Remote sensing methods for study of open systems (case study of South-East Georgia landscapes)

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Дистанционные методы исследования открытых систем (на примере ландшафтов Юго-Восточной Грузии)

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Открытые системы – это системы, развитие и устойчивость которых зависит не только от внутренних связей и запасов энергии и информации, но и от внешних факторов (баланса энергии, вещества и информации) К числу наиболее четко выраженных природных систем подобного типа относятся разнообразные ландшафты земной поверх-ности. В свою очередь каждый конкретный ландшафт представлен двумя разновид-ностями взаимопро-никающих систем – компонентными (рельеф и литоло-гический фундамент, почвы, приземный слой атмосферы, растительный пок-ров, водные объекты и т.д.) и вложенными. Последние представляют собой более мелкие под-системы микро-ланд-шафтов имеющие только им присущий набор внутренних связей и уровней устой-чивости. При исследовании этих систем мы одновременно имеем дело с определенным эколо-гическим пространством, т.е. с условно выделяемой региональной территорией, которая характеризуется уровнем экологической нестабильности, который и отличает ее от сопредельных территорий. В основе этого лежат процессы бифуркации или преоб-разования конкретной открытой системы в качественно новое состояние под воздей-ствием накопившихся в этой системе новых связей. Подобные изменения имеют место при воздействии внешнего фактора, в данном случае – антропогенной деятельности, при-вед-шей к потере ландшафтом прежнего уровня устойчивости. Таким образом, экологическое состояние конкретных ландшафтов, есть не что иное, как состояние внутренней упорядоченности и согласованности их составных частей между собой. Чем выше нестабильность между элементами системы, тем выше уровень экологической напряженности. Существует простой способ выявления состояния ландшафтов. Он заключается в выявлении характера изменения площадей конкретных ландшафтов за определенное время. Для этой цели служит анализ материалов дистанционных съемок проведенных в разные годы на одну и ту же территорию. На первом этапе проводилось ландшафтное дешифрирование всех материалов, на все годы съемки. На аэро- и космофотоснимках выделялись все разновидности ландшафтов с определением степени их антропогенной трансформации. В пределах каждого участка условно выделялись три градации ландшафтных комплексов: 1) природные, 2) природно-антропогенные и 3) антропогенные. Сравнение площадей этих групп на снимках различных годов съемки позволяет оценить скорость трансформации ланд-шафтов и уровень их экологической напряженности.

Open systems are the systems, development and stability, which depends not only on internal relationships, information and energy reserves, but on external factors (balance of energy, materials

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and information) as well (Dictionary…). To the number of the most clearly formed natural macro-systems of this sort varied landscapes of the earth surface can be attributed. In its turn each concrete landscape is presented by two varieties of interpenetrating systems - component (relief and lithological foundation, soil, surface layer of atmosphere with corresponding microclimatic parameters, vegetative cover, water objects, etc) and embedded. The latter present themselves smaller subsystems of microlandscapes with internal relationships and stability levels characteristic only of them.

Studying these systems we simultaneously deal with definite ecological space, i.e. with conditionally selected regional territory characterized by the ecological instability level that distinguishes it from adjacent territories. In the base of these lie processes of bifurcation or transformation of concrete open system (landscape) into qualitative new condition under the influence of accumulated new relationships in this system between its separate components (ground, biocoenosis, water, etc). Similar changes exist under the influence of external factor, in this case -anthropogenic activity, which led to the loss of former stability level by the system.

Thereby ecological condition of concrete landscapes as open systems is nothing else than condition of internal ordering and coordination of their component parts between themselves. The higher is instability between system elements, the higher is ecological tension level.

In the opinion of A.V. Skripchinsky, "… study of interlandscape morphological units' stability allows to value stability of not only structured parts but the landscape itself as a whole. The value of biomass is one of the main criteria for the determination of stability of natural systems and the larger it is the higher is stability of the system" (Skripchinsky). However, here raises a question: how stable is internal condition of system' s biomass, its qualitative stability. In case of pollution of the system by chemical materials this value can remain unchangeable or even increase a little, but qualitative level of relationships in the component node of subsystem will inevitably change. Thus, conclusions on stability and ecological condition of concrete landscapes should be done on the basis of change not only quantitative, but qualitative condition of these systems as well.

Analysis of dispersion streams /flows/ and transport of chemical materials inside the concrete landscapes of south-east Georgia carried out by us can be taken as an example.

On the basis of analysis of big amount of geochemical tests' data, taken in the region of Lokhi massif by specialists of the Department of Geology of Georgia, were revealed certain areas, formed by powerful geochemical anomalies connected with ring structures (RS) of magmatic origin. Within these areas, three types of geopathogenic areas stand out: leaden geochemical anomalies (Pb), copper - Cu and complex - (Pb+Cu) (Bondyrev, 2001). Existing present day data (Prokhorov *et. al*., 1998), prove that above noted metals are strong facilitators of geopathogenic effect.

It is seen from Fig.1 that such areas are timed to nodes of intersection of hetero-oriented lines of dislocations with a break in continuity and circumferences (RS), at watershed areas and higher part of the slope. This witnesses that mentioned anomalies were open as a result of their moving out to the day surface under the total influence of neotectonic, exodynamic processes and anthropogenic factor.

Analysis of the relief nature (angles of shear and their orientation) has allowed determining direction of pathogenic material ablation (material and energy). In Fig. 1 Sakire and Kamisho settlements hypsometrically are situated higher of discomfort zones, whereas Gora and Guguti settlements lie aside from the course of ablation (Bondyrev, 2001).

The sites of increased ionization, which form the third type of geopathogenic zones of the region are situated 5-8 km in straight, and along the course of run-off 12-18 km from the nearest populated areas. (Patara Dmanisi and Poladauri settlements).

However, such approach takes a lot of time and expenses on sampling and significant volume of laboratory work. Herewith, it should be mentioned that on the first stage of such tests only really existing flows of material and energies are defined, rather than their track record. For revealing the changes in the nature of available relationships it is necessary repeated studies of the whole area under study, with the test selection of the network.

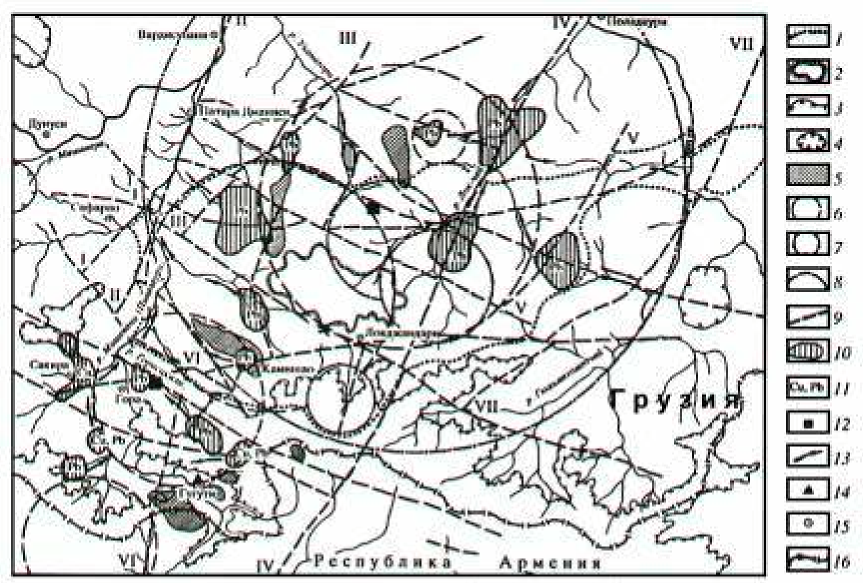

Fig.1. Geoecological Particularities of Lokhi massif (Mashavera r. basin, Georgia) [3]
Рис. 1. Геоэкологические особенности Локского массива (бассейн р.Машавера, Грузия)
1 - border of Lokhi crystalline massif 2 - dome part of Lokhi massif, situated above 1500m, 3 - mountain structures of volcanogenic Somkhiti ridge, rising above 1500m, 4 - foots of separate volcanic cones, 5 - leveled surfaces, 6 - ring structures, presenting magmatic cameras of volcanic devices reflected on surfaces, 7 - stock intrusives, 8 - reflected on surfaces mantle diapirs, 9 - rapture lines (I-VII), 10 - geopathogenic areas, 11 -geochemical anomalies, 12 - areas with increased ionizing level, 13 - direction of ablation, 14 - place of selection of water tests , 15 - inhabited areas, 16 - state border

There exists more simple way of analysis landscape structure. It consists in revealing nature of changing concrete landscapes ' areas for a certain time. Analysis of remote sensing material, carried out in different years at one and the same territory is used for this purpose. Conducted by us experience of similar studies was founded on the following strategy.

On the first stage deciphering of all landscape material was carried out for all years of survey. In aerial- and space photographs (Fig. 2 and 3) landscapes of all variety stood out with determination of degrees of their transformation under anthropogenic impact. Within each area three gradations of landscape complexes stood out conditionally: 1) Natural, 2) Natural-anthropogenic and 3) Anthropogenic. Comparison of areas each of these groups depicted in the photos taken in different years allows to estimate velocity of transformation of landscapes and level of their ecological tension.

The Mashavera River basin is situated in the area of transition from south-east slope of the Minor Caucasus to the lowlands of Kvemo Kartli, at the height 490-700m to 3000m above s.l. In the area of confluence the Khrami and Mashavera rivers was revealed intensive degradation of natural landscapes which area 8,4 km^2 has shortened to 4,68 km^2, during 20 years, i.e. velocity of transformation natural ecosystems formed 0,186km^2/year.

The aim of the research was to give on the grounds of the analysis of remote sensing material a complex analysis of spatial- temporal dynamics of natural-territorial and anthropogenic complexes of the Mashavera river basin.

Fig 2. Satellite image of the territory under study (NASA, 2001).
Рис. 2. Космичесский снимок на исследуемую территорию (NASA, 2001)

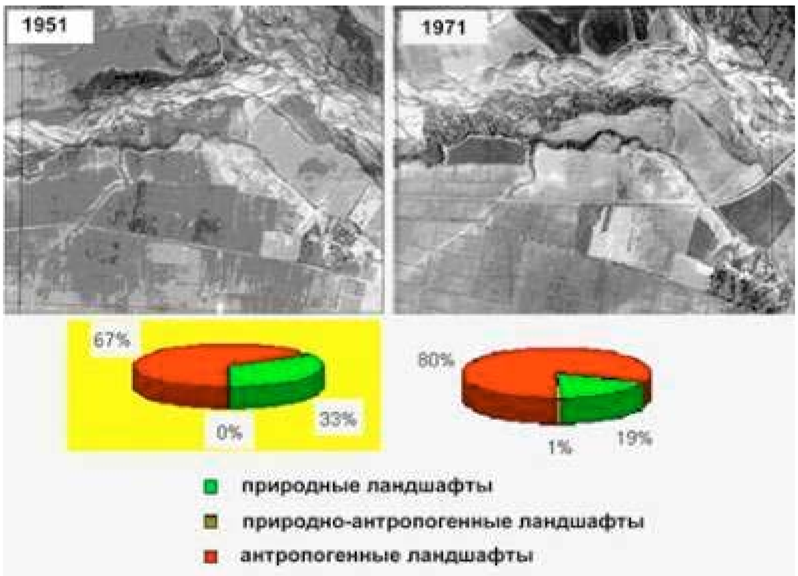

Fig. 3. Track record of Khrami-Mashavera landscapes anthropogenic transformation
Рис. 3. Динамика антропогенной трансформации ландшафтов
Храми-Машаверского участка

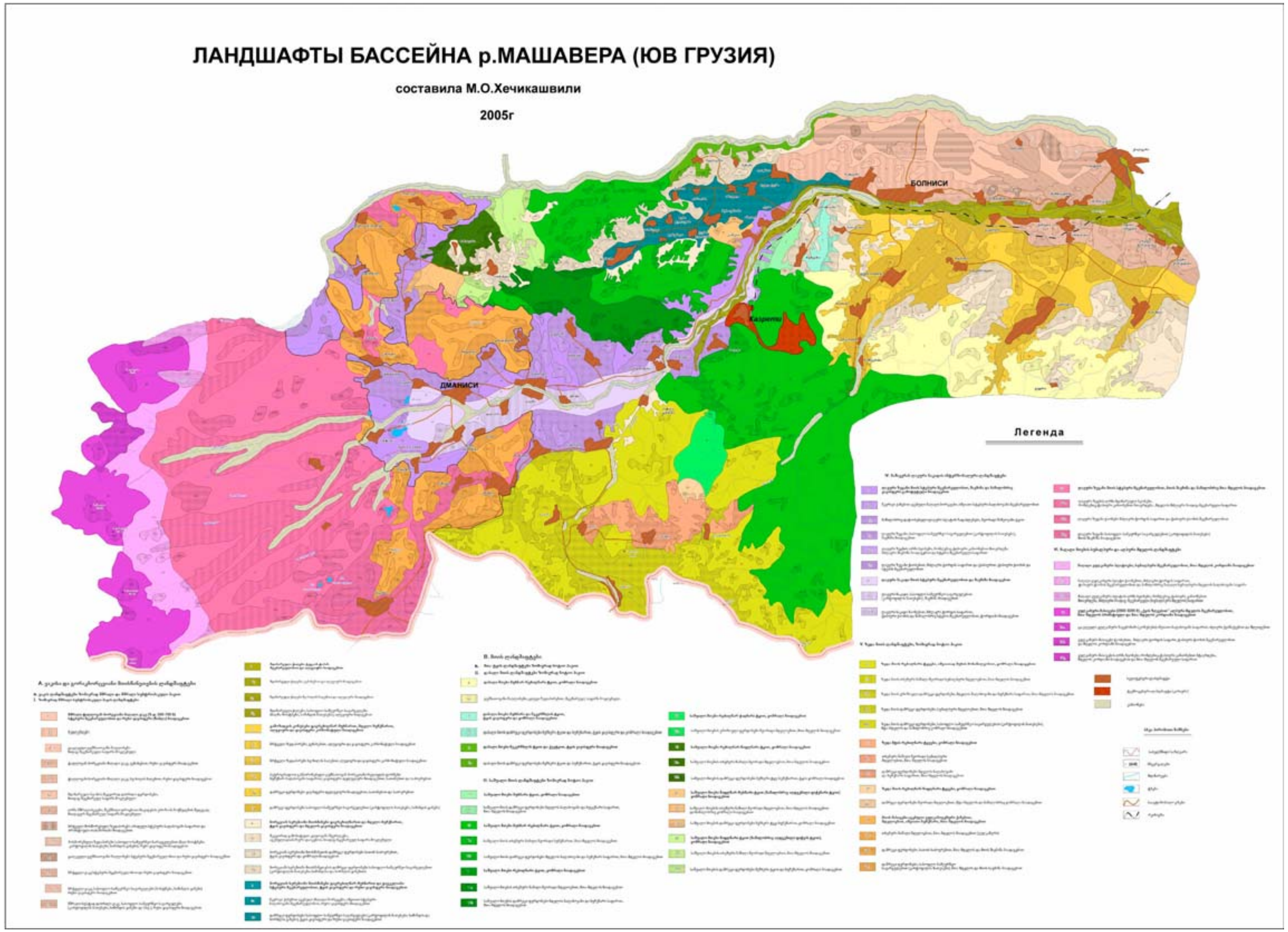

Fig. 4. Landscapes of the Mashavera River basin (see legend at the next page).

Fig. 4. (Legend)

A. LANDSCAPES OF PLAINS

a. Landscapes of plains with moderate dry and dry subtropical climate

1) High horseback hilly plain (500-700 m above s.l.) with vegetation of dry steppes in grey-brown soils (12 different type of micro-landscapes). The mentioned landscape covers 105.54 km^2 within the territory under study.
2) Fluvial plains with tugai vegetation in alluvial soils (3 micro-landscapes) - 31.04 km^2
3) Debris cone (alluvial fans) of creeks and temporary channels with carpinus-quercus forests, spine-bushy and meadow-bushy vegetation in alluvial and brown carbonate soils. (5 micro-landscapes) - 94.88 km^2
4) Hilly- pectinal type foothills with carpinus- quercus forests with spine- bushy underbrush and meadow-bushy vegetation in chestnut forest and brown meadow soils (3 micro-landscapes- 95.06 km^2.
5) Hilly- pectinal foothills with rear carpinus-quercus groves and spine bushy steppe vegetation in chestnut forest and grey - brown soils (2 micro-landscapes) -23.95 km^2.

B. MOUNTAIN LANDSCAPES

b. Mountain-Forest Landscapes with Moderate Humid Climate

II. Low-mountain landscapes

6) Low-mountain relief with quercus- carpinus forests in brown wood soils (1 micro landscape) - 63.63 km^2.
7) Low-mountain relief with quercus and maple forests in chestnut wood soils and brown wood soils.(1 micro-landscape) - 4.61 km^2
8) Low-mountain relief with maple groves and thick underbrush in chestnut wood soils (1 micro-landscape) - 5.69 km^2.

III. Highland Landscapes

9) Middle-mountain relief with quercus forests in the brown wood soils (1 micro-landscape) - 3.83 km^2.
10) Middle-mountain relief with quercus carpinus forests in the brown wood soils (2 micro-landscapes)- 197.35 km^2.
11) Middle-mountain relief with carpinus forests in brown wood soils (2 micro-landscapes) - 28.55 km^2.
12) Middle-mountain relief with carpinus- plane vegetation in brown wood soils (1 micro-landscape) - 10.26 km^2.
13) Middle mountain relief with carpinus- fagus forests in brown wood soils (2 micro-landscapes) - 8.49 km^2.

14) Middle-mountain relief with fagus-quercus forests, partially regenerated and replaced by pine tree plantings in brown wood spoils. (2 micro-landscapes) - 8.30 km^2.
15) Middle-mountain relief with fagus forests, partially regenerated and replaced by pine tree plantings in brown wood soils. (2 micro-landscapes) - 12.53 km^2.
16) Middle mountain relief with carpinus forests, rarely with carpinus quercus forests in brown wood soils (4 micro-landscapes -152.12 km^2.
17) Middle mountain relief with thick carpinus forests in brown wood soils (2 micro landscapes) - 19.59 km^2.

18) Middle-mountain relief with carpinus fagus forests in brown wood soils (1 micro landscape)- 1.94 km^2.

IV. Intrazonal Landscapes

19) Lava plateau with mountain -steppe vegetation in chernozem and partially leached brown soils (5 micro landscapes) - 102.71 km^2.
20) Lava streams with mountain-steppe vegetation in chernozem soils (2 micro landscapes) - 30.52 km^2.
V. High Mountain Landscapes
21) High mountain massifs composed of volcanogenic rocks with sub-alpine vegetation, rare bushes in mountain-meadow soils (3 micro landscapes) - 96.86 km^2.
22) Lava plateau with steppe vegetation in mountain chernozem and partially mountain meadow soils (3 micro landscapes) - 246.46 km^2.
23) High lava plateau with sub-alpine meadows in mountain-meadow and dern-peaty soils (2 micro landscapes) - 39.86 km^2
24) Volcanic massifs (2500-3050m above s.l.) with classical type stone placers of great extension and chingils, sub-alpine meadows in simple, pebble and mountain-meadow soils (3 micro landscapes) - 71.66 km^2.

The following concrete problems have been decided:

1. Analysis of different scale air-views of different years for the reason of evaluation natural-territorial complexes both in temporal and spatial borders;

2. Analysis of the most up to date cosmic surveys of the territory under investigation for the reason of specifying the general picture of landscape location and their present day borders.

3. Field check within master areas and route intersections of the most complex objects for the reason of checking the results of deciphering and adjustment of borders of separate landscape units;

Creation, on the basis of analysis of collected materials the author's variant of landscape map of the territory under investigation and inputting it into computer using GIS-technologies;

Making a final variant of landscape map of under investigation territory and revision of quantitative values of velocity of anthropogenic transformation of concrete landscapes. On the basis of using the aerial photography with cosmic information and fieldwork complex it was determined the nature of spatial differentiation of landscapes of the Mashavera river basin and constructed 1:50 000 scale map.

On the basis of using modern GIS-technologies were counted areas of all chosen landscape units.

Table 1. Levels of anthropogenic tension on master areas of Mashavera river. (Per 1948-2004 data)

Area Number	Name of area	Location	Period (year)	Velocity of transformation of landscapes (km^2/ year)	Level of anthropogenic tension	
12	**Javakheti**	Vicinities of Gulabia and Davakran mountains	11	0,01	0,01-0,10	I
9	**Karadagi**	Vicinities of Karadag mountain	8	0,11	0,10-0,12	
10	**Pantiani**	Vicinities of Pantiani and Orozmani settlements	8	0,12	0,10-0,12	
3	**Balakhauri**	Vicinities of Balakhauri settlement	20	0,13	0,12-0,13	II
11	**Karabulakhi**	Territory situated between Zemo – and Kvemo Karabulakhi settlements	22	0,13	0,12-0,13	
4	**Ratevani**	Vicinities of Ratevani settlement	5	0,16	0,14-0,17	
1	**Khidiskuri**	Area of confluence Khrami and Mashavera rivers	20	0,17-0,19	0,17-0,19	
8	**Irganchay**	Vicinities of Irganchai sttlement	8	0,21	0,20-0,22	III
7	**Sakire**	Area of confluence Sakire and Gora rivers	8	0,23	0,20-0,22	
2	**Nakhiduri**	Vicinities of Nakhiduri settlement	20	0,27	0,23-0,25	IV
5	**Patara Dmanisi**	Area of confluence Mashavera and Pinezauri rivers	12	0,41 - 0,62	0,26-0,35	
6	**Kazreti**	Vicinities of Madneuli combine	25	0,5 – 0,94	0,35-0,60	V

On 12 master areas were determined parameters of development separate landscapes and tendency of their change under the influence of human activity. It is determined that velocity of anthropogenic transformations varies from 0,01km2/year to 0,6 km^2/year.

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