Ministry of Education and Science of Ukraine

ODESA NATIONAL UNIVERSITY OF TECHNOLOGY

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2023

PROCEEDINGS

ODESA, ONUT 2023

Ministry of Education and Science of Ukraine

Odesa National University of Technology

International Competition of Student Scientific Works

BLACK SEA SCIENCE 2023

Proceedings

Odesa, ONUT
2023

ECOLOGICAL ASSESSMENT OF THE TERRITORIAL COMPLEXES OF TATARBUNARS'KYI DISTRICT OF ODESSA REGION

Authors: Iryna Voynyts′ka[1]
Advisors: Mariia Madani[1]
Mahmud Ladjel[2]
[1]Odesa National Technological University (Ukraine)
[2]Université de Bejaia (Algeria)

Abstract. *A geo-ecological assessment of the Tatarbunar district was carried out on the basis of spatial geo-informational analysis of remote sensing data. The distribution of heating of different types of land in the district and the amplitude of their fluctuations was analyzed based on thermal scanners - TIRS of the Landsat8 satellite. A seasonal analysis of the vegetation cover dynamics was carried out based on the values of the NDVI vegetation index. This is a spatial characteristic of the moisture content of different types of land in the district based on the NDMI index. According to these indicators, it is demonstrated that agricultural arable land has significantly greater heterogeneity than other types of terrestrial land. A comparative analysis of the percentage of the natural reserve fund of the district with other districts of Odesa, Mykolaiv and Kherson regions was carried out. The proposed ecologically balanced territorial structure of the land organization and measures to increase the ecological stability of the agro-landscapes of the district. A detailed hydrologomorphological analysis of the Karachaus estuary was conducted, on the basis of which reclamation and nature protection measures were proposed.*

Keywords: *Tatarbunar district, northwestern Black Sea region, GIS analysis, remote sensing, anthropogenic load, natural and territorial complexes, ecological and economic balance, ecological management.*

I. INTRODUCTION

Tatarbunars'kyi District is located in the southwestern part of Odessa region and reflects the main landscape and economic features of the region: aquatic, agricultural, resort resources, and nature conservation areas. On the other hand, it is a typical District with extensive land plowing, with a dominant anthropogenic influence in the form of agricultural activities which consist of 91% of the total area of agricultural territories that are presented by arable land, while 4.16% of the arable land is degraded [1]. That information alone is enough to come to a conclusion that such land structure and resource management has a complex negative impact on ecological and economic processes, and cannot ensure sustainable development of the region, it is particularly antagonistic to the unique transitional wetland ecosystems of international importance [2], located within the area (degradation of watercourses, siltation, xenobiotic contamination, eutrophication, reduction of biological diversity, etc.)

Earth remote sensing (ERS) data - spectrozonal satellite images, digital terrain models, and geoinformation systems (GIS) - can be involved in addressing the region's balanced environmental management problems, as it provides simultaneous coverage of the whole region under study, regular monitoring and significant reduction of the cost of expensive expedition work, allowing to obtain a large array of characteristics of the status of territorial complexes of the area. Remote methods are based on the ability of spatial objects to emit, scatter, and absorb electromagnetic waves of varying intensity. The value of environmental indicators based on ERS is found like a function of the amount of reflected or absorbed radiation, which contributes to its remote identification [3].

II. LITERATURE ANALYSIS

Quantitative methods, based on the ratio of natural and anthropogenic elements [4], for estimating anthropogenic changes of landscapes have become the most prevalent for assessing the level of transformability of natural-territorial complexes. Methods of landscape and ecological optimization, as well as estimation of economic and ecological balance of the region based on the inventory of the areas with their ranking according to the degree of anthropogenic changes are presented in the works of O. L. Popova (2012) [5] and L.P. Tsaryk (2009) [6]. An integrated approach to the sustainable management of the usage of administrative territorial units is discussed in the following works [7-13].

Several issues regarding Ukraine's planning of the land-usage structure were addressed with the consideration of international experience, natural and economic features [5, 14, 15].

In the works of the Institute of Plant Physiology and Genetics of the NAS of Ukraine and the Space Research Institute of the NASU-SSAU (including joint ones) methods for assessing the characteristics of terrestrial plant biomass from spectra reflection (spectral signatures) were developed and proposed, issues of satellite data validation using spectrometric field measurements were considered [16-18].

In the monograph of V.I. Lyalko and M.O. Popov the following issues of multispectral space information application for solving nature management problems were considered: establishment of forests' species composition; forecasting of grain yields; determination of the geo-ecological status of natural technogenic systems, etc.; materials, methods, and models of interpretation of Earth remote sensing data for environmental monitoring were outlined [19].

The use of spectroradiometer data, the Landsat and MODIS series of satellites in particular, in the assessment of thermal fields and the moisture content of artificial and natural terrestrial surfaces (territorial complexes) is reviewed in the works [20, 21].

Adaptive-landscape principles of applying field-protecting forest cultivation, including the area of required field-protecting forest areas [23], were reviewed in Odesa region, including Tatarbunars'kyi District.

The environmental status of land resources of the mentioned District has been estimated based on plowing indicators, humic matter content, environmental sustainability, erosion, and others, including integral indices [22]. It is clearly demonstrated that the land resources of the area do not meet the requirements of rational natural use due to, first of all, the violation of the ratio of arable land.

Recommendations for the location of agricultural crops are proposed, and so is the use of ERS data for the quantitative assessment of vegetation of Tatarbunars'kyi District [24]. An assessment of the recreational potential of the administrative regions of Odesa region by the integral characteristics of the resource, ecological, infrastructural, and consumer factors is carried out in [25], where it is shown that Tatarbunars'kyi District is very promising for studies of ecological tourism, balneology, and recreation at the expense of a large number of objects of nature conservation fund, firth and estuary natural complexes. Structural features of the eco-network, including the objects of the nature conservation fund, their territories and prospects for expansion [2], are also taken into consideration. An analysis of natureprotecting regime of coastal protection lanes (CPL) of Tatarbunars'kyi District's hydro-ecosystems and their structures has been reviewed in [26] and it is noted that the District is characterized by a very little amount of CPLs with corresponding project documentation. In the very same work, there is an analysis of the problems of efficient and integrated use of the Sasyk estuary that was desalinated as a result of river water transmission from the Danube-Sasyk channel. Collective works [4, 27], with a consideration of anthropogenic influence, have analyzed the peculiarities of hydrological, hydro-chemical and hydro-biological regimes of the ecosystems of estuary complexes located within the area, estuaries of the «Tuzlov group» (Shagany, Alibey, Burnas) in particular. The morphometry and toponymy of the water bodies of the «Tuzlovs'kyi estuaries» national park were also discussed in [28]. For these objects, a comparative classification according to morphometric and hydrological characteristics, as well as their natural resistance, has been conducted [29, 30].

Highlighting previously unresolved parts of the general problem. Certain possibilities of using the Earth remote sensing data for functional estimation of the lands that were changed by anthropogenic activities are carried out in this work. First of all, arable land, with an analysis of the ecological and economic balance of the area based on geoecological coefficients, and then emphasis on the areas that are primarily exposed to ecological risks of exogenous processes and the influence of anthropogenic factors based on geomorphological features using digital terrain models. Measures to improve the ecological stability of agro-landscapes and the landscape-anthropogenic structure of the area's lands are proposed. Hydrographic zoning and catchment areas of Tatarbunars'kyi District were conducted. For one of them - the catchment area of the Karachaus estuary, hydrologic-morphological features were analyzed, and an improved scheme for nature management was developed. The presented cartographic material of the aforementioned components, and despite the fact that the materials of the article are primarily demonstrative and methodological, can be used for further, deeper spatiotemporal assessment of the ecological status of territorial complexes of the region, aimed at developing new management plans for sustainable nature usage.

Formulating the purpose of the article. The purpose of the work is: functional assessment of the ecological status of the economic landscape structure, and development of recommendations for protecting natural territorial complexes of Tatarbunars'kyi District in Odesa region based on the use of GIS and ERS data.

The main tasks aimed at achieving the goal were:

- estimation of ecological parameters (temperature of warming of the territorial complexes, aridity, condition of plant-based biomass), and their interrelation in spatial and temporal dynamics simultaneously in the whole District;
- assessment of the state of nature management and its balance;

- terrain analysis and emphasis on the areas that are primarily the most at environmental risk of exogenous processes and influence of anthropogenic factors;
- hydrographic zoning and measure development for sustainable use of nature, for natural conservation of the catchment area of the Karachaus estuary at the «Tuzlovs'kyi Complex».

III. OBJECT, SUBJECT, AND METHODS OF RESEARCH

The Landsat8 satellite images with OLI and TIRS sensors [31], as well as 30m digital terrain relief models obtained from the international «Shuttle radar topographic mission» (SRTM30), radar image [32] were used as an output. Spatial distribution of the population was carried out on the basis of «OpenStreetMap» data [44], using automatic IDW (inversely-weighted distance) interpolation. Spatial analysis and data processing were performed in QGIS v 3.4.6 software software package with integrated SAGAGIS and GRASSGIS tools, namely: vector and raster data processing, spectral index calculation, morphometric and topographic terrain analysis, hydrographic zoning, density calculation and construction of interpolation surfaces, visualization and design of cartographic materials. Radiometric calibration and atmospheric correction of the Landsat8 satellite images were carried out on the basis of the use of the additional «Semi Automatic Classification Plugin» geo-information module also in QGIS v 3.4.6.

To calculate the spectral brightness of distant infrared radiation in a unit of temperature, the values of the calculated coefficients were used according to the calculation method from the metadata file attached to the satellite images [34].

The Normalized Difference Vegetation Index - NDVI [35-37], which is one of the most common indices for the quantification of vegetation, has been calculated for its main purpose.

The watershed distribution was estimated using the modified Normalized Differential Moisture Index (NDMI), which is derived from the near and short-wave infrared parts of the wavelength spectrum and characterizes the aridity level of landscape complexes [38].

The analysis of land use structure and determination of the anthropogenic load was conducted based on ranking and consolidation of territorial objects into homogeneous groups. The coefficients of anthropogenic transformation of the landscape structure of natural territorial complexes were calculated according to the methodology [5].

LS-factor (length and slope factor) was used to calculate areas with planar erosion potential, which combines the influence of the slope and bevel length of the terrain, calculated according to a corresponding methodology based on the digital terrain model [10].

As a basis for the data of remote sensing of the development of recommendations for the catchment basin of the Karachaus estuary, in addition to the relief data, a Sentinel2B satellite image was used [39].

IV. RESULTS

The spatial distribution of NDVI over time in the area allowed to detect a significant change of the figure within just one month. For example, the calculation of

NDVI on 24.05.2021 has showed that the maximum figures in the range of 0.5-0.81 - dense plant cover (Table 1) had a land area of 341.66 km^2 (Fig. 1), at the end of summer - on 26.08.2021 - lands with maximum index values in the range of 0.5-0.79 occupied an area of 55.45 km^2 (Fig. 2), and a month later plant cover with an index value in the range of more than 0.5 decreased to an area of 13.641 km^2 (Fig. 3), which is 25 times more compared to May, which is primarily related to harvesting and the formation of «bare» land in its place.

A characteristic feature of agricultural landscapes, namely arable land, in comparison with other natural territorial complexes (landscapes) is the presence of significant seasonal dynamics of the amount and density of plant biomass, according to the values of the NDVI index, especially in the May-October period. This feature is associated with the process of treatment and cultivation of this type of land. However, the corresponding values of plant biomass of other types of land during the same period do not change that significantly (Table 2).

Table 1. NDVI index figures for different objects [35]

Type of land cover	NDVI (scale from -1 to 1)	NDVI (scale from: 0 to 255)
Dense vegetation	0.500<=NDVI<=1	210<=NDVI<=255
Sparse vegetation	0.140<=NDVI<0.500	118<=NDVI<210
Poor vegetation	0.090<=NDVI<0.140	105<=NDVI<118
Bare land	0.025<=NDVI<0.090	88<=NDVI<105
Clouds	0.002<=NDVI<0.025	83<=NDVI<88
Snow and ice	-0.046<=NDVI<0.002	70<=NDVI<83
Water	-1<=NDVI<-0.046	0<=NDVI<70

Assessment of the water supply of the territory is an important feature in the field of water management and development of rational water resources usage principles of the region. Spectrozone satellite imaging data, along with field and meteorological studies, provide additional information on soil moisture content and soil cover with the help of, for example, the Normalized Differential Humidity Index (NDMI). High moisture content is inherent in healthy vegetation, which grows faster and is more resistant to fires.

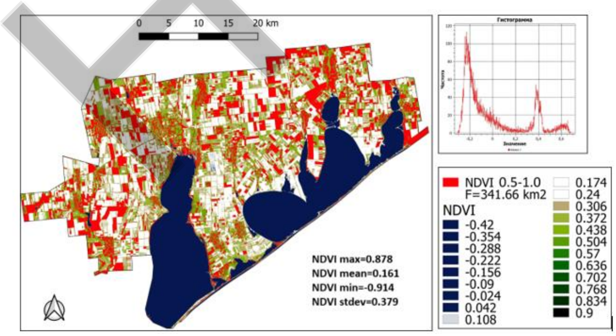


Fig. 1. Distribution of NDVI index on the territory of Tatarbunars'kyi District from 20.07.2021

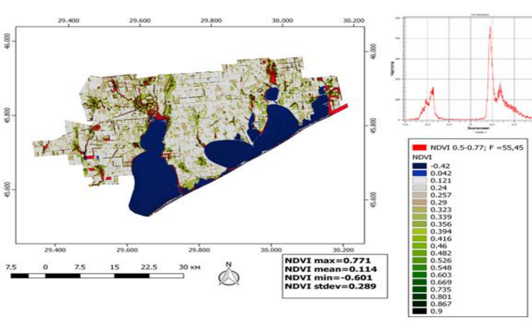


Fig. 2. Distribution of NDVI index on the territory of Tatarbunars'kyi District from 26.08.2021

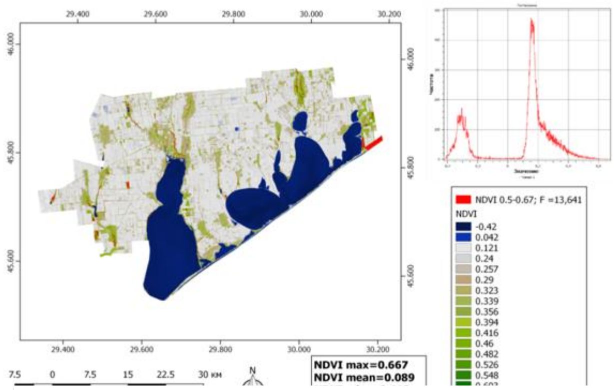
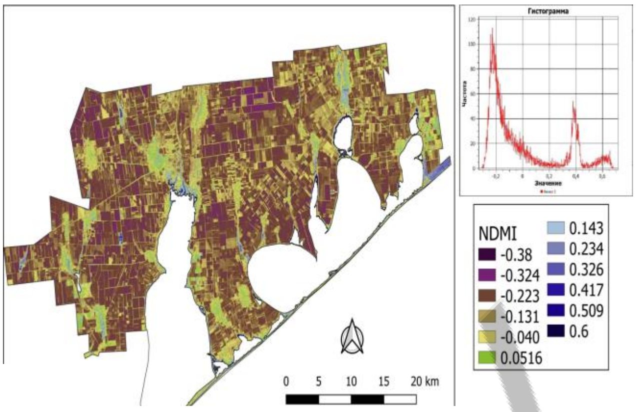


Fig. 3. Distribution of NDVI index on the territory of Tatarbunars'kyi District from 22.09.2021



– Fig. 4. NDMI Index Distribution for Tatarbunars'kyi District from 2021.09.22 according to Landsat8

Table 2. NDVI index figures for Tatarbunars'kyi District

Type of land	24.05.2021			20.07.2021			22.09.2021		
	Mid.	Max.	Min.	Mid.	Max.	Min.	Mid.	Max.	Min.
Arable land	0,57	0,81	0,11	0,51	0,77	0,08	0,14	0,69	0,05
Meadows	0,53	0,79	0,40	0,46	0,70	0,31	0,33	0,56	0,22
Reed beds	0,57	0,81	0,43	0,58	0,79	0,50	0,42	0,62	0,31
Forests	0,75	0,81	0,53	0,74	0,81	0,49	0,55	0,64	0,34

As follows from the distribution of the index on 2021.09.22, its smallest figures are found in plowed soils, the highest figures are found in plant-covered and coastal areas (Fig. 4).

Based on the analysis of the geomorphological features of Tatarbunars'kyi District, which stipulate geochemical flows of terrigenous matter transfer, soil erosion, and other processes, sections with a slope of more than 3º have been highlighted using SRTM30 digital terrain models, which, according to literary data [25], are at the greatest ecological risk of exogenous processes and influence of anthropogenic factors (Fig. 5).

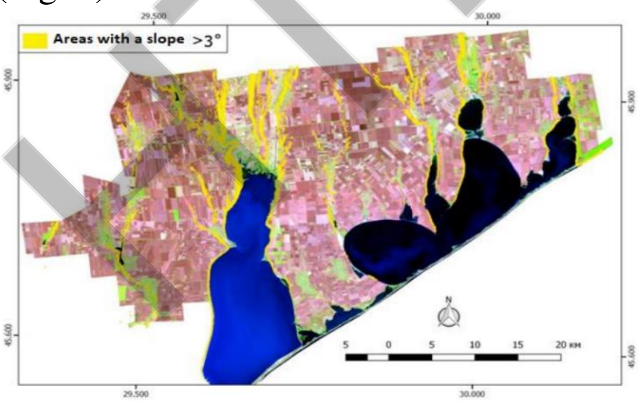


Fig. 5. The distribution of sites with a ≥3º slope on the territory of Tatarbunars'kyi District according to SRTM30 digital terrain models superimposed over a Landsat8 satellite image from 22.09.2021

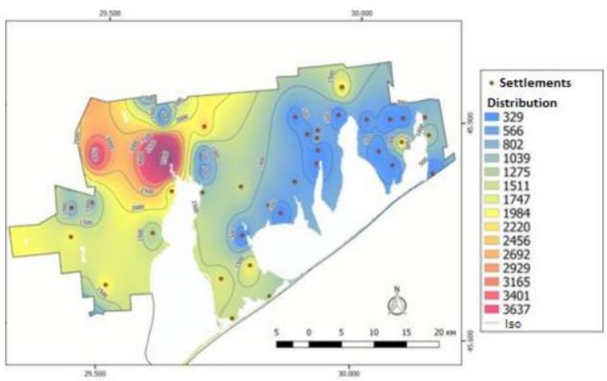


Fig. 6. Population density distribution in Tatarbunars'kyi District, built according to OpenStreetMaps data in the QGIS software package

The location of such sites is inherent in the ridge-girder structures, river valleys and slopes of the estuaries. These areas are recommended to be used in the «natural» state (hayfields, pastures, perennial plantations, recreation and tourism areas) with the removal of arable lands. By their location, almost all of them are part of coastal protection lanes and lands of the water fund in accordance with the Water Code of Ukraine [40], where a full project documentation hasn't been developed yet. From the point of view of ecological and economic balance of the territory, it is most expedient to carry out an inventory of landscape and economic structure, especially in these areas, with their submission to cadastral schemes and land management plans, with the formation of an appropriate environmental regime.

The distribution of settlements and population density in Tatarbunars'kyi District indicates that a large number of them are located precisely on the grounds of river valleys and in places with a slope of more than 3º (Fig. 6), which also leads to intensification of exogenous processes and pollution of water bodies. The aggravating fact is that many of them do not have a centralized sewer system. In general, the territory is characterized by the absence of large cities and low population density.

Another approach to forming a balanced land use structure, ecological network, and sustainable development of the area is hydrographic zoning. According to the requirements of the EU Water Framework Directive [41], which are currently being implemented in national legislation, management of the ecological status of water bodies is based on a basin approach with the development of appropriate management plans and the formation of basin management administration. Small rivers, catchment parts of the Tuzlovs'kyi complex, the Sasik estuary, etc. are located on the District's territories (Fig. 7).

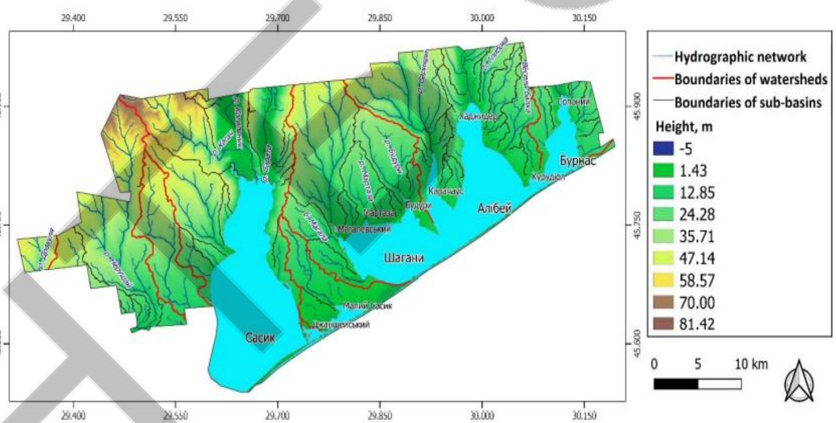


Fig. 7. Hydrographic network of Tatarbunars'kyi District and its watershed boundaries

For further hydrologic morphometric analysis and development of environmental measures, a Karachaus catchment area was selected (a subsidiary estuary with a developed gully-girder system) from the Tuzlovs'kyi complex, within the boundaries of the District. Current capabilities of GIS analysis have made it possible to calculate a number of hydrologically-morphological indicators of the catchment area (Fig. 8), which allow to determine places of the greatest manifestation of exogenous and anthropogenic processes (slope sites, direction and intensity of surface runoff, displays of linear and planar erosion).

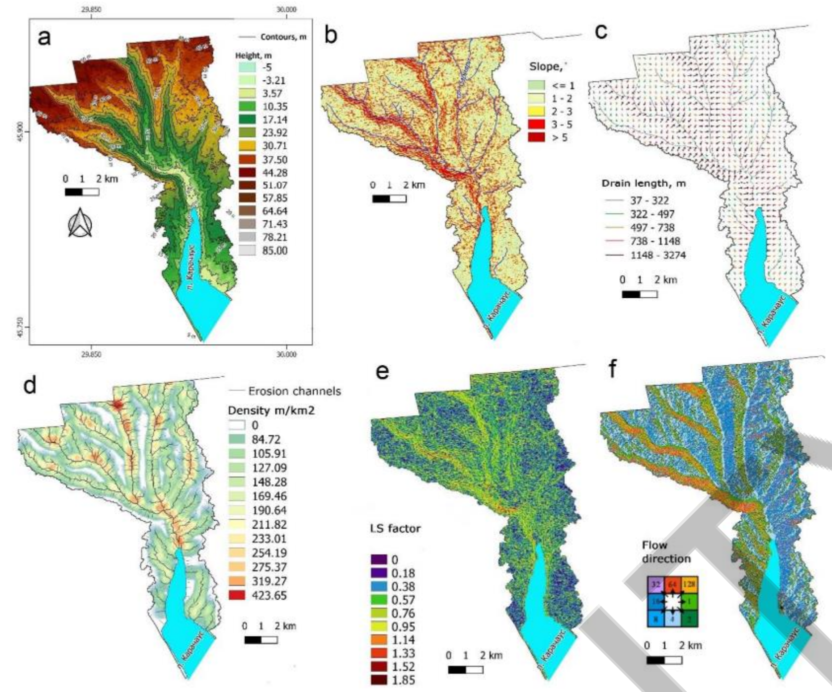


Fig. 8. Hydrologic and morphological features of part of the catchment area of the Tuzlovs'kyi estuary complex within the borders of Tatarbunars'kyi District: a - terrain heights; b - biases; c - flow vectors; d - linear erosion structures and density; e - the risk of plane erosion; f - the drain direction of each raster cell

As evidenced by careful hydrologic morphological analysis, this area does not imply widespre intensive use of nature, as it has a developed gullygirder system and terrain fragmentation. It is clear that environmental management in such conditions must be differentiated in spatial, intensity-based, landscape and settlement-balanced terms, taking the functions of the ecological network into account. Moving on to the proposed sustainable environmental management measures for the further development of an ecological management plan, one should also mention the legally stipulated environmental measures for the water fund lands, and their introduction into nature, especially the nature protection lanes (NPLs) along the watercourses. The principles of their establishment, structure and nature protection regime are determined in accordance with the law of direct action in this field - Water Code of Ukraine (Articles 88-90), which includes NPLs along watercourses, NPLs along seas and estuaries (with beach area allocations) [40].

At present, nature management in the form of ubiquitous plowing of land, unauthorized rural settlement development on the territory of the catchment area is conducted without taking terrain and gully-girder structure into account, without observing agro-technical land protection norms, resulting in both deep and planar erosion (Fig. 9 a), in addition to that, windbreaks are not enough to protect against wind (deflation), and water erosion of soils, as well as the associated reduction of the ecological status of water bodies. Given the hydrological and morphological conditions, state of the lands, regulation of watercourses and environmental legislation, it is proposed to reorient the structure of land use, to increase the number of environmental protection areas, to allocate sites with extensive form of land use, which is certainly going to be ecologically beneficial (Fig. 9 b).

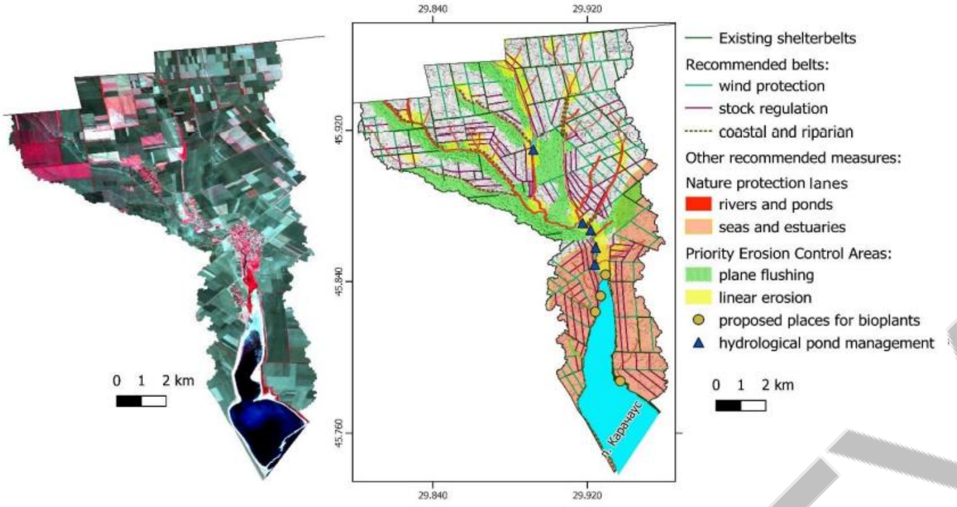


Fig. 9. The existing and recommended structure of land use of the Karachaus catchment area within the boundaries of Tatarbunars'kyi District: a - full-color satellite Sentinel2B image from 2021.09.15 from the combination of NIR-Green-Blue channels (vegetation is red); b - a scheme of reclamation and environmental measures (management plan at its first approximation) [39]

First of all, it is necessary to transfer the water fund lands to the «nature» of applying them to land management plans of settlements and land cadasters. Furthermore, proper agro-technical measures were not met throughout the whole District, among other things agricultural territories are insufficiently countered by protective windbreaks. The existing structure of windbreaks consists of 80.9 km, about one third of the fields do not have any windbreaks at all, the distance between the windbreaks is 1 km on average, the corresponding edging area - 200 ha. This windbreak structure does not fulfill its environmental function, so it is recommended to increase it by 3 times. At the same time it should at least include additional wind protection (92.1 km), stock regulation (124.7 km), coastal and riparian (30.8 km). Additional windbreaks were plotted as follows: windproof, taking into account prevailing wind directions with a cell size of 500 per 1000 m; stock regulation windbreaks were placed on slope sections along the horizontal lines at a distance of 400 - 300 m, depending on the slope; coastal and riparian windbreaks along eroded girders 3 - 5 m from the shorelines. As a prevention of land erosion spread, it is also recommended that some of them (on the slopes of gully-girder systems) carry out sedimentation, conservation, and exploitative reorientation (use in a quasi-natural state - perennial crops, pastures, hayfields, etc.). In order to control the quality and colmatage (mudding) of the organized runoff of ravines and girders, it is proposed to create biological filters in their mouths along the estuary - biological plateaus (artificial ecosystems with sinusoidal filtration biocenoses). Small local rivers from the basin were basically destroyed as a result of a rupture of the hydrographic network and pond overregulation.

It is recommended to either completely eliminate unauthorized ponds, or to allow their operation solely in case of proper environmental documentation and operating modes depending on the water content of the year. It is advisable to use arable land on planar grounds and based on the principles of adaptive agriculture, with the introduction of soil protective crop rotations and the use of unconventional agrotechnical measures (minimization of soil cultivation, optimization of rotation, improved irrigation systems etc.).

V. CONCLUSIONS

The results of GIS thermal channels analysis of Landsat8 satellite images revealed a significant amplitude of temperature fluctuations of Tatarbunars'kyi District's territorial complexes. The warming of plowed soil is higher by 10 °C than under plant cover in the summer period, which certainly influences the hydrological, geochemical and biological processes of the area at the current level of agricultural development of arable land.

The distribution of vegetation dynamics by NDVI across the area revealed a significant value change seasonally and even within one month. Territories with the maximum index values corresponding with the dense vegetation cover occupied an area of 341.66 km^2 on May 24, 2021, at the end of summer - August 26, 2021, - 55.45 km^2 respectively, and a month later the area of vegetation in this index range decreased to 13.64 km^2 , which is more by 25 times compared to May, primarily due to harvesting and tillage in the form of arable land.

The calculation results of the complex geoecological indicators also showed ecological imbalance of the lands' structure. Irrational farming has led to degradation of the hydrographic network of small rivers in the area, formation of soil erosion, trenching, reduction of the ecological status of water bodies, including nature protection areas with an international status of Ramsar lands.

The distribution of settlements and population in Tatarbunars'kyi District indicates that a large number of them are located on the grounds of river valleys and in places with a slope of more than 3º, which also leads to intensification of exogenous processes and pollution of water bodies.

Management plan of the Karachaus estuary (its first approximation), which is developed on the basis of a hydrologic morphological analysis of the catchment area and land use structure, includes the application of natural protection lanes to the settlements' land management plans and land cadasters, conducting appropriate agro-technical measures, particularly increasing the length of the windbreak system by 3 times with their respective functional purpose. As a prevention of land erosion spread, it is also recommended that some of them (ones on the slopes of gully-girder systems) carry out sedimentation, conservation and operational reorientation (use in a quasi-natural state - perennial crops, pastures, hayfields, etc.). For the possibility of quality control and mudding of the organized runoff, it is proposed to create biological filters (bio-plateaus) in the mouths along the estuary. It is recommended to either complete eliminate unauthorized ponds, or to operate them solely in case of proper environmental documentation and operating modes depending on the water content of the year. Placement and use of arable land is proposed to be based on the principles of adaptive agriculture.

The result of the GIS assessment is geoinformation databases in the form of raster and vector layers that can be used by executives and other stakeholders for further development of the sustainable development strategy of Tatarbunars'kyi area.

VI. REFERENCES

1. Ekolohichnyi pasport rehionu za 2020 rik. [Environmental passport of the region for 2020]. Retrieved from: http://ecology.odessa.gov.ua/ekologchnij-pasport-regonu/ [in Ukrainian].

2. Popova, O.M. (2017). Pryrodno-zapovidnyi fond Odeskoi oblasti v systemi fizyko-heohrafichnoho raionuvannia Ukrainy i shliakhy yoho optymizatsi*i* [The nature reserve fund of the Odesa region in the system of physical and geographical zoning of Ukraine and ways of its optimization]. *Visnyk Odeskoho natsionalnoho universytetu. Seriia : Heohrafichni ta heolohichni nauky*, 29-47 [in Ukrainian].

3. Svidzinska, D.V. (2014*)*. *Metody heoekolohichnykh doslidzhen: heoinformatsiinyi praktykum na osnovi vidkrytoi HIS SAGA* [Methods of geoecological research: geoinformation workshop based on open GIS SAGA]. Kyiv: Lohos [in Ukrainian].

4. Zajceva, Ju.P., B.G. Aleksandrova, B.G. (Ed.) (2006). *Severo-zapadnaja chast' Chjornogo morja: (biologija i jekologija)* [North-western part of the Black Sea: (biology and ecology)]. Kiev: Naukova Dumka [in Russian].

5. Popova, O. L. (2012). Ekodiahnostyka pryrodo-hospodarskoi orhanizatsii terytorii Ukrainy: ahrolandshaftnyi aspekt [Eco-diagnostics of the environmental and economic organization of the territory of Ukraine: agro-landscape aspect]. *Ekonomika i prohnozuvannia*, 3, 92-101 [in Ukrainian].

6. Tsaryk, L.P., P.L. Tsaryk, P.L. (2009). Heoekolohichni pidkhody do otsinky stupenia zbalansovanosti pryrodokorystuvannia [Geoecological approaches to assessing the degree of balanced nature use]. *Visnyk Lvivskoho universytetu. Seriia: heohrafiia*, 37, 43-48 [in Ukrainian].

7. Izakovičová, Z., Špulerová, J., Petrovič, F. (2018). Integrated approach to sustainable land use management. Environ. *Open Access J. Environ. Conserv. Technol*., 5, 37. https://doi.org/10.3390/environments5030037

8. Izakovicova, Z., Miklos, L., Miklosova, V. (2018). Integrative Assessment of Land Use Conflicts. *Sustainability*, 10, 3270. https://doi.org/10.3390/su10093270

9. Marchi, M., Ferrara, C., Biasi, R., Salvia, R., Salvati, L. (2018). Agro-Forest Management and Soil Degradation in Mediterranean Environments: Towards a Strategy for Sustainable Land Use in Vineyard and Olive Cropland. *Sustainability*, 10, 2565. https://doi.org/10.3390/su10072565

10. Moore, LD., and Burch, G.J. (1985). Physical Basis of the Length-slope Factor in the Universal Soil Loss Equation. *Soil Sci. Soc. Am. J*., 50, 1294-1298.

11. Pen, J.; Ma, J.; Du, Y.; Zhang, L.; Hu, X. (2016). Ecological suitability evaluation for mountainous area development based on conceptual model of landscape structure, function, and dynamics. *Ecol. Indic*., 61, 500-511.

12. Turner, K.G., Anderson, S., Gonzales-Chang, M., Costanza, R., Courville, S., Dalgaard, T., Dominati, E., Kubiszewski, I., Ogilvy, S., Porfirio, L. et al. (2016). A review of methods, data, and models to assess changes in the value of ecosystem services from land degradation and restoration. *Ecol. Model*, 319, 190-207. https://doi.org/10.1016/j.ecolmodel.2015.07.017

13. Yang, J., Li, S., Lu, H. (2019). Quantitative influence of land-use changes and urban expansion intensity on landscape pattern in Qingdao, China: Implications for urban sustainability. *Sustainability*, 11, 61-74 https://doi.org/10.3390/su11216174

14. Rudenko L., Maruniak E., Lisovskiy S. (2014). Landscape Planning for Ukrainian Rural Communities: Challenges, Outputs, Prospects. *Geoadria*, 19(2), 191-204.

15. Stoiko, N., Parsova, V. (2017). Environmental dimensions of rural development in land use planning circumstances in Ukraine. *Engineering for rural development*, 1, 964-969. https://doi.org/10.22616/erdev2017.16.n197

16. Donec, V.V., Kochubej, S.M., Jacenko, V.A., Kazancev, T.A., V.V. Brovchenko, V.V. (2013). Sozdanie polevogo spektral'nogo apparaturno-programmnogo kompleksa dlja podsputnikovoj validacii distancionnogo issledovanija rastitel'nosti [Creation of a field spectral hardware and software complex for sub-satellite validation of remote vegetation research]. *Systemy obrobky informatsii*, 8/115, 36-42 [in Russian].

17. Popov, M.O., Semko, I.D. (2013). Otsiniuvannia kharakterystyk zelenykh nasadzhen z vykorystanniam zasobiv dystantsiinoho zonduvannia Zemli [Evaluation of the characteristics of

green spaces using the means of remote sensing of the Earth]. *Osnovy pryrodokorystuvannia ta bezpeka zhyttiediialnosti*, 12, 51-62 [in Ukrainian].

18. Jacenko, V.A., Kochubej, S.M., Handriga, P.A., Donec, V.V. (2007). Novyj metod distancionnogo ocenivanija soderzhanija hlorofilla v rastitel'nosti i ego programmno-apparatnaja realizacija [A new method for remote estimation of chlorophyll content in vegetation and its software and hardware implementation]. *Kosmichna nauka i tekhnolohiia*, 13(3), 35-44 [in Russian].

19. Lialko, V.I., M.O. Popov, M.O. (2006). *Bahatospektralni metody dystantsiinoho zonduvannia zemli v zadachakh pryrodokorystuvannia* [Multispectral methods of remote sensing of the earth in the tasks of nature management]. Kyiv: Naukova dumka [in Ukrainian].

20. Sakhatskyi, O.I., Stankevych, S.A. (2007). Do mozhlyvostei otsiniuvannia zvolozhenosti zemnoho pokryttia za bahatospektralnymy kosmichnymy zobrazhenniamy optychnoho diapazonu na prykladi terytorii Ukrainy [Towards the possibilities of estimating the moisture content of the earth's surface using multispectral space images of the optical range on the example of the territory of Ukraine]. *Dopovidi NAN Ukrainy*, 11, 122-128 [in Ukrainian].

21. Stankevych, S.A., Pylypchuk, V.V., Lubskyi, M.S., H.B. Krylova, H.B. (2016). Otsinka tochnosti vyznachennia temperatury shtuchnykh ta pryrodnykh zemnykh poverkhon za rezultatamy infrachervonoho kosmichnoho znimannia [Assessment of the accuracy of determining the temperature of artificial and natural earth surfaces based on the results of infrared space imaging]. *Kosmichna nauka i tekhnolohiia*, 22(4), 19-28 [in Ukrainian].

22. Serbov, N.G., Tkachuk, M.N. (2019). Ocenka jekologicheskih riskov zagrjaznenija gruntov (na primere Pridunajskih rajonov Odesskoj oblasti) [Assessment of environmental risks of soil pollution (on the example of the Danube districts of the Odessa region)]. *Sciences of Europe*, 45, 37-45 [in Russian].

23. Hladun, H. B., Hladun, Yu. H., Yeterevska, L. V. (2014). Adaptyvno-landshaftni pryntsypy zastosuvannia polezakhysnoho lisorozvedennia v Odeskii oblasti [Adaptive landscape principles of the use of protective afforestation in the Odesa region]. *Ahrokhimiia i gruntoznavstvo*, 81, 59-65 [in Ukrainian].

24. Andreev, S.M., Krasovskij, G.Ja., Solovej, V.V. (2011). Metod ocenki plodorodija pochv po materialam kosmicheskih sjomok (na primere Tatarbunarskogo rajona Odesskoj oblasti) [Method for assessing soil fertility based on satellite imagery (on the example of the Tatarbunarsky district of the Odessa region)]. *Uchenye zapiski Tavricheskogo nacional'nogo universiteta im. V.I. Vernadskogo. Serija Geografija*, 3, 16-23 [in Russian].

25. Gorun, V.V. (2012). Kompleksnaja ocenka rekreacionnogo potenciala administrativnyh rajonov Odesskoj oblasti [Comprehensive assessment of the recreational potential of the administrative districts of the Odessa region], *Krajobraz i turystyka w warunkach zrownowazonego rozwoju*. Proceedings of the Landscape and tourism in a sustainable develophent. Kielce-Sobkow [in Polish].

26. Rubel', O.E. (2009). Jekonologija vetlandov [Ecology of wetlands]. Kishinev : Eco-TIRAS [in Russian].

27. Tuchkovenko, Ju. S., Gopchenko, E. D. (Ed.) (2011). *Aktual'nye problemy limanov severo-zapadnogo Prichernomor'ja: Kollektivnaja monografija* [Actual problems of the estuaries of the northwestern Black Sea region: Collective monograph]. Odessa: TJeS [in Russian].

28. Popova, O.M. (2016). Morfometriia ta toponimiia hidrolohichnykh obiektiv natsionalnoho pryrodnoho parku «Tuzlovski lymany» [Morphometry and toponymy of hydrological objects of the national natural park "Tuzlov estuaries"]. Visnyk ONU. Seriia heohr. ta heol, 2 (29), 64-84 [in Ukrainian].

29. Minicheva, H. H., Ye. V. Sokolov, Ye. V. (2014). Otsinka pryrodnoi stiikosti lymaniv Pivnichno-zakhidnoho Prychornomoria vidpovidno do pryntsypiv vodnoi dyrektyvy YES [Assessment of the natural sustainability of estuaries of the North-Western Black Sea Coast in accordance with the principles of the EU Water Directive]. *Naukovi dopovidi Natsionalnoho universytetu bioresursiv i pryrodokorystuvannia Ukrainy*, 5, 46-51 [in Ukrainian].

30. Sokolov, E.V. (2015). Tipizacija limanov severo-zapadnogo Prichernomor'ja na osnove gidrologo-morfometricheskih harakteristik [Typification of Limans of the North-Western Black Sea Coast Based on Hydrological and Morphometric Characteristics]. *Naukovi zapysky Ternopilskoho natsionalnoho pedahohichnoho universytetu imeni Volodymyra Hnatiuka. Seriia: biolohiia*, 1(62), 49-56 [in Russian].

31. USGS GlobalVisualizationViewer. Retrieved from http://glovis.usgs.gov/

32. NASA LP DAAC, 2013. NASA Shuttle Radar Topography Mission (SRTM) Version 3.0 (SRTM Plus) Product Release. Land Process Distributed Active Archive Center, National Aeronautics and Space Adminitration. Retrieved from https://lpdaac.usgs.gov/about/news archive/

33. OpenStreetMap Data Extracts. Geofabrik downloads. Retrieved from http://download.geofabrik.de/europe/ukraine.html

34. Using the USGS Landsat 8 Product. Retrieved from http://landsat.usgs.gov/ Landsat8_Using_Product.php.

35. Dalezios, N.F. (2002). *Environmental Remote Sensing, University Teaching*. University of Thessaly: Volos [in Greek].

36. Fuller, D.O. (1998). Trends in NDVI time series and their relation to rangeland and crop production in Senegal, 1987-1993. *International Journal of Remote Sensing*, 19(10), 2013-2018. https://doi.org/10.1080/014311698215135

37. Rouse, J., Haas, R., Schell, J. Deering, D. (1974). Monitoring vegetation systems in the Great Plains with ERTS. In Proceedings of the Third ERTS-1 Symposium NASA SP-351, Washington, DC, USA.

38. Wilson, E. H. & Sader, S. A. (2002). Detection of forest harvest type using multiple dates of Landsat TM imagery. *Remote Sensing of Environment*, 80 (3), 385-396. https://doi.org/10.1016/S0034-4257(01)00318-2

39. Sentinel-2B_MSIL1C Products. Copernicus Open Access Hub. Retrieved from https://scihub.copernicus.eu/dhus/#/home\

40. The Water Code of Ukraine with amendments and additions introduced by the Verkhovna Rada of Ukraine from 04.09.2014 under 1193-VII (1193-18). (2014, October 9). *Holos Ukrainy*, pp. 10-48 [in Ukrainian].

41. DIRECTIVE 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy (2000). Retrieved from http://eur-lex.europa.eu/legalcontent/EN/TXT/?uri=CELEX:32000L0060