	0,064	0,121	0,011	0
Pastures/Meadows	0,059	0,091	**0,319**	0,079	0,049	0,017
Orchards	0,033	0,155	0,073	**0,088**	0,017	0,138
Arable	0,057	0,046	0,453	0,483	**0,866**	0,694
Residential	0,001	0	0,003	0,074	0,020	**0,128**
Industry	1,000	1,000	1,000	1,000	1,000	1,000

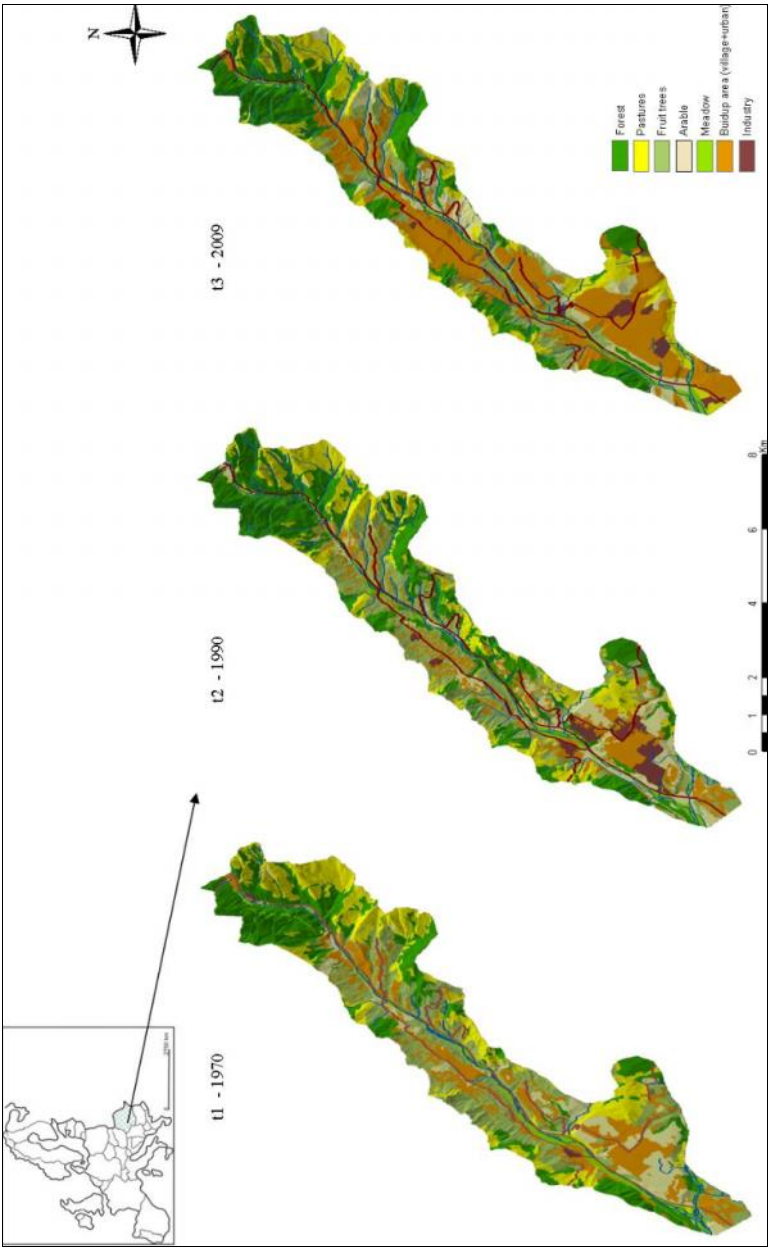

Figure 8. The mountainous and subcarpathian sectors of Prahova Valley. *Land use and land cover types* (processed after topographic map 1: 150. 000, 1970, 1990, satellite images from Google Earth Pro, 2009)

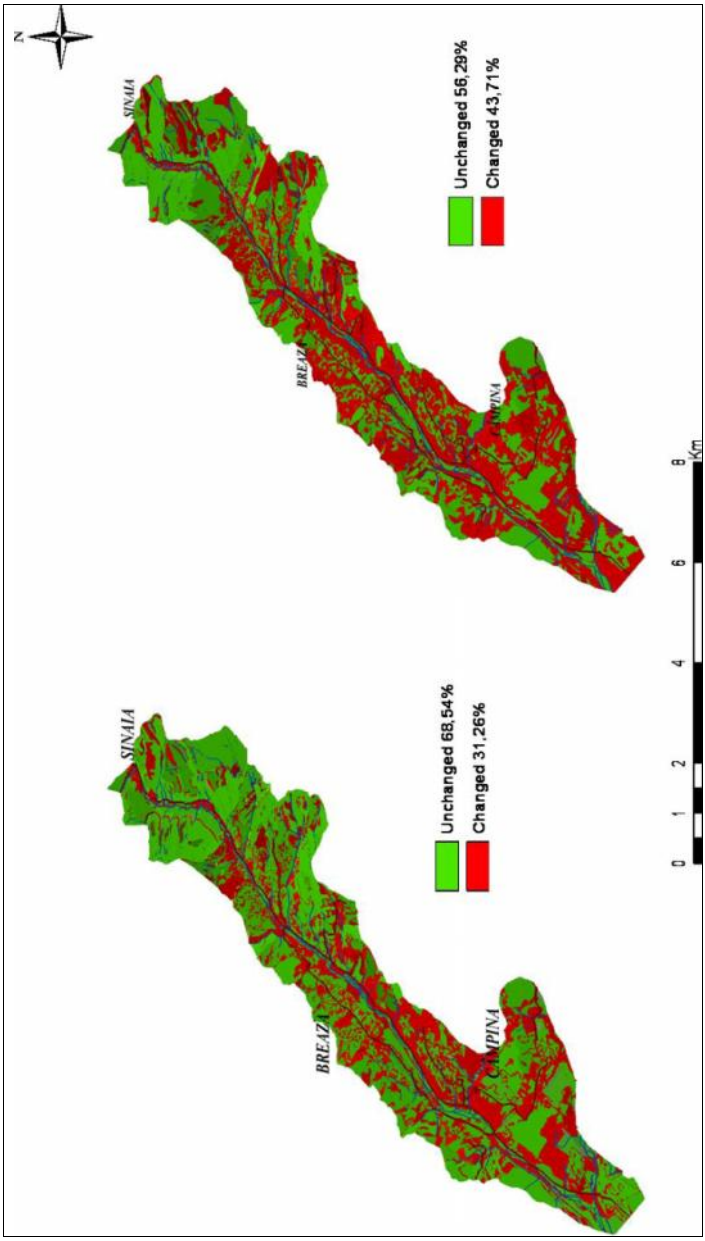

Figure 9. The mountainous and subcarpathian sectors of Prahova Valley. *Spatial distribution of binary index* (processed after topographic map 1: 150. 000, 1970, 1990, satellite image from Google Earth Pro, 2009)

3.1.3.1. The dynamics and the transitions at the land use level

Globaly speaking, for the entire area it can be observed a certain level of stability for the period 1970–1990. Thus, the binary index value is 0,375 and the kappa index is equal to 0,599, both values indicating a moderate level of change. The rate of convergence is ρ=1,317 and the normalized entropy is *H '(P) = 0,332*, the lower value of 0,5 indicates that the model is closer to the deterministic one. Conditional kappa index values (Table 5) indicate reduced changes in the forest case (value equal to 0,86), moderate changes in the case of pastures, orchards, meadows and built-up surfaces and substantial changes for the arable land and the industrial areas.

The binary index value and the value of kappa index for the period 1990–2009 shows a significant change in the landscape, compared to the previous period, given that both indices have diminished significantly. Thus, the binary index is equal to 0,126, and the kappa index is 0,440. Landscape dynamics is also reflected in the convergence rate *ρ = 1,285* and the normalized entropy, *H′ (P) = 0,435*, indicating a more random Markov model. Of the conditional kappa index values (Table 5), we deduce that the landscape elements that have diminished in favor to other landscape elements are built areas (both urban and rural areas), forest and meadow.

Tabel 5

The conditional kappa index values for Prahova Valley (1970–1990)

	1970–1990	1990–1970	1990–2009	2009–1990
Forest	0,860	0,603	0,574	0,702
Pastures/meadows	0,627	0,732	0,397	0,515
Orchards	0,515	0,583	0,231	0,408
Arable	0,236	0,269	0,020	0,018
Rezidential	0,517	0,685	0,818	0,288
Industry	0,202	0,047	0,119	0,244

3.1.3.2. Land use change and associated processes

The most relevant processes that can be deducted directly from the frequency matrices (Table 1 and Table 3) and the transition matrices (Table 2 and Table 4). Comparing the figures, we see that there are significant differences between the two time periods (see figure 9,

where was represented the binary change map). This confirms one of the limitations of Markov chain model: transition probabilities are stationary over time (Baker, 1989).

The most obvious phenomenon that can be observed for the period 1970–1990 is the reforestation that took place in two ways. The first is that of controlled reforestation (due to reforestation programs that were undertaken nationally and locally in the communist period). A fundamental example is that of the agricultural area: due to the fact that the region is exposed to soil erosion, reforestation was needed on some terrains in order to prevent the degradation expansion (landslides, erosion). Explicitly, forests have gained 16.5% of the total arable land and 17.4% of the meadow areas (while the reverse changes involve lower percentage values); these data confirm the phenomenon of controlled reforestation. The second way is the natural expansion for forests: forest areas are increasing against the adjacent pasture and meadow areas (Table 2 shows that 21% of the area covered with pastures in 1970 and 16.4% of the area covered with meadow in 1970 became forest in 1990). A possible explanation is related to the policies of collectivization. This region was not collectivized, but in order to avoid this process and to pay lower taxes, farmers from this area have preferred that the land they owned to be reforested, not to increase the agricultural area. Another dynamic sector between 1970 and 1990 is the industrial area. First, it is worth mentioning that these areas grew four times in the considered period (from 0.741 km^2 to 3122 km^2). It should be noted that there was a conversion of industrial spaces in forests or grasslands, but it was compensated by the expansion of the industrial areas at the expense of arable land or meadow. This phenomenon may be associated with socialist policies aimed at building new industrial areas and to demolish the existing ones, especially the unproductive or those established during the monarchy.

Below we present the relevant processes for the period 1990–2009. The predominant phenomenon is the expansion of residential areas, increasing their surface more than twice. Thus, their area increased from 16195 km^2 in 1990 to 38.2 km^2 in 2009 (Table 3), especially at the expense of industrial areas, arable land and orchards (69%, 48.3% and 45.3% of the corresponding areas were converted into residential areas). Also, 3298 km^2 of the forest area was lost in favour of the urban sprawl, but this surface, relative to the total forest area represents only 5.7%.

This expansion is explained by significant changes that occurred after 1989, particularly in relation to reinvesting the property and the right to own several homes. Another consequence of the political regime change is the demolition of many industrial areas, their land being especially designed for the residential sector. In exchange new industrial areas emerged, a phenomenon that manifested in the context of the local and foreign investments. The political factor decisively influenced the deforestations that have occurred after 1990, since land restitution laws and reconstruction of property did nothing else than to fragment the forests in Romania (Giurgiu, 2010).

3.1.3.3. The sustainability of land use

The transition matrix which is associated with a period of n years can generate two models of landscape evolution (figure 10). The first is based on the computation of land cover classes's distribution after other n years, based on matrix multiplication (eg Pena et al., 2005, Pena et al., 2007 can be found a description and an application of this model). The second possible approach is to calculate the equilibrium distribution vector and to estimate the asymptotic tendency of the distribution of land cover types.

In the case study on the Prahova Valley, the transition matrices $P_{70\text{-}90}$ and $P_{90\text{-}09}$ that are corresponding to the time periods 1970–1990, respectively 1990–2009 (Table 2 and Table 4) show completely different trends for the future evolution of the landscape in the study area. In particular, it shows that the determination and comparison of asymptotic trends is more relevant than the calculation of the proportions for the land cover classes after a finite number of years.

We also calculated the product $P_{90\text{-}09} \cdot P_{70\text{-}90}$, which is nothing more than the transition matrix $P_{70\text{-}09}$ corresponding to the period of time from 1970 to 2009. For each of these three transition matrices we calculated the equilibrium distribution vectors. Thus, the three matrices lead us to three alternative scenarios of land cover type distribution and appropriate equilibrium vectors were represented in Figure 3. The first scenario, created from the corresponding asymptotic trends over the first period of time (1970–1990), indicating a massive reforestation in the future (asymptotic value for the percentage of area occupied by forests is over 65%).

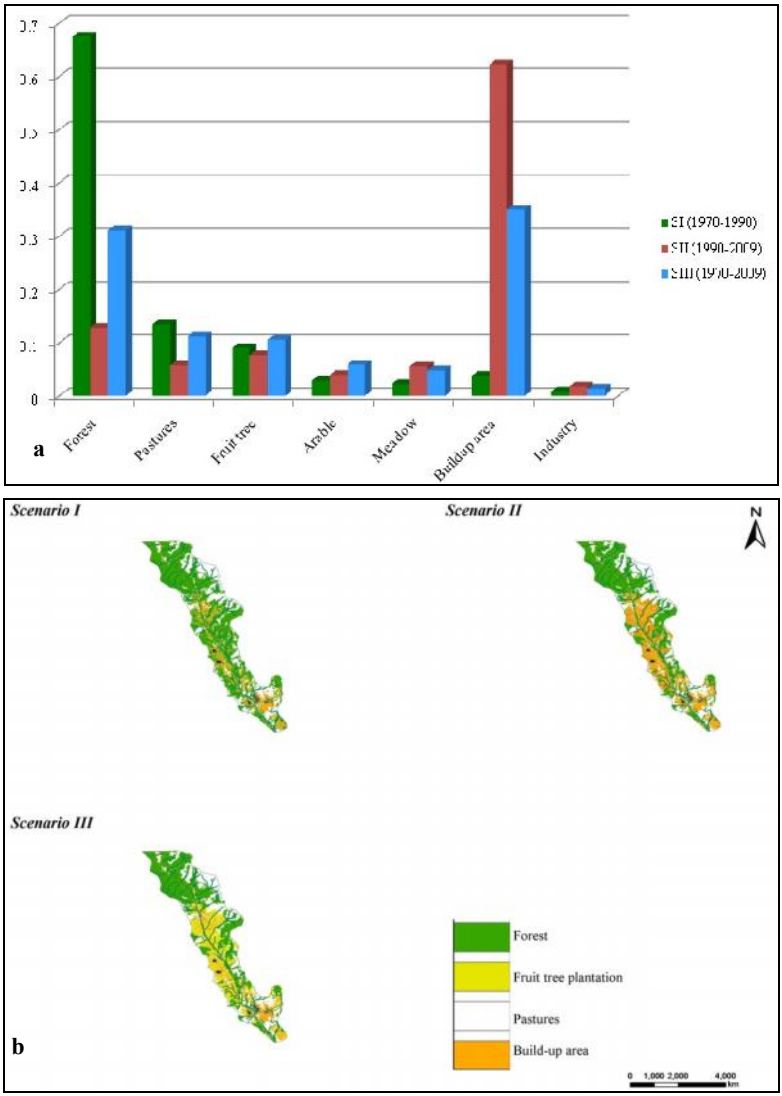

Figure 10. The mountainous and subcarpathian sectors of Prahova Valley. **a.** the equilibrium distribution for three alternative scenarios *(SI, SII, consequently SIII), corresponding to three transition matrices: 1970–1990, 1990–2009, respectively 1970–2009*; **b**. SI, SII prognosis, respectively SIII (processed after topographic map 1:150.000, 1970, 1990, satellite images from Google Earth Pro,2009)

But it is clear that this scenario is not realistic, given the significant changes that have occurred after 1990. The second scenario, corresponding to the second transition matrix (1990–2009) states, on the contrary, a significant increase in the residential areas, which would occupy over 60% of the habitat, whilst the forests will only cover 13%. We affirm that this scenario is unlikely to materialize. For example, increasing urban pressure will be, eventually, stopped or controlled by internal factors (the need for regional stability and equilibrium, which can be controlled by appropriate local development policies) or by external factors (eg of economic nature). The third scenario, which takes into account the whole time period 1970–2009 is one of the middle and seems more realistic: the area occupied by forest will be about 31% (approximately the same percentage as in 1970) and the increasing area that is occupied by residential areas is significant but not radical (from 14% in 1970 to an asymptotic value 35%).

Conclusions

Our purpose was to produce, based on the available cartographic materials, a pilot study that indicate the current state and landscape dynamics in the Prahova Valley. The main conclusion is that there is some instability in the region regarding the landscape dynamics, due to strong interdependencies between the landscape transformations in the historical and political context. In particular it is difficult to develop highly accurate prognosis regarding the future evolution of the landscape structure. On the other hand, indicators and scenarios presented above demonstrate that human pressure must be controlled in order to avoid excessive deforestations. Explicitly, local authorities need to rethink public policies and to develop new ones in order to better manage the conflict between human pressures and the environment. Since the landscape is a resource, it must be managed wisely in order to ensure sustainable development. In this way, it can be prevented landscape degradation and the loss of natural and cultural values.

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3.2. The integration of satellite images in landscape analysis

3.2.1. General features of the satellite images

3.2.1.1. Comparative advantages of using satellite images in landscape analysis, in opposition to other cartographic materials

The integration of the advantages of satellite images in landscape studies, especially in the case of complex landscapes, facilitates the production of a detailed geospatial database (Manuel, 2010). In this regard, satellite images represent snapshots of a dynamic situation (Robin, 2002) that portray the landscape evolution.

The landscape cartographic evaluation is limited by several inconsistencies regarding the map projection and scale which vary between years, the presence of digitisation errors and the high variation of the intervals for which cartographic materials are available (Pătru-Stupariu et al., 2011).

Thus it is necessary to complement the geospatial database with satellite images that enable a higher accuracy and a reiterative caption of the images for different years.

As for the quality of the information derived from these satellite images, it largely depends upon parameters like image resolution, landscape complexity, as in the case of a intricate urban landscape. The precision of this information is determined by spatial, radiometric and temporal resolutions and the number of spectral bands, available for each year (Tonye & Akono, 2000).

The main disadvantage of using satellite images in landscape analysis is the significant volume of processing required to improve and eliminate some effects induced by topography and atmosphere. Moreover, to evaluate the land cover dynamics by superposing images from different years, a georeferencing process is necessary in order for all the scenes to meet the same features related to resolution and positioning.

Satellite images are obtained through the help of a sensorial system (figure 11) and their application covers several domains (figure 12).

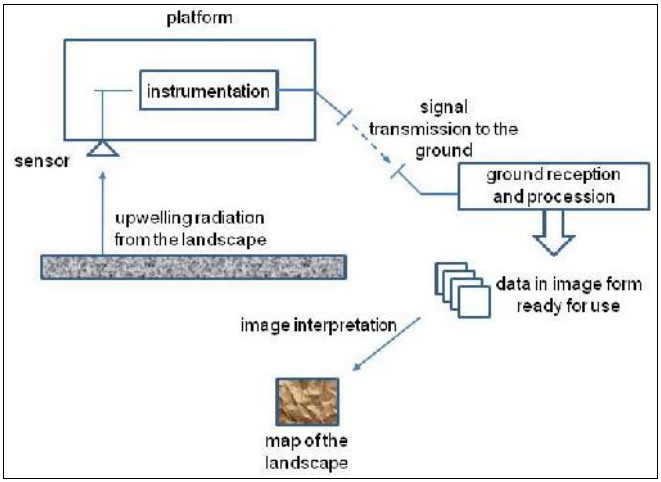


Figure 11. Satellite image integration in landscape analysis. *The signal and the data lowded in a sensorial system.* After Richards, J. A., Xiuping, J. (2006)

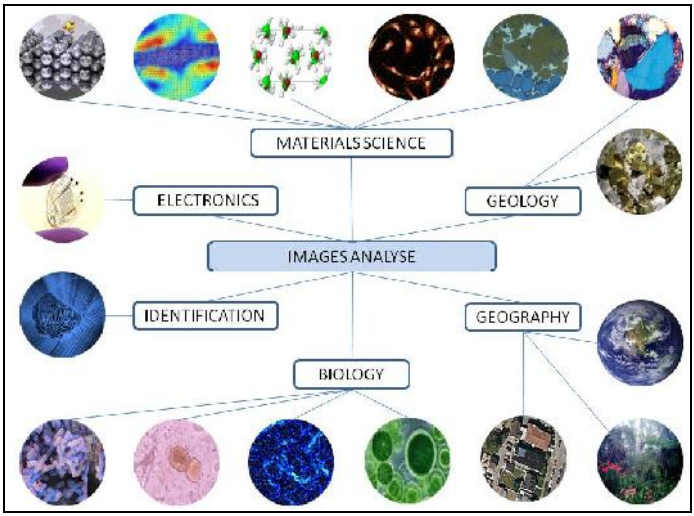


Figure 12. Satellite image integration in landscape analysis.
Satellite image palette of applications. After Coster M. & Chermant J. L. (1989)

In addition, to monitor the dynamics of specific landscape elements it is necessary to use recent and precise geo-databases. The updating can be achieved through the use of satellite images that contain visible and infrared bands which allow to research landscape features that can't be observed in the case of classical aerial images (Tonye & Akono, 2000).

Satellite images integrate the facilities offered by remote sensing in acquiring and processing information regarding the landscape as digital images by using the electromagnetic radiance as a vector of delivering this information (Robin, 2002).

The landscape is defined in the studies that concern the exploitation of the satellite images as „*a complex of interconnections between atmosphere, biosphere and anthroposphere. Being a representation of the connexions between these spheres, the landscape is simultaneously a system*." (Eastman, 1993) Each landscape illustrates a particular radiometric surface, different from the neighbouring landscape, thus it allows delineating between urban, agricultural, forest landscapes (Donisă & Donisă, 1998).

The applicability in territorial planning of the databases which were created through the interpretation of satellite images, derives from the identification of current built-up areas, highlighting the land cover change dynamics, emphasising the change trajectories, the delineation between protected areas and the analysis of the report between the built-up areas and those covered with vegetation (Abdellaoui & Benblidia, 2006).

In last two decades, numerous analysis methods of the landscape changes were developed and evaluated, based on remote sensing (Rogan et al., 2002; Woodcock & Ozdogan, 2004). Satellite images are valuable materials that offer a global image over the territory also being a support in landscape analysis, in landscape prognosis and various projections.

Examples illustrating the integration of satellite images in landscape evaluation and for producing landscape management strategies are specific especially for the last years. A relevant study in the issue of satellite image use in territorial planning focuses on Flanders-Bruxelles region, being presented by Lien Poelmans and Anton Van Rompaey in 2001. The authors concentrate on the *urban sprawl*, using Landsat

satellite images, in two different areas, one being highly urbanised and the other one semi-urbanised, through the supervised classification and reclassification in Idrisi software, consequently being inserted in the landscape change modelling in GIS Analysis.

3.2.1.2. Types of satellites that provide images for landscape analysis

The civil satellite systems are divided in two main categories (Robin, 2002):

– Geostationary satellites (METEOSAT, GOES);

– Passing satellites (NOAA, LANDSAT, SPOT, ERS, IRS, etc.).

On these platforms are embarked a great diversity of sensors (captors). A significant employment was specific, in the first years of the spatial epoch, to photographic devices with panchromatic film, the multispectral ones, along with the black-white and coloured films, the analogical and digital cameras (CCD), currently a large share of these devices is attributed to systems for image capturing through mechanical scanning or photo-element detectors, strap or digital matrix, the active systems like the side-looking radar (SLAR) or the synthetic-aperture radar (SAR), etc.

The instruments accompanying the satellites lead to gathering materialised information as digital images with different resolutions which vary from kilometres to meters and with a temporal reiteration from 30 minutes and up to 15 days (Robin, 2002).

As for the spatial resolution, the sensors are classified in four types (after Tonye, 2000) that are subsequently presented.

1) Sensors with *low spatial resolution* (between 5 Km and 2–3 Km) have a very high frequency of capturing images;

2) Sensors with *medium spatial resolution* (between 1000 m and 100 m) have a high passage frequency (four times in 24 hours), currently being intensely used in several application destined to study and monitor dynamic phenomena on expanded areas;

3) Sensors with *high spatial resolution* (between 80 m and 5 m), offer special conditions for detecting and discriminating the objects on

the earth surface. Several sensors used in operational missions and programs are now available: Multispectral Scanner (MSS) – 80 m resolution and Thematic Mapper (TM) – 30 m resolution, embarked on the LANDSAT 1–5 satellites; LISS-1 on the IRS satellites (25 m resolution in multispectral mode and 5 m in the panchromatic one); HRV on the SPOT satellites (20 m resolution in multispectral mode and 10 m in the panchromatic one); MOMS – 02 which was embarked on the American space shuttles – 10 m resolution. Among the last generations of sensors from this category, we can mention: ETM on the LANDSAT 7 satellite (15 m resolution), AVNIR on ADEOS satellite (8 m resolution), PAN/LISS – 3 on IRS/1D satellite (5.8 m resolution), HRG which is embarked on SPOT/5 (5 m resolution), AVIRIS (20 m) and HIRIS on the platform EOS.

4) Sensors with *very high spatial resolution* (less than 3 m) are Earth Watch/Early Bird (3 m resolution) and Orbimage from the Orbview mission (2–3 m resolution), IKONOS (1 m resolution), Quickbird, etc.

3.2.1.3. Landsat satellite images

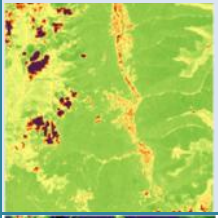
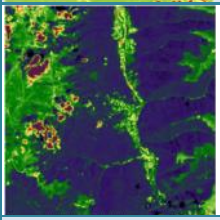
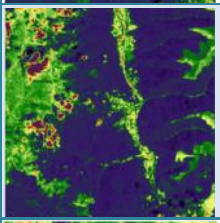
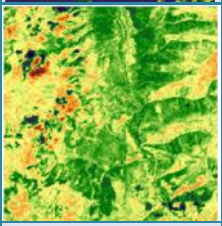
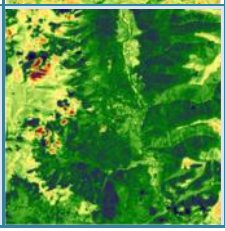
The Landsat programme is the most enduring action undertaken in order to produce and acquire earth images from space. The first Landsat satellite was launched into space in 1972. The most recent of the series is Landsat 7 and was launched into orbit on April 15th 1999.

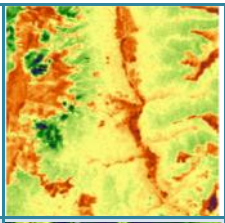
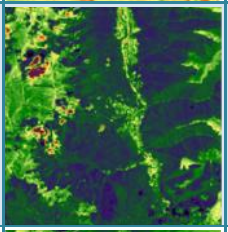
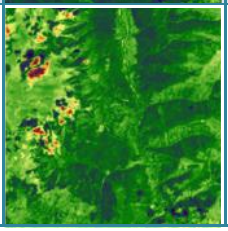
Landsat images proved to be useful in crop monitoring, natural resources exploitation (oil and gas exploitation, mineral extraction) and diverse environmental studies (Draeger et al., 1997).

Landsat satellite enables the coverage with images provided by sensors through the capture of the natural reflected energy, in several spectral bands (each spectral band represents a layer of information regarding the reflectance of the earth surface on that specific band), varying from 4 band in the case of MSS sensor, to 7 for the TM sensor and consequently 8 for ETM^{+} (Tonye, 2000). The mutation of the electromagnetic signal, accordingly to the nature of the object then allows researchers to identify it from distance. Each spectral band is described in table 6

Table 6

Satellite image integration in landscape analysis. *Types of spectral bands.* After Badea (2006), quoted in remote sensing tutorial of UVT and Bogdan (2007)

Spectral Band		Length/μm	Spectral coverage	Use and features
1		0.45–0.52	blue	Band useful for mapping coastal areas, to differentiate soil / vegetation, the observation of details regarding the water (turbidity), forest surface mapping and detection of infrastructure (roads, highways).
2		0.52–0.60	green	Band corresponding to the green color reflection that suggests healthy vegetation and is useful for detecting infrastructure (roads, roads) and to observe the details of water (especially turbidity).
3		0.63–0.69	red	Band useful for distinguishing the different species of plants and to determine the limits of different types of soils and geological structures, it is also useful for detecting construction works.
4		0.76–0.90	near-infrared	Band that is particularly useful to determine plant biomass in a scene. It is useful for identifying crops and to emphasize the contrasts soil/ crop and land/ water. It can be used to delimit aquatic and terrestrial surfaces.
5		1.55–1.74	mid-infrared	Band which is a sensitive to the amount of water in plants, it is useful for studying the phenomenon of drought and the plant development stage analysis. It is also useful to distinguish on the image the snow clouds from snow and respectively ice and for delineation of aquatic and terrestrial surfaces.

6		10.40–12.50	thermic infrared	Useful to determine the stage of vegetation, heat intensity, the effects of insecticides and the location of thermal pollution. It can be also used for locating geothermal activity. Energy captured in the band 6 is emitted by the Earth surface and data acquisition is possible during the night.
7		2.08–2.35	mid-infrared	Important band to distinguish types of rocks, the limits of soil types and for determining soil moisture and vegetation chlorophyll activity. It is used for the delimitation of aquatic and terrestrial surfaces.
		0.52 – 0.92	panchromatic	Band that allows detailed analysis of human elements, boundaries and limits of vegetation types.

The sets of satellite images can be downloaded from Global Landcover Facility site (http://glcfapp.glcf.umd.edu:8080/esdi/index.jsp) Earth Science Data Interface, where Landsat products are available for free in research. Identifying a collection of satellite imagery scenes is possible by a particular code.

The images that are finally chosen must be captured on similar months (preferably representing the maximum vegetative months), thus facilitating the comparison over a significant period in terms of landscape elements dynamics. In addition, in this case the seasonal variations that would limit the comparison between scenes are reduced, since the images are captured in different years. Unlike vegetation, built areas have some invariableness across the seasons, allowing a broader comparison.

Criteria for selecting proper satellite images in landscape analysis. The landscape analysis which is based on satellite images should take into account several aspects, namely: a) study budget;

b) extension of the target area; c) the frequency with which the landscape is analyzed; d) the analyzed landscape elements (index calculation, digitization, classification, etc.).

3.2.2. Landsat satellite image exploration. Processing phases

Obtaining useful information in a particular activity sector involves completing specific phases, which are shaped in relation to the existing computing capabilities and objectives (Barnoaia, 2011).

IDRISI Andes software (Integrated GIS and Image Processing System) is considered the most effective program of geographic analysis based on raster maps (Robin, 2002), allowing to rectify and to process satellite images. The system was developed by Clark Labs (Graduated School of Geography, Clark University in Worcester, Massachussetts, USA).

In order to produce relevant results for the studied area, the images obtained by the processing program Idrisi Andes were subsequently imported into ArcGIS Desktop 10 software. Several steps must be completed in order to apply a series of functions for assessing the dynamic changes in the landscape. These steps can be grouped after Liellesand and Kiefer (2000) in a few representative categories, which succession can be slightly different:

a. *Preprocessing,* which includes preparation of preliminary satellite images for further processing and includes primarily geometric rectification, radiometric correction and improving distorted or degraded images;

b. The actual *image processing*, to replace visual analysis with quantitative analysis of details present in these images through automatic identification procedures. For this purpose, it is necessary for the classification of each pixel in the image, consequently the compliance with a particular class, that is related to the spectral recognition of forms or the spatial recognition forms;

c. *Post-processing* of the images, consequently the integration of the available information, obtained from their processing in GIS framework.

3.2.2.1. The visual analysis of the satellite images

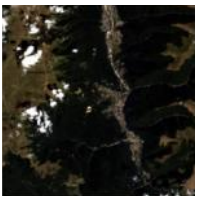
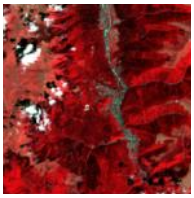
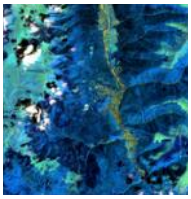
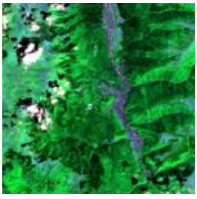
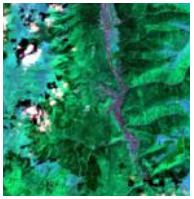
The visual analysis of the satellite images allows the observation of changes in the landscape without using specialized analysis software (Abdellaoui, 2006). It consists in comparing the satellite images with data that varies between the identifiable differences. In our example we notice significant differences, especially in terms of natural vegetation and built-up areas (rural and urban).

Delimitation of the target area on the satellite images. Since the images downloaded often include a region larger than the area of interest for the research, the satellite images should be adjusted according to the geographical coordinates of the study area (Eastman, 1993). For example, in Sinaia, keeping the original UTM 35N projection, we proceeded to resample the satellite images to an area of interest. This resanpling was produced for each band of the Landsat considered time series, using maximum X values (390,990) / X minimum (379 306) and maximum Y (5028882) / Y minimum (5017083).

The processing of composite images for the visual assessment. The analysis of satellite imagery requires a contrast enhancement, a process that aims to facilitate visual interpretation by increasing the differentiation between image components. A classic method is to use combinations of bands (Abdellaoui & Benblidia, 2006). Satellite images contain distinct spectral signature bands, but because there is an obvious correlation between them, if a pixel corresponding to a real element has a strong reflection on a particular band, it is expected that the same pixel would have a high value on a different band (Eastman, 1993). The procedure is called synthetic RGB combination; for the target area we used the following combinations of spectral bands (Table 7) for each year.

Tabelul 7

Satellite image integration in landscape analysis.
***Spectral bands combination.* after Eastman (1993)**

Image	Band Combination MSS, TM şi ETM+	Results
	**3-2-1 RGB**	Are used the visible bands, the combination results in a natural color image, which allows recognition of the area analyzed. The disadvantage is that it produces images that are slightly blurry.
	**4-3-2 RGB**	Whereas 4 is a band of the infrared domain, it allows highlighting vegetation areas, being important in determining the relationship between built-up areas and those covered with vegetation.
	**4-5-3 RGB**	Shorter wavelength bands are not included in the combination (bands 1 and 2), different types of vegetation are decoded, and also the interface between land and water surfaces.
	**7-4-2 RGB**	It has similar properties to the 4-5-3 combination, the main difference being the representation of vegetation in green.
	**5-4-1 RGB**	It's a combination that is suitable for viewing crops.

3.2.3. NDVI index analysis

The Normalized Difference Vegetation Index, NDVI, was introduced in the scientific literature by Rouse in 1973 (Eastman, 1993). The first researcher who used the NDVI in various studies and scientific articles was Compton Tucker who was followed by other researchers, among which remarkable results are associate with Jensen (1986), Goward et al. (1991), Goetz (1997), Wang (2001), Jiang et al. (2006), Tagil (2008), Laidler et al. (2008). For Romania it is significant the thesis of Roman (2003), who highlighted the relevance of using satellite imagery in landscape analysis for the Moldavian Plain.

The notion of *vegetation index* came from the need to identify and delineate the vegetation on multispectral images, based on the characteristics of their spectral response, in relation to other objects that are located on the Earth's surface. Vegetation indices were built using the radiance or reflectance values of the two channels, having multiple applications in monitoring vegetation dynamics, the determination of the photosynthetic active radiation, the photosynthetic capacity of the vegetation and conductance (Eastman, 1993). Vegetation indices are optical measures of the composite state of the vegetation cover that is defined by the chlorophyll found in leaves, the leaf index, the soil cover with vegetation and its structure.

Vegetation interacts differently with the solar radiation from other natural materials such as soils or waters. Absorption and reflection of the solar radiation is the result of many interactions with different plant material, which varies considerably in terms of wavelength (Robin, 2002). Water, pigments, nutrients and carbon are each one expressed in the reflected optical spectrum which vary from 400 nm to 2500 nm, having overlapping but distinct reflectance in spectral terms. These signatures allow researchers to combine the known spectral reflectance measurements at different wavelengths, in order to enhance the vegetation characteristics, thus defining vegetation indices[7].

NDVI is defined as:

$$NDVI = (RNIR - RRED)/(RNIR + RRED)$$

[7] PNCDI2 RISCASAT

Where:

– RNIR is the reflectance on the near infrared spectral band;

– RRED is the reflectance on the red spectral band.

In figure 13 is presented the VEGINDEX instrument which can automatically determine the NDVI index. RRED is band 3 (red), and RNIR is band 4 (near-infrared).

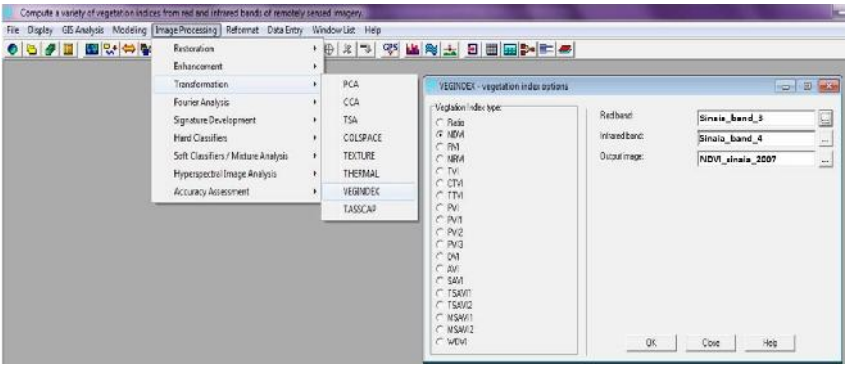


Figure 13. Satellite image integration in landscape analysis. *Image Processing – VEGINDEX interface used to compute the NDVI index, Sinaia, 2007*

Also, vegetation indices are used to estimate the vegetation effect on the seasonal variations of atmospheric carbon dioxide and to quantify the effect of CO2 and the temperature variations on vegetation. Vegetation indices are a very effective means of monitoring and evaluating the drought phenomena, based on the images scale thanks to the precise discrimination of vegetation.

In calculating the index it will be taken into account the climatic and biophysical parameters correlation, which determine the state of vegetation and the plant turgidity such as height, leaf index, biomass, etc. For the integration of the satellite imagery in landscape analysis and to calculate NDVI index it must be taken into account the seasonal variations, but also the unusual weather phenomena such as droughts. The steps for the integration in the landscape analysis require a precise use of this index through reclassification into GIS and by generating the landscape change maps (figure 14).

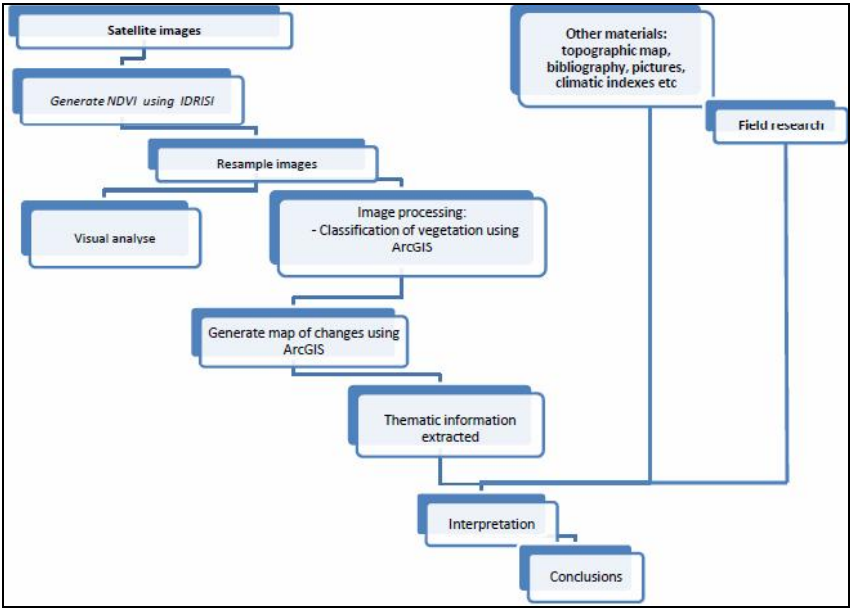
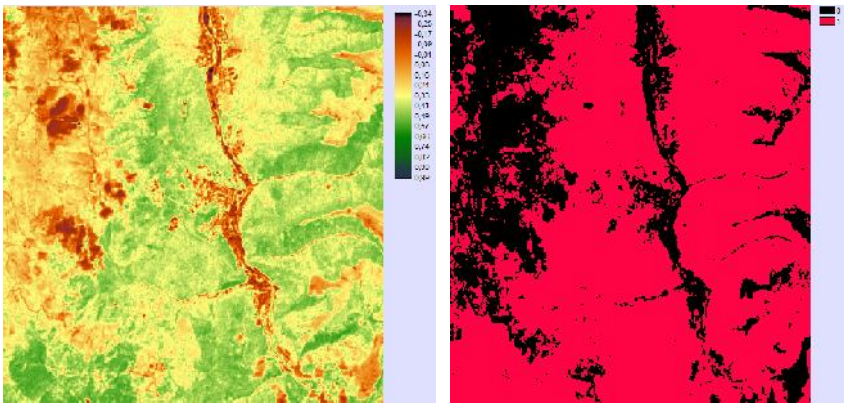


Figure 14. Satellite image integration in landscape analysis. *The flowchart for integrating the NDVI index in landscape analysis.* After Abdellaoui et al. (2011)

NDVI is an important factor describing the biological status of the canopy and providing information on the health of the vegetation and its evolution over time. Specific color palette associated to the normalized vegetation index is designed to indicate the surfaces covered with vegetation which are shown in dark green and the built-up ones which are shown in brown (figure 15 a).

Since an image is a matrix of pixels, some of which are residual, in order to achieve a more accurate representation of the NDVI index values, it is necessary to eliminate the redundant pixels. For this purpose it must be created a graphical representation in Idrisi, such as a histogram, showing the frequency distribution of the vegetation classes. By changing the minimum and the maximum values, this will change the color palette of NDVI images; by representing only the pixels with values over 0.3 which is the value above which vegetation is clear (figure 15 b).



a) b)

Figure 15. Satellite image integration in landscape analysis. *NDVI index a) Simple; b) Stretch* (processed on Landsat image from 2007, 28,5 m resolution)

Resampling the satellite images. The difference between the resolutions of the satellite imagery does not allow overlapping scenes from different years to be created, in order to produce images of the diachronic evolution of the landscape. To remedy this inconvenience it is necessary to resample the NDVI resulting images so as to have a common resolution. In Idrisi, through the Resample function, the image resolution is converted by linking to a correlation file which contains the georeferenced four points of a reference image. In our example images were resampled to have the same properties: maxx = 390 990, minx = 379 306, maxy = 5028882, miny = 5017083, the number of columns = 410, number of rows = 414. The common resolution for all NDVI images that will be used to illustrate the diachronic evolution is 28.5 m (figure 16).

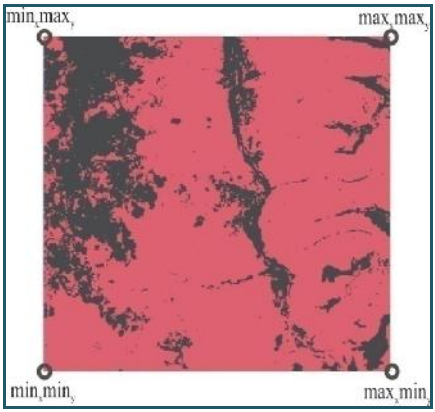


Figure 16. Satellite image integration in landscape analysis. *Satellite Image resampling* (processed on Landsat image from 2007, 28,5 m resolution)

The creation of the diachronic images. From the combination of the NDVI images for different years it resulted a diachronic representation (figure 17), where the vegetation that expanded is represented in red, green suggests the vegetation that disappeared and yellow indicates the unchanged area, where no transformations were recorded (Table 8).

Tabelul 8

Satellite image integration in landscape analysis. ***Possible combinations to illustrate the evolution of the NDVI index between pairs of years***

Band 1 (NDVIx0)	**Band 2 NDVI first year**	**Band 3 NDVI al second year**	**Resulting color**	**Change types**
0	0	**1**	**Red**	Vegetation grew
0	**1**	0	**Green**	Vegetation diminished
0	**1**	**1**	**Yellow**	Vegetation unchanged
0	0	0	**Black**	No vegetation

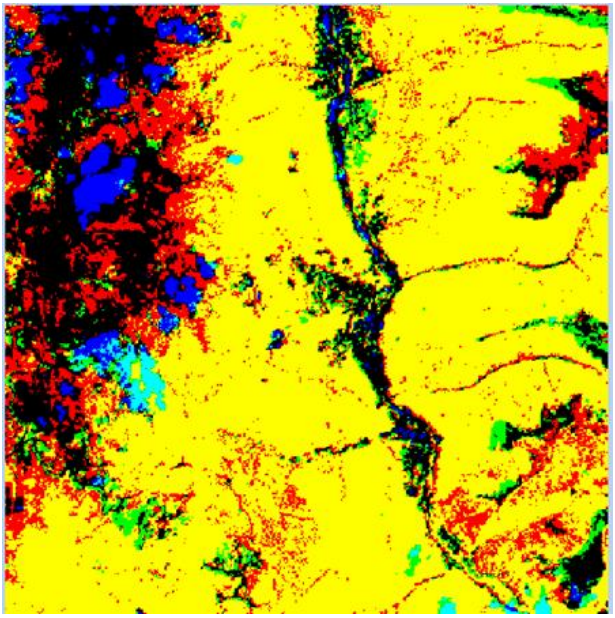


Figure 17. Satellite image integration in landscape analysis. *NDVI index, the diachoric images* (processed on Landsat image from 2007 and Landsat 2000 with 28,5 m resolution)

3.2.4. Image reclassification in ArcGis and the integration of the grid for manual classification

IDRISI program allows automatic classification of the images, but often errors can be avoided by assigning values manually, based on a fundamental knowledge of the field. Such diachronic change representation of the landscape elements can be achieved in ArcGIS, for which it was necessary to delimitate the territory into rectangular grids with the same shape and size. Each values of the cells included in the grid are established based on the NDVI images, which are compared with the natural and false color images of the target area and, particularly, through field investigations and other relevant documents. The classification process is a more accurate field representation, given that the low resolution of Landsat images that were used in this example do not allow a precise automatic classification.

The *grid method* facilitates the landscape analysis, through which it can be illustrated the evolution of the landscape between at least two different dates. Defined by R. Brown et al. (1992), the grid method is a way of gathering and processing data for statistical analysis and mapping of an area divided into equal squares. Satellite images provide information in the form of pixels that can be integrated as vector or raster mode in the GIS software. In this optic it provides a basis on which the manual classification can be done, pixel by pixel, and also the comparison with other cartographic materials and ancillary documents. The result is an updated and comprehensive database for the analysis of a complex landscape.

Thus, the satellite images that captured the extent of the considered landscape are divided into equal squares (cells), ideally one for each pixel. Cellular automate began to be used in geography in the `80s by Philipps (1989) and Couclecis (1985, 1988) to study the human impact on the landscape, especially urban sprawl. In the '90s, cellular automate began to be described in specialized scientific journals.

The georeferenced grids, containing a collection of cells as vectors, can be produced with GIS tools: ArcGIS, MapInfo Professional, GeoConcept and then, using logical and mathematical expressions, it will help us create diachronic analysis images of the landscape.

In the case of Sinaia, the cells (5264 in total) correspond to squares of 50 m x 50 m; this size avoids errors related to generalization, especially in the case of the built-up / vegetation interface.

To assign values to the cells manually, we identified and differentiated the main themes of interest and the specific sub-themes, particularly the built-up types: residential, commercial and industry, leisure, using the satellite images that were processed in IDRISI Andes, through traditional methods meant to improve the visual contrast, the combination of bands and the NDVI index calculation.

Robin (2002) identified two types of errors associated with the manual classification of the satellite images that capture the urban landscape, which we found during the analysis:

a) The presence of a masking effect: vegetation covers the built-up surface, the canopy covers portions of roads and buildings, especially in the peripheral areas of diffuse urbanization;
b) Ambiguity of interpretation of the radiometric signature: the color of the pixels is identical, even if they are different, so no distinction is made between rocks and construction sites. Peripheries are difficult to decipher in the urban context, because of confusion caused by the existence of parcels filled with construction sites, soil and vegetation.

Given these possible errors, the interpretation of satellite images must be verrified on the field, in order to eliminate ambiguities (Tony & Akone, 2000). The diachronic images (figure 18) were finally obtained by concatenating the input values for each cell (Table 9).

Tabelul 9

Satellite image integration in landscape analysis. The evolution of land covers types between *1979 and 2007 in Sinaia, at cell level.* (0 = vegetation and 1 = built-up)

Line	Column	Year 1979	Year 1990	Year 2000	Year 2007	Values resulted for the interval 1979 – 2007
114	89	0	0	0	1	**0001**
113	89	0	0	0	0	**0000**
112	89	0	0	0	1	**0001**
111	89	0	0	1	1	**0011**
110	89	0	0	0	0	**0000**
109	89	0	1	1	1	**0111**

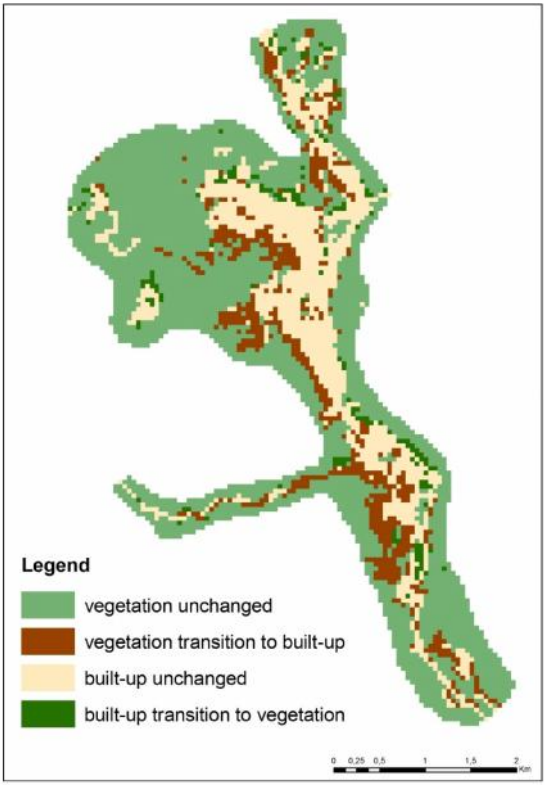


Figure 18. Satellite image integration in landscape analysis. *Land cover changes between 1979 and 2007 in Sinaia, at cell level.*

Conclusions

The main advantage of using satellite imagery in landscape studies is the inovative character. The disadvantage of their use is that image resolution is not sufficient enough to allow a fine analysis of the landscape and to understand some features that require thorough knowledge of remote sensing and GIS software. The analysis must be followed by field research in order to compare the results with the reality.

Knowing the status of the landscape in different stages of its evolution it is possible to create scenarios. Idrisi tools allow creating prognosis based on Markov chain models, the Cellular Automata and combined method, CA_Markov. The existing models vary, depending

on the simulation objective, the spatial scale and the temporal availability of data, the method of classification, the rules of transition of a cell between two points in time, the instruments referred for extrapolating these rules in the future (Santé, 2010).

The modeling of future changes of the landscape elements facilitates is an abstraction or an approximation of the reality, which is achieved by simplifying the complexity of the possible relationships (Yikalo, 2009). References on achieving forecasts were found in the study undertook by López et al. (2001) for the urban fringe of the city Morelia. The purpose to achieve such a future scenario for the evolution of landscape is to observe the trajectories of built-up expansion that determine the most significant changes in land use, often in the detriment of protected natural areas and landscape identity.

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*** *Curs de teledetecție online al UVT* (http://www.uvt.ro/)

4. LANDSCAPE VISUAL ASSESSMENT

ILEANA PĂTRU-STUPARIU, ALINA HUZUI, ANA STĂNESCU

4.1. In situ assessment

4.1.1. The mountain sector – Sinaia town (landscape quality in Bucegi Massive Bucegi Natural Park)

Sinaia town is located in the northern part of Prahova County (45° 21′ 0″ lat. N şi 25° 33′ 5″ long. E), occupying 1,89% of its surface. The territorial characteristics of Sinaia town are expressed through:

- Under a physical aspect, the town is located at the junction between the Eastern Carpathians (Baiului Mountains) and the Southern Carpathians (Bucegi Mountains), which are separated by the discontinuity area, Prahova Valley (figure 19).
- The town developed on both sides of Prahova river, mainly on the terraces located on the Prahova slopes of Bucegi Massive, which is included in Bucegi Natural Park.
- The built-up areas are inserted in a forest matrix, forest being the predominant landscape element (figure 20).
- The city`s expansion on the slopes of Bucegi is limited by a series of natural risk, represented by torrents, erosion, displacement of land which are caused by the geological structure of Sinaia formations from Ceahlău layers (Eastern Carpathians flysch) (P.U.G. Sinaia, 1996).

Figure 19. The mountainous and subcarpathian sectors of Prahova Valley. *Geographic positioning of Sinaia town* (after topographic map 1:50.000)

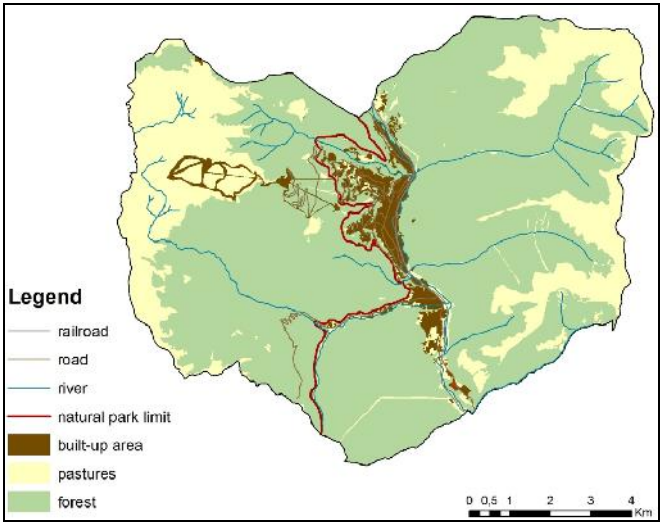


Figure 20. The mountainous and subcarpathian sectors of Prahova Valley. *Land use types* (processed after orthophotoplan, 2008)

Bucegi Nature Park is included in the IUCN category of "terrestrial / marine protected landscape: protected area that is managed mainly for the land and sea landscape conservation and for recreation". Within the park it can be distinguished the reserve "*Abruptul Prahovean*" and the nature reserve "*Colţii lui Barbeş* Mountains" which was enacted by JCM nr. 965/1943 and Law 5/2000 (Management Plan Bucegi Natural Park, 2011).

Bucegi Massif is part of the European ecological network Natura 2000, identified by code ROSCI0013 Bucegi (order no. 1964/2007).

The eastern boundary of the Massif is represented by Prahova River, which is dominated by the edge of Bucegi synclinal, the *Abruptul Prahovean* (Prahova Cliff) with bumps that reach 1000–1500m (Management Plan Bucegi Natural Park, 2011).

The interwinings within the area of sustainable management and the area of sustainable development (figure 21), between the resort and the protected area, determine a maximum landscape use, through the concentration of access roads, cable transport structures, routes and ski slopes and tourist accommodation units.

The proposal to organize the European Youth Olympic Festival, the winter games in 2013, in Bucegi the micro-region, increases the pressure on the sustainable development area (78 ha), by amplifying the number of structures destined to carrying out the tourist activity.

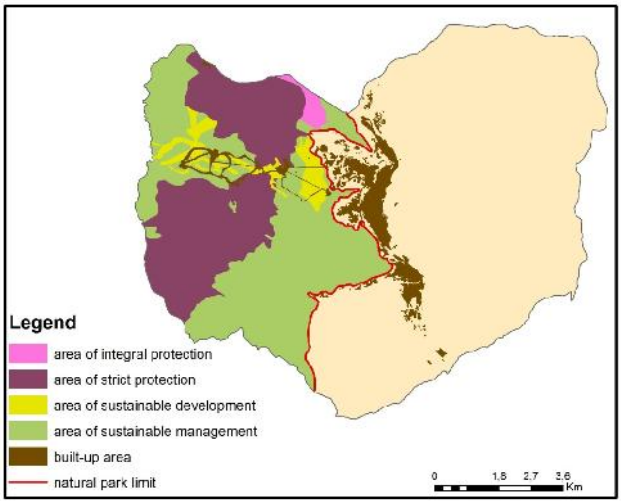


Figure 21. The mountainous and subcarpathian sectors of Prahova Valley. *Bucegi natural Park internal zoning* (after Bucegi Natural Park Management, 2011)

4.1.2. The subcarpathian sector – Cornu locality

Cornu locality (commune) is located in the north-western part of Prahova county, on the left side of the Prahova river in the middle of the subcarpathian area, being adjacent to the Breaza city, the Nistoreşti district in northern part; Câmpina city in the south; Şotrile commune in the east; with Breaza – Podu Vadului in the west; it is located at a distance of 90 km – north of the capital city and 70 km – south of Braşov municipality (figure 22).

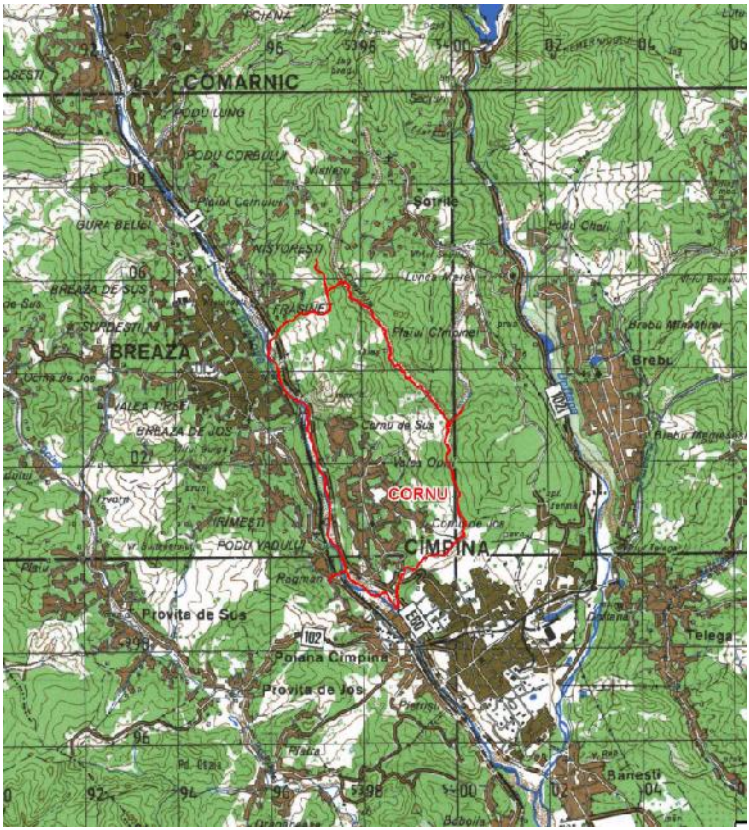


Figure 22. The mountainous and subcarpathian sectors of Prahova Valley. *Geographical positioning of Cornu commune* (after topographic map 1:200.000)

The territorial characteristics of Cornu locality are expressed through:

- The development of the locality on a step shaped like a buttress at the foot of on an abrupt, fragmented, where harsh packets of rocks stand out and which dominate the Prahova Valley with about 300 m;[1]
- Cornu area is known in the geological literature by the *layers of Cornu* representing the upper part of Tarcău formations (figure 23 a) and is characterized by the predominance of pelite and limestone deposits;[2]
- Drainage of salt deposits explains the presence of salt springs, disseminated in the area, which exploitation may be possible[2];
- The territory of the locality overlaps an interfluve situated between the valleys Prahova and Câmpiniţa – Câmpea, which is subject to an intense penetration of the torrents into the catchments (figure 23 b);
- The subcarpathian sector benefits from a climate of high favorability, the differences between the mountains – hills and plains are very attenuated[3];
- The southern exposure emphasizes the degree of sunstroke which maintains an environment with beneficial consequences in the landscape conditions (Teodoreanu et al., 1984);
- The presence of old roads on the Prahova Valley, with many inns, customs points have attracted an intense humanization that circumscribed also the Cornu settlement (figure 24);
- The context of this concentration of households is a consequence of the development and evolution of the industrial centers in Ploieşti and Câmpina and of oil exploitation and processing, as well as a local industry;
- From the city's development strategy are emphasized areas affected by pollution (especially aer pollution along the national road DN1, many areas of potential domestic waste, figure 25).

[1] Velcea V., Velcea (1965) *Valea Prahovei,* Editura Ştiinţifică, Bucureşti, p. 56

[2] Velcea, I., Velcea, V, et al. (2003) *Monografie Geografică, potenţialul balneoclimateric al localităţii Cornu*, Universitatea Creştină „Dimitrie Cantemir", Facultatea de Geografia Turismului, Sibiu

[3] *Fişa climatologică*, document aflat în Arhiva Primăriei Cornu, vol. Studiu pedologic, elaborat de Oficiul Judeţean pentru Studii Pedologice Ploieşti în anul1998, p. 9.

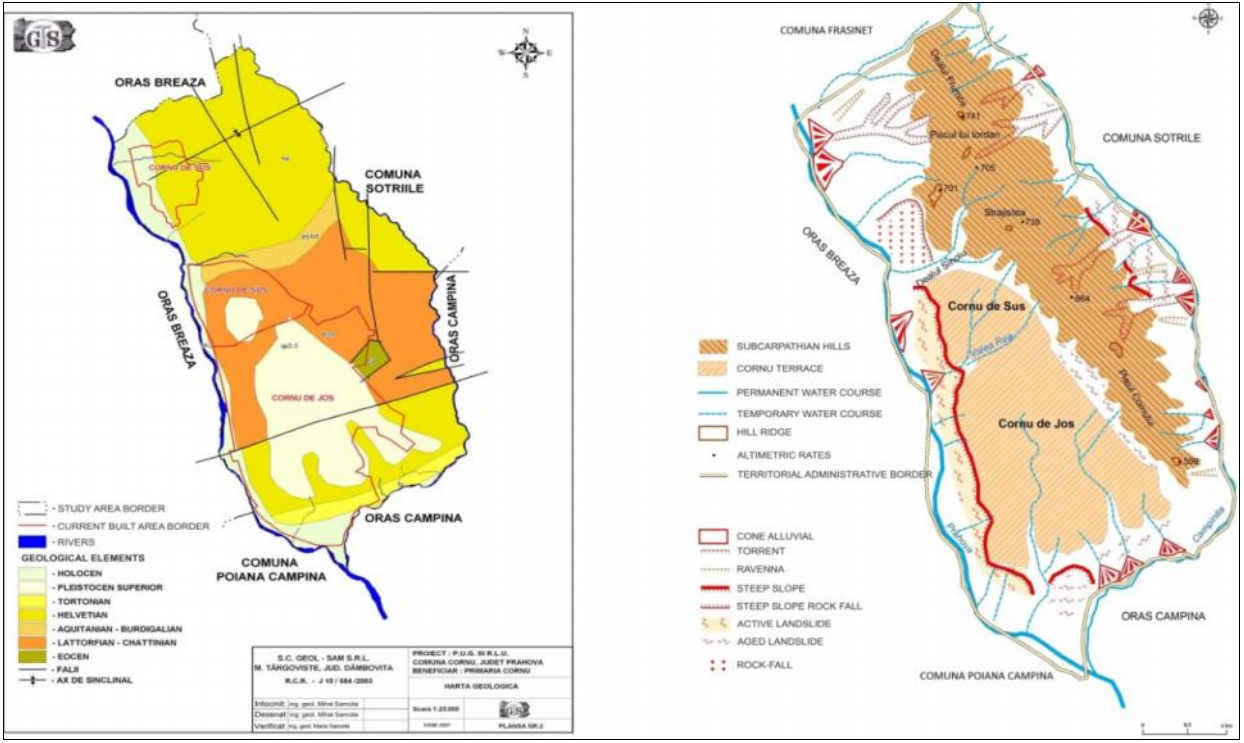


Figure 23. The mountainous and subcarpathian sectors of Prahova Valley. **a** Geology (produced by S.C. GEOL-SAM S.R.L. in the Development Strategy for Cornu locality for the period 2008–2013); **b**. Relief (produced by S.C. GEOL-SAM S.R.L. in the Development Strategy for Cornu locality for the period 2008–2013);

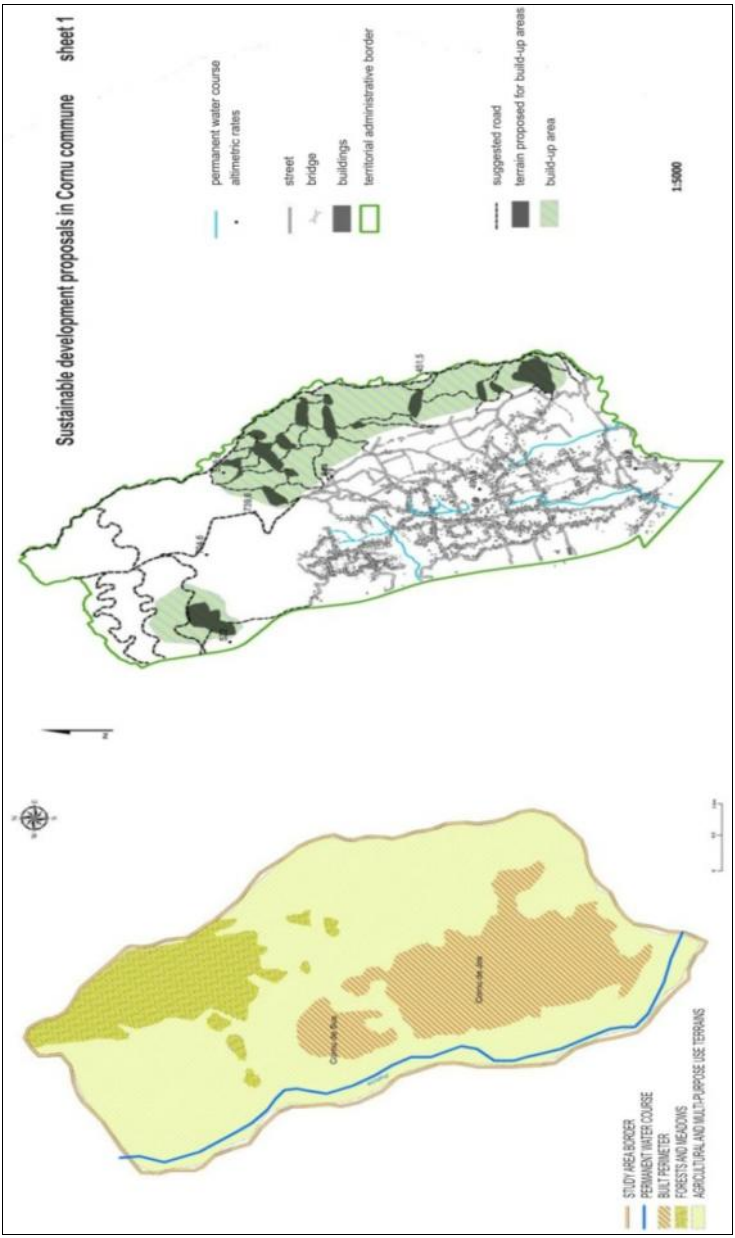


Figure 24. The mountainous and subcarpathian sectors of Prahova Valley. **a** *Land use types* (produced by Ana Stanescu, after CLC 2006); **b**. *Sustainable development proposal* (after the Development Strategy for Cornu locality for the period 2008–2013)

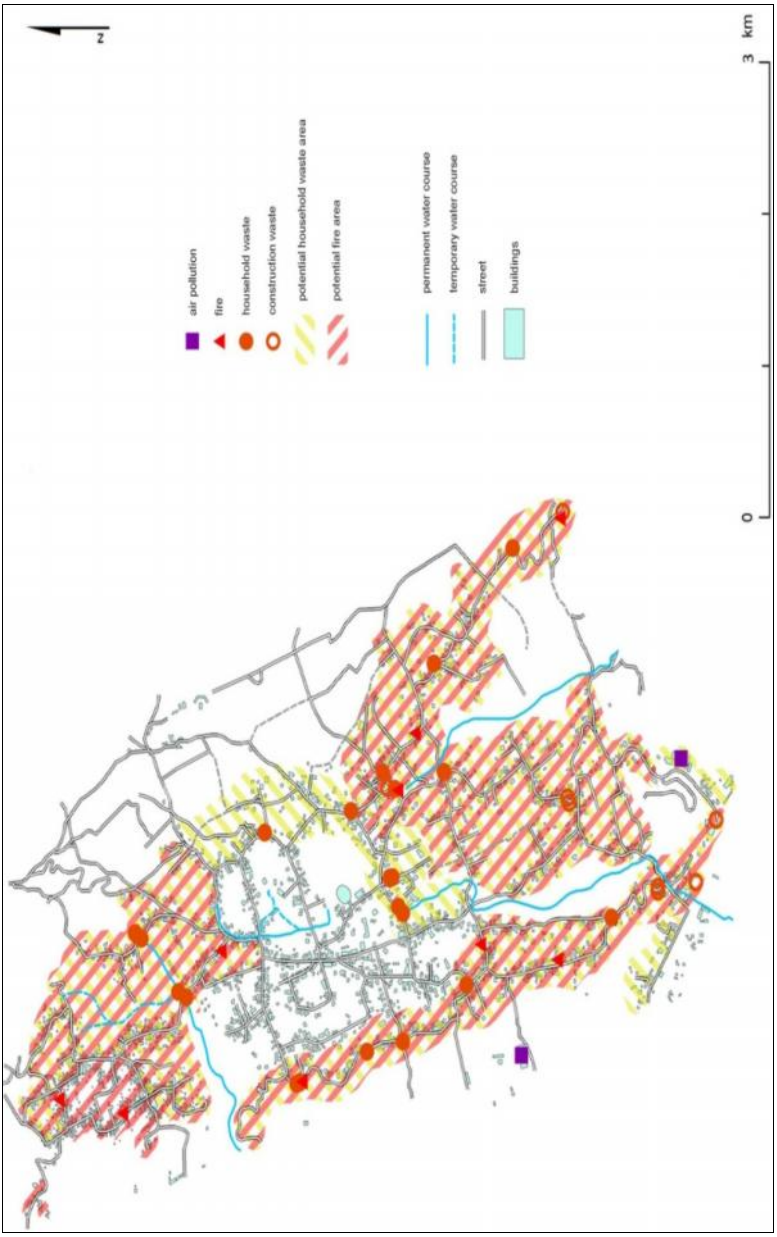


Figure 25. The mountainous and subcarpathian sectors of Prahova Valley. *Pollution sources* (after the Development Strategy for Cornu locality for the period 2008–2013)

4.1.3. The visual landscape assessment

The visual assessment (*in situ*) was an important starting point for achieving both data gathering and algorithm creation for landscape evaluation and for developing the project. Thus, these databases, made on sheets of surveying the landscape type (Pătru-Stupariu, 2011) in numerous field campaigns, have been downloaded in the attribute procedure and quantified and processed with the related software. The principle was the same, to assess and quantify each landscape element as already presented in the standard models (Pătru-Stupariu, 2010, Pătru-Stupariu, 2011). The purpose of the evaluation was a digitization of the landscape elements and their classification according to the information provided by the European Landscape Convention: degraded landscape, everyday landscape (common); good quality landscape; high quality landscape; outstanding landscapes.

A. One of the sites which were evaluated was Breaza-Cornu area. We avoid referring to the administrative boundaries of the municipalities (as assessments were made from panoramic view points: Cornu de Sus monastery, Cornu de Sus cross, Breaza cross, Breaza relay) but we mean the visual perception limit of the landscape from these points. After identifying the points (figure 26) and determining the degree of openness of the landscape (see sheet for surveying the landscape, Pătru-Stupariu 2011) were dotted with GPSMAP (Garmin 76), the reference points for the delimitation of the landscape types were identified in the field. Subsequently, the information obtained from aggregating the scores and the drawn points were spatialised (figure 27).

A first confrontation of the map with the terrain shows that landslides, especially on the forehead by Breaza terrace, are emerging as the type of degraded landscape. The assessment was made in several seasons, so for the period of late autumn, winter without snow, early spring these landslides were very visible, giving in most cases a desolate aspect. During the vegetative season (spring, summer) these are mostly covered and this explains why these areas are often surrounded by areas with remarkable scenery. These ones owe their status especially to the vegetation and our algorithm combined the information obtained from all the seasons – a fair assessment of the landscape must be made on the four seasons (Cañas & Sanchez, 2001).

Landscapes in good quality and high quality are associated to terraces bridges and partially to terraces slopes, and the largest share is associated with everyday landscapes (common) which are generally found towards the limit of the settlements.

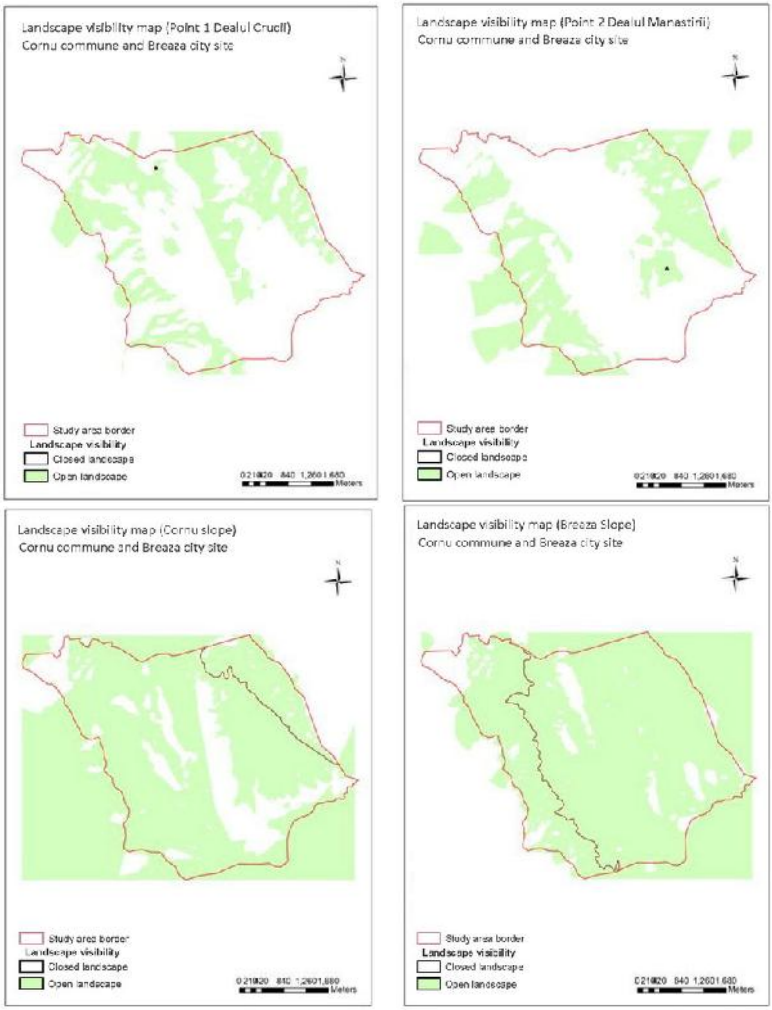
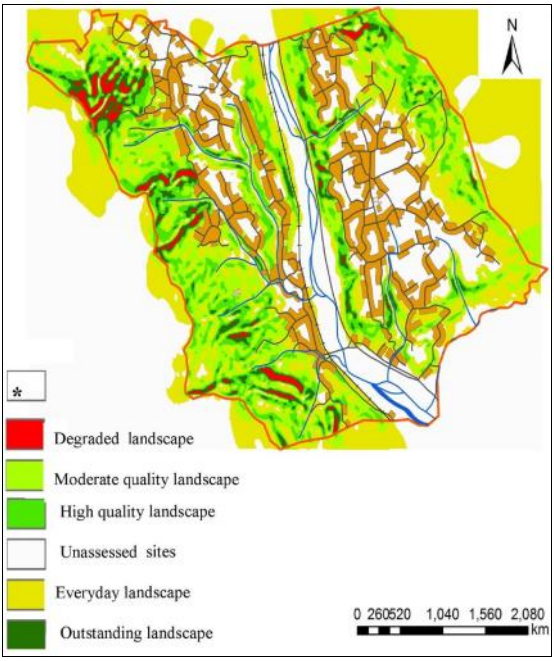


Figure 26. The mountainous and subcarpathian sectors of Prahova Valley. *Panoramic view points`s identification. The visual accessibility of the landscape.*



* *Typology according to the European Landscape Convention*

Figure 27. The mountainous and subcarpathian sectors of Prahova Valley. *In situ evluation (classification after C.E.P.)*

B. For Sinaia site, the comparison between the Bucegi Mountains and Bucegi Natural Park allows the confrontation of two types of landscapes, a heavyly humanized one, represented by the resort, and another one, the protected area. *Landscape assessment points* were established according to high visual accessibility, which is attributed to the tops: Furnica, Vârful cu Dor, Piatra Arsă and Cota 1400 and also Poiana Stânei Regale meadow. Visual assessment of the area affected by the tourism infrastructure has been achieved over the seasons that change the value of the landscape. In the evaluation we took into account the seasonal variation of the landscape visual quality. *Degraded landscape* is shaped on the areas of unmanaged tourist trails and roads, the erosions that expand on Carpului Valley and the northern part of Mount Furnica. It is highlighted during the vegetative season, when the different construction sites for tourist facilities and transport structures are clear. It also outlines the degraded landscape in Soarelui Valley and Dorului

Valley, which is marked by construction sites for a new cable transport system and a reservoir for artificial snow cover of the slopes. In winter, the landscape rises to a common (everyday) value, when these interventions are blurred for the vision. The *high quality landscapes* are associated with Mount Vânturiş. Within this area are found some of the old forest sites identified by ICAS in 2000–2004 and referred to in the Park Management Plan. Abruptul Prahovean (Prahovean Cliff) in the Piatra Arsă area, meets the good quality landscape condition, especially in fall season when from Poiana Stânei Regale panoramic view point, the difference between forest species is highlighted and also the forest inversion of anthropic origin, which is specific to this slope. From Franz Joseph rock and Cota 1400 we observed the interplay between the areas of sustainable management from Bucegi Natural Park and the built-up one, being a landscape that meets the high quality value. For comparison, from the same point it is observed on the slope Baiului the visual fracture in the northern city of Sinaia, between forests and meadows and namely constructions, encompassing the value of a *good quality landscape*.

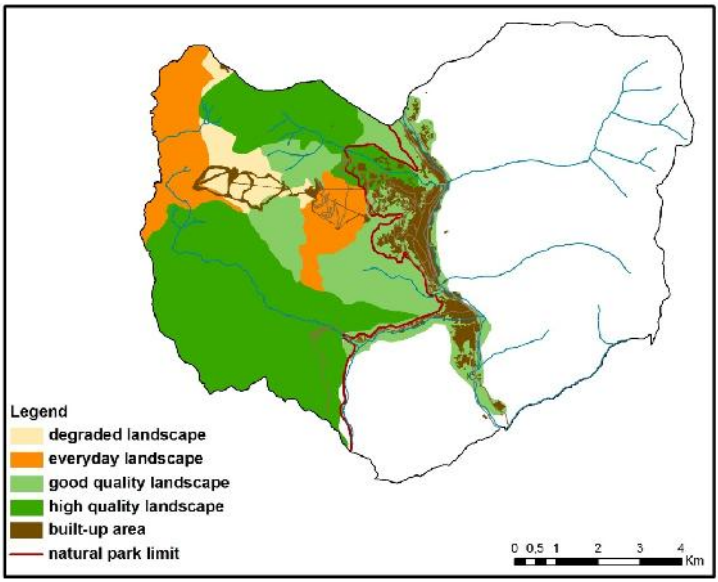


Figure 28. The mountainous and subcarpathian sectors of Prahova Valley. *In situ assessment of Sinaia town (classification after C.E.P.)*

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*** (2011) *Planul de Management al Parcului Natural Bucegi*, aprobat prin H.G. nr. 187 din 23 februarie 2011

*** Legea Nr. 5 din 6 martie 2000 privind aprobarea Planului de amenajare a teritoriului național – Secțiunea a III-a – zone protejate

*** Ordinul ministrului mediului şi dezvoltării durabile nr. 1964/2007 privind instituirea regimului de arie naturală protejată a siturilor de importanță comunitară, ca parte integrantă a rețelei ecologice europene Natura 2000 în România

Official site of Cornu commune: www.primariacornu.ro

Iulia-Elena Călin

4.2. Landscape and photography

Through photo it is understood any scene that is encompassing some of the natural landscape, humanized or anthropic landscape, in which its composing elements are distributed on several levels, therefore, in the landscape photography, depth plays an important role (*Săndulache, 2009*).

The term *photography* has a triple meaning in the everyday speech:
– It is a technique that can create images under the action of *light*;
– It is an image obtained by this *technique*;
– It is a branch of *graphic art* that uses this technique[4]

It derives from two Greek words: *fotos* which translates as *light* and *graphy* which translates as *drawing, written*. Literally, the word *photo* can be translated by *painting with light*.

Light then plays, according to the etymology of photography, an important role in the conception and actual creation of photos, but also for viewing images captured by cameras and the subsequent degradation of photos which were printed on different media (film, slide, photo paper (Săndulache, 2009).

Ansel Adams, the greatest landscape photographer of the XXth century, known as "the genius of photography", but also a great lover of nature, said that *photograph represents a powerful means of expression and communication, offering an infinite variety of perceptions, interpretations and ways of execution*.[5]

As a tool in the evaluation of landscape, photography is an important resource in our opinion. Photographic database are a testament to the changing landscape.

We can mention some of the geographers scientists who used photography in the landscape analysis: Harper (1934), Gruell (1983), Rogers et al. (1984), Kullman (1987), Webb (1996), Klasner & Fagre (2002), Munroe (2003, 2007). In Romania, we considered important 2 papers created by Cristea and Iarovici (1980) and Săndulache (2009).

In order to take photographs of high quality it is required a professional equipment and basic knowledge in geography. "*Not the photo camera makes the photography, but the eye of the artist"* (Radu, 2008), we could say that the landscape planner or the geographer are the ones who make it.

Of particular concern is the *contextualization* of landscape perception which is very different in the field using the photography technique (panoramic photography and the related software which was used), showing very clearly that we can capture a landscape and all the information we need for the analysis and we can especially turn it into a

[4] Wikipedia (2011)
[5] www.foto-magazin.ro

more objective real image or how we can make a landscape to become a great illustration.

Panoramic photograph was used in our project for the *in situ* landscape analysis.

Making panoramas is one of the methods of monitoring certain landscapes, through capturing of such images with a larger time interval or for the landscape inventory in the office.

The proper use of the equipment and the respect to simple rules are often the way to transform regular photos to be materials as precious as the references.

With the help of a correctly exposed photo and proper software for panorama, any geo-photographer can obtain remarkable images (Foto-Video, 2011) that he can use in various projects, landscape analysis, etc.

In addition to vector or digital databases, *photo databases* (raster databases) which are periodically updated made valuable sources of information on the state of the landscape over time and regarding the changes in landscape. A relational database provides a huge benefit, allowing the user (the researcher) to have a more objective perspective upon all aspects of the landscape (Călin, 2010).

What are the panoramas? Panoramic photos are obtained from several superposed digital images (minimum 30%) in any of the 8 directions: N, NE, E, SE, S, SV, V and NV.

How are panoramas created? Besides the camera, a tripod is recommended to be used in a perfectly horizontal position and also the use of a GPS to record the geographical coordinates of the points where the photo was taken. It is important that the point should be noted also on a cartographic support, with the direction in which photos were taken.

After downloading the images from the camera (figure 29), they must be imported into one of the dedicated software in order to obtain panoramas. Some of the software which is able to make panorama are: Panorama Factory, PtGui and PixMaker. Panoramas can also be obtained with software of integrated applications (called *stitch assists*), in the newer digital cameras.

In our study we used PtGui application (version 9.0) because it is easy to use and has very good results. We chose the automatic soldering method, therefore making the panorama is automatically (figure 30),

including cutting the final image (optional). It can cover a viewing angle of 360° or less, depending on how many photos were taken on the ground.

Figure 29. The 4 photos that will create a platform

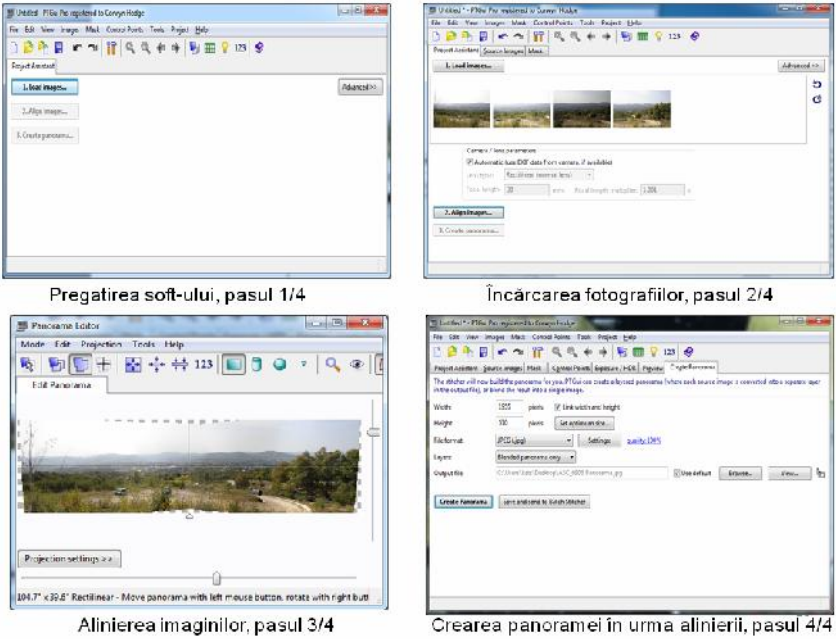

Figure 30. The steps required to create a panorama

Interpretation of panoramic images in landscape studies can be done in several ways, depending on the landscape elements that we want to highlight (figure 31).

Figure 32 represents a panoramic photo taken from Franz Joseph rocks in Sinaia and gives us a good overview of a portion of the mountainous sector of Prahova Valley. On this picture we marked the

important elements that stand out in relief and we marked the urban landscape which is visible from that panoramic view point.

Figure 31. The final result – panorama from Cornu Monastery

Figure 32. Panoramic image taken from Franz Joseph rock

Landscape limits define the depth of the vision field. Perception of the landscape or the objects diminishes along with the distance, thus we distinguished several levels:

– Close-up, in a radius of 50 m, which represents the detail area (in our case, vegetation);

– Medium plane, which is the area of forms and mass reports; no details are perceived;

– Distant plane, at distances over 1 km, where we perceive only volumes; over 2–3 km we can only perceive large ensembles (topographic, vegetation, urban).

Images 33 and 34 are panoramic images taken from other panoramic view points on the Prahova Valley, Breaza cross and respectively Clăbucet. In these two cases vegetation restricted the total visibility towards the valley, requiring higher points from which to take the picture (e.g. the pedestal of Breaza cross and the cable transport in

Clăbucet). To achieve panoramic images of higher quality it is needed to benefit from open landscapes and higher panoramic view points without natural or man-made elements that limit the visibility of the landscape that is intended to be analyzed.

Figure 33. Panoramic image taken from the view point at Breaza cross

Figure 34. Panoramic image taken from the view point at Clăbucet – Predeal

Also, for landscape change analysis at an interval of time, photographs were made in pairs, which are used by many researchers to assess changes since the '30s. For example we made two images (figure 35) from the same panoramic view point (Comarnic), exactly the first image, taken in May 2009 and a second image which was taken in September 2011. It is easily noted by visual analysis the differences in the vegetation (quantity phenophase) and the built-up areas. In the recent years the visual analysis passed to a more complex and accurate analysis by using software that quantifies various landscape elements (Roush et al, 2007).

We want to mention that the most important elements that a photographer must take into account in landscape photography are: *color* (bright colors, especially red adds value to a photo), *clouds* (those with special shapes, especially at sunset and sunrise), *tranquility, weather, geographical location from which the shot is taken* (north or south of the landscape that we want to photograph, to benefit from lateral light which emphasizes the relief and the textures, shapes and

shadows), *the first plane* (the best landscapes are usually those who have a strong foreground). Such detail can give an illusion of three-dimensional, very important for the image impact).

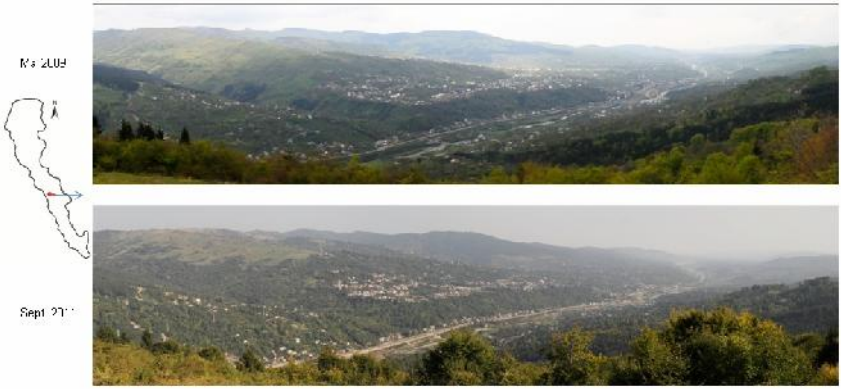

Figure 35. Panoramic image taken from the view point at Comarnic

Little Planet is a modern photographic composition, represented through a stereographical projection. This is an innovative approach to landscape photography because it highlights the uniformity of its components.

By this technique, the best results are obtained especially in the urban landscape, in markets, in areas with generous and open spaces between buildings.

The working steps for achieving this projection are:

– Achieving spherical panoramas with pictures taken on the field that are covering an angle of 360 degrees, according to the method described above;

– Introduction the panorama in Photoshop, where it is rotate by 180 degrees, followed by vertical scaling and distortion so as to make it square;

– Using a distortion filter called *polar coordinates* with the *rectangular to polar* option and correcting the areas without information.

For exemplification we created a *little planet* at Cornu Monastery, presented in figure 36.

Positioning the photos on a cartographic support. The process is called "geotagging" and is actually registering the geographical locations (tags) in the details of digital photographs, helping to ease the placement of these images on a digital cartographic support.

Some digital cameras have the potential to record GPS coordinates of the location where a photo was taken with a GPS device attached. Using such a device, the GPS coordinates of the points from which pictures were taken are stored in the "Exif" of an image.

Figure 36. Little planet – Mânăstirea Cornu

Uploading images and their location on a map can be done manually or automatically. Autoloading can be achieved by directly uploading on sites that support Exif's import (e.g. Flickr, Google Earth, Panoramio) or indirectly upload from different imaging or reading metadata software (Adobe LightRoom, OPanda). There are tools for offline handling data which manually load coordinates, for example ArcGIS or ArcView.

Using the online method has several advantages such as the availability of images for anyone, anytime and anywhere, provided there is an Internet connection. We propose creating an online database with photos that illustrate a landscape issue, a database that could serve to monitor a given territory.

For our project we chose to upload photos to Flickr (figure 37). For each point on the map there is the attached photo, so it provides a very real and clear image on that landscape.

There is a concentration of landscapes with problems in the places close to roads and towns. They are generally represented by waste storage or constructions, illegal forest exploitation, the presence of buildings that are in a state of decay, etc.. We offer for example the chaotic waste storage represented in figure 38.

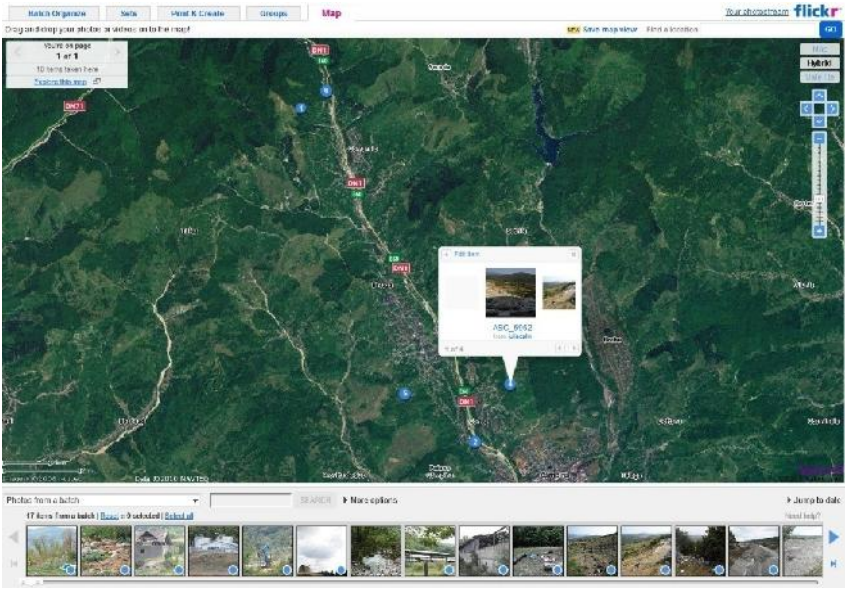

Figure 37. Photo uploading in Flickr

Figure 38. Waste deposits in the forest (Sinaia), in the proximity of the "royal trail"

In making this map is intended to draw awareness and involvement from local authorities to tackle these problems created by human activity.

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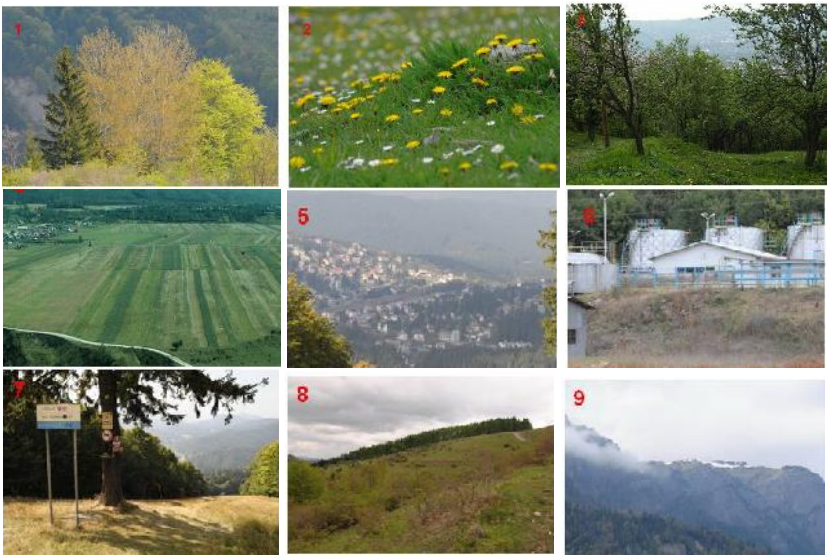
*** www.wikipedia.com (accesed in Iunie 2011)

*** www.foto-magazin.ro (accesed in August 2011)

Annex 1

Landscape functionality (photos taken by Iulia Călin)



Montainous and subcarpathian sectors of Prahova Valley 1. Natural landscape (Forest); 2. Agricultural landscape (Pastures/ Meadows); 3. Agricultural landscape (Orchards); 4. Agricultural landscape (Arable land) Valley; 5. Anthropized landscape (built-up area); 6. Anthropized landscape (industrial area); 7. Anthropized landscape (Leisure/ sports); 8. Transition landscape (Forest/ pastures); 9 Transition landscape (Forest/ rock)

Annex 2

Databases

Cartographic resources:

Historical maps: earth.unibuc.ro, site: Eolvos Lorand University

Topographic maps, orthophotoplans: purchased from contract no. 11767) purchased from project 1013/2009 PCE, CNCSIS National Fond Geodesic /ANCPI)

Corine: Corine Land cover – EEA: http://www.eea.europa.ea

Software:

Microsoft Office Professional 2007 (license X14-01711 Microsoft; purchased from contract type A CNCSIS „*Metode şi mijloace de prioritizare a peisajelor dintre Prahova şi Râmnicul Sărat, în vederea gestionarii lor durabile, 2006–2008*

Geoconcept (licence no. 1w7hi8x) purchased from the international Proiect *„Apports de la teledetection pour l`etude des georisques en Roumanie"*, financed by AUF 2003–2005

Logicarte (license no. NT4 (C) AgiSoft, purchased from International Project *„Apports de la teledetection pour l`etude des georisques en Roumanie"*, financed by AUF 2003–2005

ALEPP – developed with the project *„Elaborarea şi implementarea unui algoritm de evaluare şi prognoza peisagistică. Aplicații la sectorul montan şi subcarpatic al Văii Prahova"*, CNCSIS, 1013/2009 PCE.

Fragstats *(FRAGmentation STATistics (free access)*

Arc GIS 10, license (contract no. 11767) purchased from project 1013/2009 PCE, CNCSIS

The topographic maps were processed and produced through scanning, georeferencing and processing: Roxana Cuculici, Alina Huzui, Magda Năpăruş

The orthophotoplans *(0,5m resolution, 2006):* Roxana Cuculici, Alina Huzui, Magda Năpăruş

Satellite images: Alina Huzui, Iulia Călin

Projection system:
The maps were reprojected in UTM Stereo 70/ Dealul Piscului
CORINE: Reference system ETRS 1989

1. Figure 1–6: processing, Roxana Cuculici/analysis, Răzvan Oprea
2. Figure 7: processing and analysis, Ileana Stupariu
3. Figure 8–10: processing, Roxana Cuculici/analysis, Ileana Stupariu
4. Figure 11–19: processing and analysis Alina Huzui, Iulia Calin
5. Figure 20–22: processing and analysis Alina Huzui
6. Figure 23–26: processing, Ana Stănescu
7. Figure 27–28: processing and analysis Ileana Stupariu
8. Figure 29: processing and analysis Alina Huzui
9. Figure 30–39: processing and analysis, Iulia Călin
10. Annex 1: photos, Iulia Călin