Information & Security: An International Journal

Azimov, Bunina & Dorofey, v. 40: 1, 2018, 29-37 https://doi.org/10.11610/isij.4002

USING REMOTE SENSING METHODS TO REFINE THE LANDSCAPE-MORPHOLOGICAL REGIONALIZATION FOR THE TERRITORY DUE TO THE SECONDARY POLLUTANT REDISTRIBUTION ACROSS SOIL COVER

Oleksandr T. AZIMOV, Anastasiia BUNINA,
and Yelyzaveta DOROFEY

Abstract: Multispectral satellite imagery engagement provides the landscape-morphological zoning. This procedure was carried out over Mariupol City and its vicinities. The research area was subdivided into elementary landscape elements in accordance with migration conditions. The structure-coordinate morphological terrain network was created. The ways of pollutants' migration from industrial objects can be determined using remote sensing data. The main localities of matter accumulation within the city are the river valleys of Kal'mius and Kal'chyk. These areas are dangerous for human livelihood.

Keywords: industrial pollutants, chemical elements migration, lateral flows, landscape zoning, remote sensing data.

1 Introduction

Large industrial enterprises are the main drivers of anthropogenic impact onto environment. Because of industry activity the troubling chemical substances fall and accumulate in environment. Long-term permanent geochemical anomalies are formed inside some components of the landscape that affect negatively on ecosystems' dynamics. The main drivers of such anomalies' formation are the industrial dust emissions into atmosphere and their deposition inside soil, the drops of contaminated wastewater into hydrological basins and the toxic atmospheric precipitation.

Surface pollution of soils is a variable value, because soil serves as an ecological linking element among the geosystems in the process of secondary redistribution of pollutants. Emerging in the landscape the pollutants move out according to motion law for matter into the environment. This is true for Mariupol City (Donetsk Oblast, Ukraine), territory of which we consider in our study using remote sensing data.[2, 3, 6]

Within the industrial zone of Mariupol the environmental pollution is already negatively affect the health, working ability, and life expectancy of people and may be considered as the real threat for future generations.

2 Research methodology

The chemical element migration in atmosphere, lithosphere, hydrosphere, and biosphere is determined by the kinematic features, lithologic composition and geographic conditions,[1, 4] first and foremost by terrain elevations. Landscape's lithological elements within the same conditions of soil moisture are reliable detected inside geomorphological boundaries.[3] Such boundaries can be recognized using multispectral satellite imagery. Secondary transportation of the pollutants from the industrial sources is described as continuous erosion, denudation and accumulation of soils and sediments enclosed them along the paths of lateral matter flows. Elementary landscapes in frame of the urban ecosystem of Mariupol form the original subsystems, which are connected them together by the energy exchange and migration of various substances, i.e. chemical elements.

2.1 Landscape-morphological zoning of studied area

According to the available classifications, the following landscapes are distinguished:[5] eluvial, transeluvial, superaqual, subaqual ones, which are intrinsic to the territory of Mariupol and the adjoining suburbs. Let's characterize these areas in detail.

An eluvial landscape is autonomous. The chemical substances from aqueous and supraqueous landscapes don't enter there. The main source of pollutant accumulation in this landscape is the atmosphere. Therefore, the matter is removed by the descending moister flow, but the active biological capture of elements by the vegetation traps them into the biochemical cycle.[8] The ground-water level in general duplicates the relief changes of soil surface and its changes. At the watersheds and the plots of the first third part of slopes the occurrence of ground-water is seasonal. Water (temporary water) is appeared in snow thaw period only and after heavy and long rains. The superaqual landscape is formed in the topographic lows, where ground water is situated at the surface.

A transeluvial landscape embraces the convex tops and the upper steeper parts of slopes. The inputs of chemical elements and their compounds into the landscape occur from the atmosphere as well as due to the lateral solid and liquid runoffs and their removal is directed vertically and down the slope (falling, sliding, etc.).

A superaqual landscape is formed in the topographic lows. Ground water in such regions are close to the land surface.

A subaqual landscape is formed at the bottom of various water bodies (lakes, rivers, reservoirs, etc.). The superaqual and subaqual landscapes are related geochemically due to their formation depends on the products of weathering and pedogenesis, which are carrying by the superficial and underground runoffs from the eluvial landscapes.

Thus, using the topographical data and digital elevation model (DEM) obtained by the satellite data (Fig. 1), we have divided the research area into the elementary landscapes, which are consequently vary in the migration conditions of the matter (Fig. 2). The analysis of the schematic map of landscape-morphological regionalization for Mariupol constructed by above-mentioned means reveals these features within the city borders.[3]

The recent valley formation of Kal'mius and Kal'chyk Rivers by the action of surface and underground waters is straightforward that induced by the strict directions of elementary earth grade. The general and regular source of nourishment for the Kal'mius and Kal'chyk Rivers is atmospheric and ground waters. The first of them are located over the first impermeable horizons. They are replenished by periodical

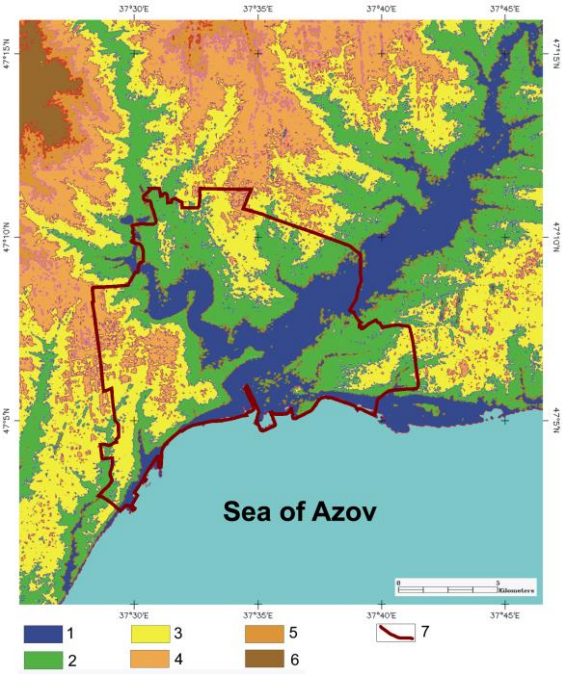

Figure 1: Digital elevation model for the selected area (ASTER_GDEM-2009 data). 1–6 – bench marks above the Azov sea level for landscape, m: 1 – 2–20, 2 – 21–49, 3 – 50–74, 4 – 75–99, 5 – 100–119, 6 – 120–163; 7 – city limit of Mariupol.

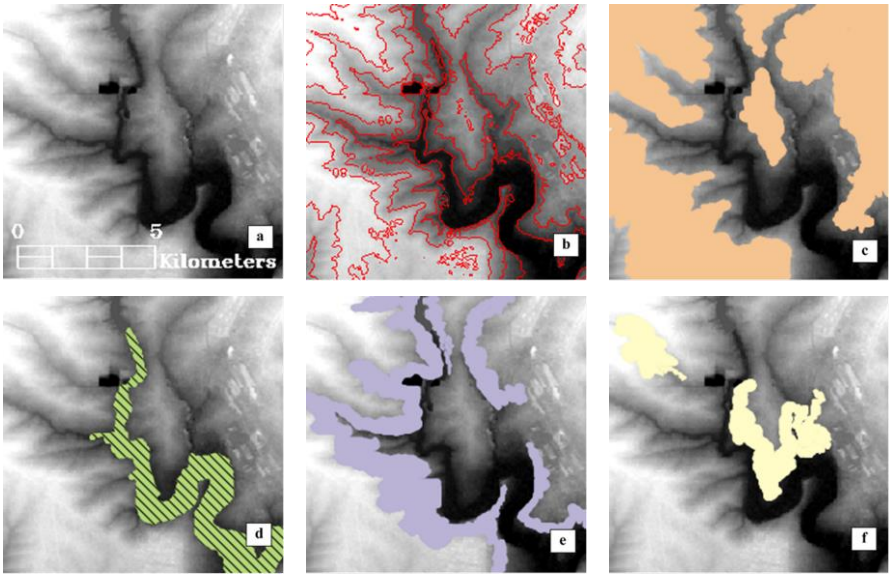

Figure 2: The elementary landscape decomposition using DEM. (a) digital elevation model for the earth's surface in the north-western Mariupol using ASTER_GDEM data; (b) elevation isolines from the DEM data; c–f – elementary landscapes: (c) eluvial, (d) superaqual, (e) transeluvial, (f) transeluvial-accumulative ones.

atmospheric precipitation, whereas groundwater is formed as a result of the infiltration of atmospheric precipitation. They migrate in the lateral direct towards the hypsometrically lower localities.

The watersheds of Mariupol are covered by grit and sandy eluvial deposits with the uneven and hilly surface. The first upper third of the slopes of watersheds is composed of sandy-loam sedimentary varieties. At the second middle third of slopes loamy soil is well-developed. At the last third of the slopes deluvial argillic deposits are spread and in the wide flat not flooded plains there are plane surfaces of heavy eluvial clay.

2.2 Composition of framework structural coordinate network for landscape of selected area

The basic geomorphological parameters analysis for landscape of Mariupol uses the topographical maps and ASTER_GDEM digital terrain elevation data (DTED) and enables to subdivide the land surface into planar elements that are constrained within the top, bottom and side structural boundaries (Fig. 3). Both normal (vertical) and morpho-isograph (horizontal) curvature of the land surface reflect the internal mor-

phology of the surface elements.[7] The mutual position of land surface elements is characterized by ones' height or depth. The extreme values correspond to most stable frame primitives – crest and keel lines. The least stable lines of maximum and minimum terrain's deviations determine the zones of soil cover intense destruction. Finally, the convex slopes allocate the area of denudation change.

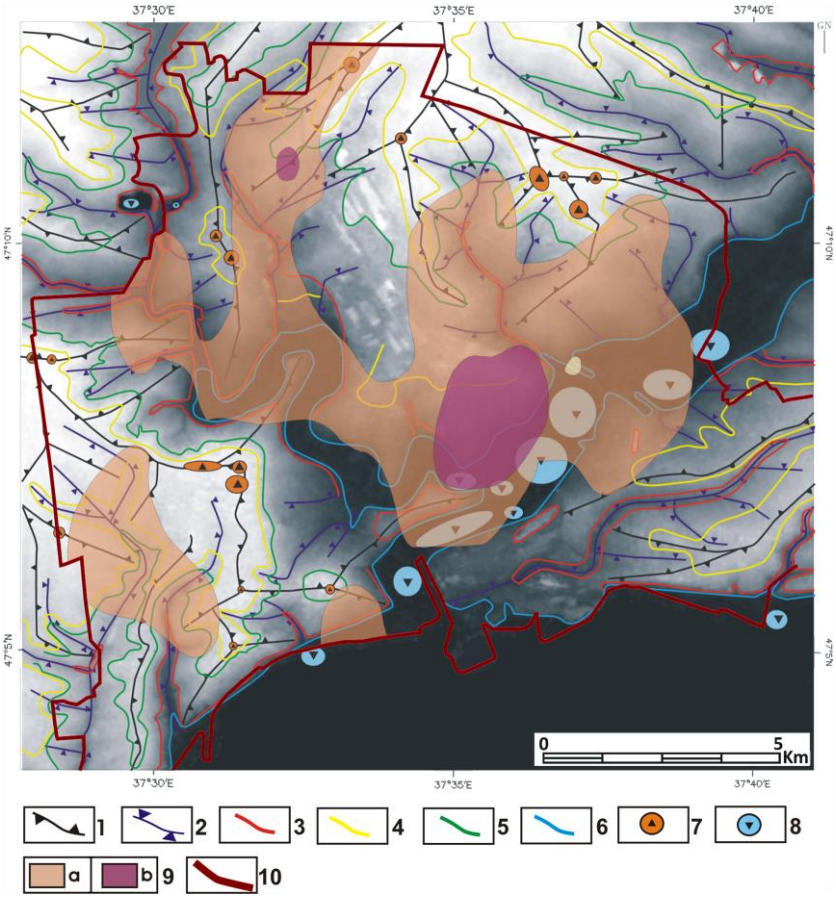

Figure 3: Framework structural coordinate network for landscape within Mariupol together with the mapped heavy metal pollution anomalies of recent soils. 1 – crest lines; 2 – keel lines; 3 – maximum slope lines; 4 – minimum slope lines; 5 – convex curves lines; 6 – concave curves lines; 7 – positive flat tops; 8 – negative flat tops; 9 – anomalies of cumulative index for heavy metal pollution in soil layer in the interval of 0–5 cm by Karmazynenko et al. 2014 data,[6] which are values in the range of: 32–128 (a), 128–600 (b); 10 – city limit of Mariupol.

Structural parameters clearly influence the direction of the matter lateral flows and the lithospheric balance. The lines of maximum and minimum terrain's deviations determine directions of the matter lateral flows on a horizontal plane. The matter lateral flows are moved from the upper to the lower elements of the earth's surface along the tracks of the potential and actual displacement matter. Positive vertical curvature (convex profile) is related with the acceleration of matter flow and the expenditure of the balance matter. The higher the positive values of normal (vertical) curvature of the earth's surface, the greater the acceleration of flow and consumption of disintegrated matter. Negative vertical curvature (concave profile) determines the opposite trend in changing the flow and balance of mineral masses. The increase in the negative and positive values of the horizontal curvature of the earth's surface downward in a concave and convex slope contributes to an increase in the profit and expenditure part of the balance of matter, respectively, due to the concentration and dispersion of the matter lateral flow. At zero values of horizontal and vertical curvature (of straight lines in the plan and in line profiles in the slopes), the matter lateral flows and the balance of matter do not change.

So, the ways of pollutants' migration from industrial sources can be determined using remote sensing data. The multispectral satellite imagery engagement provides the landscape-morphological zoning. This procedure was carried out over Mariupol city and vicinities. So, the research area was subdivided into elementary landscape elements in accordance with migration conditions using topographical maps and DTED. The structure-coordinate morphological terrain network was created including crest/keel lines and auxiliary elements. The main directions of the matter lateral flows were detected by morphodynamic analysis of terrain. As a result, the zones of pollutants transit, denudation and accumulation were allocated. The main sites of secondary pollutants accumulation within the Mariupol city area are the valleys of Kal'mius and Kal'chyk Rivers.

Our results are well correlated spatially with ground geochemical data obtained for heavy metals in recent soils of Mariupol, which are cumulated as a result of secondary redistribution of hazardous emissions from the industrial enterprises.[6] The most intensive sources of pollution, which influence on the urban environment are the enterprises of ferrous industry such as the Joint Stock Company (JSC) "Illich Iron and Steel Works" (1897 is the year of establishment) and JSC "Azovstal Iron and Steel Works" ("Azovstal") (1933 is the year of establishment). So, the heavy metal pollution anomalies elongated in a plane are identified in the soil layer at the depth of 0–5 cm below the surface (see Fig. 3) just along the valleys of Kal'mius and Kal'chyk Rivers and their tributaries with the cumulative pollution index (Zs) varying in the range of 32 to 128. It is considered [4] that these indices are typical for the category of dangerously polluted soils. Attention should be given to spatial fusion of these anom-

alies into one, which is irregularly shaped in a plane. It proves that the scopes of soil pollution in Mariupol are significant and dangerous to population health.

However, the heaviest metal pollution anomaly for recent soils in the section of 0–5 cm at Zs ranging over 128–600 is mapped at the confluence of valleys of above mentioned rivers. In the opinion of Dzhuvelykyan et al., 2009 [4] for the values of Zs > 128 the soils are labeled as highly dangerous polluted ones. The sizes of anomaly are 2.4×3.7 km. It is elongated in a plane and has a shape of slightly distorted oval in the north. This anomaly is spread to north-east along the valley of the right bank of Kal'mius River. The similar pattern takes place in the section of soil cover at the depths of 5–10 cm below the surface, where the cumulative pollution index for this anomaly is 128–600.[6] This anomaly in size is similar those, which is identified in the higher soil layer. Only the anomaly strike changes to submeridional one.

It is likely that the landscape and geochemical features for the valley of Kal'mius River (type of relief, type of soil, mineralogical and granulometric composition of soil, its humusness and moisture, depth of groundwater table and its mineralization, acidity of surroundings, etc.) define the barrier-cumulative functions on the routes of secondary pollutant migration from the primary their origins and from the places of their initial input on the land surface. Probably, kinetics of biochemical reactions in recent soils involving compounds, which contain heavy metalls is crucial. However these problems need the further detail study.

Nevertheless, landscape-morphological classification for Mariupol area using satellite imaging data and with account of matter migration [3] reveals above-mentioned geochemical anomaly at the soil layer of 0–5 cm manifested to superaqual and transeluvial landscape stratua (or elementar landscapes of the proper type The map of framework structural coordinate network for landscape (see Fig. 3) shows minimal slopes for this terrain, presence of numerous negative flat tops and other features that prove the slowing the mass transfer processes. It's needs to focus that the soil anomaly of the high dangerous pollution is spatially located near the settlements of Mariupol such as Kolonia, Sadky, Novyi Blok, as well as along the Zaozerna Str., which is filled by residual buildings.

Thus, the studies using remote sensing data subject to the results of ground geomorphological, hydrological, pedogenic, geochemical, hydrogeological, etc. measurements allow identifying the areas with the intensive secondary pollution, which are dangerous for human livelihood.

3 Conclusions

Through the atmosphere due to horizontal and vertical motion of air masses the industrial emissions from the enterprises in Mariupol harmful to environment and hu-

man activity are accumulated in the subsurface layers of soil.[2] The landscape-geomorphological regionalization of studied territory assists in the determination of the further pollutant migration in the environment because it reflects the geochemical features of surroundings. The soil pollution from industrial facilities can be estimated quickly and inexpensively using remote sensing data. The further migration of polluted substances returning from the atmosphere and initially incoming to soil is assessed by the digital elevation model.

The results can be used to make recommendation relative to the future planning and allocation of residential communities, recreation zones, industrial objects, warehousing facilities, etc. The next investigation is desirable to direct to the detail analysis of the morphodynamic characteristics of relief using remote sensing data. The suitable results need to forecast the redistribution of pollution and the change of areas of its accumulation due to the natural processes.

References

1. Oleksandr T. Azimov, "Monitoring of the Urban Agglomeration Environment by Aerospace Survey Data," in *Ecology and Human Health. Protection of Water and Air Basins. Waste Utilization*, edited by S.V. Razmetaiev and V.F. Kostenko, Proceedings of the 12th International Scientific & Technological Conference, volume 1 (Kharkov: USSRI UkrVODGEO, 2004): 47–50 (in Ukrainian).
2. Oleksandr T. Azimov and Anastasiia Bunina, "Estimation of Pollution Areas of Atmospheric Air Using the Satellite Data (the Mariupol Hub as an Example)," in *Aerospace Technologies for Sustainable Development and Security (GEO-Ukraine)*, Proceedings of the 5th Ukrainian Conference (Kyiv: SRI of NASU-SSAU, NTUU "Igor Sikorsky Kyiv Polytechnic Institute," 2016): 38–40, (in Ukrainian), https://drive.google.com/file/d/0B3_rN9Ji08-VU3htSGhlZkRYWU U/view, accessed June 5, 2018.
3. Anastasiia Bunina, Oleksandr T. Azimov, and Yelyzaveta M. Dorofey, "Application of Geoinformation Approach to the Study of Secondary Migration of the Pollutants from the Industrial Pollution Sources," in 16th EAGE International Conference on Geoinformatics – Theoretical and Applied Aspects, https://doi.org/10.3997/2214-4609.201701875.
4. Hachik Dzhuvelykyan, Dmitriy Shcheglov, and Nadezhda Gorbunova, *Pollution of Soils with Heavy Metals. Methods of Soil Pollution Monitoring and Regulation* (Voronezh: Voronezh University Press, 2009) (in Russian).
5. John A. C. Fortescue, *Environmental Geochemistry: A Holistic Approach* (New York: Springer-Verlag, 1980).
6. Sergii Karmazynenko, Irina Kuraeva, Anatoly Samchuk, Julia Voitiuk, Vyacheslav Manichev, *Heavy Metals in the Components of the Environment Ma-*

riupol City: Ecological and Geochemical Aspects (Kiev: Interservis, 2014) (in Ukrainian).

7. Alexander Lastochkin, *Relief of the Earth's Surface: Principles and Methods of Statistical Geomorphology* (Leningrad: Nedra, 1991) (in Russian).
8. Ludmila Malysheva, *Geochemistry of Landscapes* (Kiev: Lybid, 2000) (in Ukrainian).

About the Authors

Oleksandr Telmanovich AZIMOV is Doctor of Sciences in Geology and Remote Sensing and Leading Researcher in Department of Energy and Mass Exchange in Geosystems at the Scientific Centre for Aerospace Research of the Earth of the Institute of Geological Sciences of National Academy of Sciences of Ukraine. His primary research interests include remote sensing methods, environmental ecology, emergency management and exploration geology. *E-mail*: azimov@casre.kiev.ua.

Anastasiia BUNINA is a Postgraduate Student of Institute of Geology, Taras Shevchenko National University of Kyiv. Her research focuses on ecological monitoring using remote sensing methods and GIS technology. *E-mail*: 2940954@gmail.com.

Yelyzaveta Mykolaivna DOROFEY is a Leading Engineer in Department of Energy and Mass Exchange in Geosystems at the Scientific Centre for Aerospace Research of the Earth of the Institute of Geological Sciences of National Academy of Sciences of Ukraine. Her research interest is connected with soil geochemistry and mass transfer in the vegetation–soil system forming the useful signals, which may be detected by satellite remote sensing.