JEB
Journal of Environmental Biology

Journal Home page : www.jeb.co.in
E-mail : editor@jeb.co.in
ISSN: 0254-8704 (Print)
ISSN: 2394-0379 (Online)
CODEN: JEBIDP

Analysis of land use changes near large water bodies in Ukraine using GIS

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Publication Info

Paper received:
15 July 2013

Revised received:
20 October 2013

Re-revised received:
18 June 2014

Accepted:
22 September 2014

Abstract

Analysis of land use and land cover changes in Ukraine were evaluated with special attention given to the interaction of land and water resources. The rational fresh water management in agriculture under future climate change conditions is of great importance. The hydrological regime of a river has huge impact on the environment of the surrounding area. Creating reservoirs, changes the landscape of river valleys and lake basins. Changes in the hydrological regime of the river and the process taking place in the coastal zone are reflected in land cover, wildlife and micro-climatic conditions. In the area closer to the shore line of the reservoir, there is greater amplitude of fluctuations in the level of ground water due to low rate of filtration behind fluctuations in the level of the reservoir. The interaction of water reservoirs with the environment, especially with the nature of the catchment area is substantially different from the natural water bodies. Analysis was done using GIS and remotely sensed data of land use near large water reservoirs and processed statistically. The ratio of arable lands and forested territories and future analysis of land use has been discussed.

Key words

GIS, Land cover, Land use, Water bodies, Ukraine

Introduction

Fresh water supply for people, agriculture and industry is increasing day by day due to population increase and global climatic change. This need is fulfilled by reservoirs, large water bodies and very complex artificial engineering objects, allowing to distribute the river flow over time and space. The reservoirs have become the basis of versatile and technological utilization of water resources and should be viewed as natural-technical systems (Berga *et al*., 2006; Vendrov and Diakanov, 1976). The main parameters such as volume, area, mode of regulation, etc. are determined by the engineers of this field. There are special technical systems, facilities and equipment in the water works, allowing a change in the volume and level of water in the reservoirs. They also contribute to the economy and the nature of the territories where these are created with a number of adverse unwanted changes.

The interaction of natural and technical sub-systems can greatly increase the chances of sustainable and integrated use of reservoirs but any negligence can lead to significant losses or even a catastrophe. It is possible to develop processes and phenomena in the natural subsystem for controlling the technical subsystem of a reservoir (Starodubtsev, 2004). A person manages water supplies directly but it has indirect impact on the ecosystem and geosystem. Creating reservoirs changes the landscape of river valleys and lake basins. The hydrological regime of a river has huge impact on the environment of the surrounding area and its environs. Interaction of water reservoirs with the environment, especially with the nature of the catchment area is substantially different from natural water bodies.

The greatest change occurs in the upper part of a reservoir and in the bays where the water leaves the flooded floodplain and the state of the river stored only in its former bed. A lower landscape of a reservoir-river system also changes, especially for seasonal and long-term flow regulation. Changing the mode of sediment load causes erosion of the river bed, at the same time the changes of channel processes in estuaries occur. These changes can be observed at distance of hundreds or thousands of kilometers (Matarzin, 2003) away from the source.

Change in the hydrological regime of the river and the processes taking place in the coastal zone are reflected in land cover, wildlife and micro-climatic conditions. Ground water level in the areas adjacent to the reservoir undergo fluctuations during the year in response to change in water level in the reservoir, when the drawdown of the reservoir water level starts to drop. Areas that are closer to the shore line of the reservoir, there is a greater amplitude of the fluctuations in the level of ground water due to low rate of filtration behind the fluctuations in the level of the reservoir. Also, at some distance groundwater level can decrease, while the level of the reservoir increases. Seasonal fluctuations in the water level do not apply to the entire width of the inlet pressure of groundwater. Increased groundwater levels, causing waterlogging and flooding of the territory, leads to a change in soil chemical composition of groundwater and vegetation (Vendrov, 1976; Starodubtsev, 2004, 2012).

River system is the integrator of geomorphological processes in the pool; it is very sensitive to changes in the landscape, and closely connected with other components of the landscape. Since river basin subsystems are closely related with each other and factors and components of physical and geographical environment, they operate on a specific pattern of the river basin. Later has specific features: a change in the nature and intensity of anthropogenic pressure closely related to the transformation of the landscape, changes in the structure of the river system. Water features play an extremely important role not only in shaping the landscape, the functioning of natural biomes, conservation of gene pools of terrestrial, aquatic and semi aquatic flora and fauna they also play an important role in a number of biological, environmental and historical and cultural events (Sokil, 2010).

Among many factors of reservoir impact on adjacent territory criteria given by Starodubtsev (2004) and Vendrov (1976) are pointed out in the present study.

Hydrogeological impact, which occurs with different intensities depending on climatic conditions, geography of the region, reservoir regime, geomorphology of the coasts, soil and subsoil infiltration characteristics, etc. On the reservoir coast there is a constant flux of infiltrated water from the watershed to the reservoir and vice versa. In the Forest-Steppe zone, the area of groundwater head is usually spread over a few kilometers.

Waterlogging of coasts occurs when ground water table or capillary fringe elevates and joins the plant root layer of soil, increasing natural soil moisture, causing positive and negative effects on agricultural land use depending on its intensity and local conditions, in some cases it could be followed by acidization or salinization (Filkin and Eremchenko, 2011; Romanenko, 2000). There is an impact of large water bodies because of the difference between the solar radiation balance.The reservoirs play a role of “air conditioner” in the landscape and have a cooling effect in the spring and a warming effect in autumn. Changes in plant cover can be stipulated by the reservoir impact by seasonal and extreme flooding and waterlogging of different intensities. Slight waterlogging will initiate good growth and fast development of grasses on pastures and croplands.

Blue-green algal development, especially in shallow waters of the reservoir can cause a real damage reducing the amount of free oxygen in water, then they get deposited on the coasts and decay. Aim of the present study was detect land-use changes in the areas near large water reservoirs in Ukraine.

Materials and Methods

Dnipro is the third largest transboundary river of Europe after Volga and Danube. Dnipro's Basin is located in the territories of three countries of the Eastern Europe –Russian Federation, Belarus Republic and Ukraine. The total area of the basin is 511.000 sq. km. It is 19.8% of the catchment area of the Dnieper basin within the Russian Federation, in Belarus 22.9%, and in Ukraine 57.3% (Fig.1).

Dnipro Basin has medium population density in Eastern Europe with 32.4 million inhabitants; including in 3.6 million inhabitants the Russian part of the basin. 6.3 million Belarus Republic and 22.2 million inhabitants in Ukraine. About 69 % of the Basin population lives in large cities and metropolitan areas, which are characterized by strong diversified economic

Fig. 1 : Map showing Dnipro river basin in Russian Federation, Belarus and Ukraine

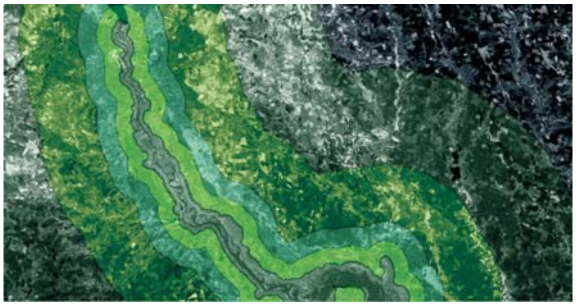

Fig. 2 : Buffer zones from Kanivske reservoir: 1km, 5 km, 10 km, 25 km, and 50 km respectively

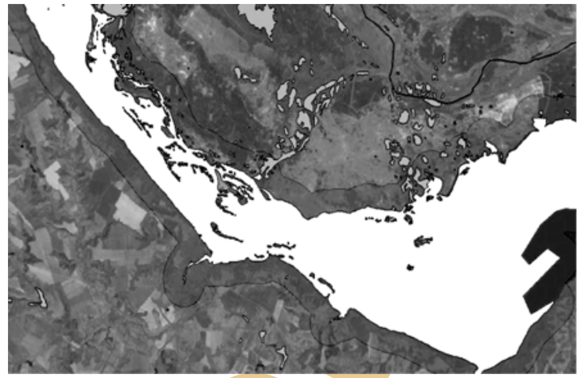

Fig. 3: Vector shape of Kanivske reservoir of the Dnipro river and surrounding lakes overlayed on Landsat TM image (1992)

Fig. 4 : QGIS project view, with thematic layers on the left

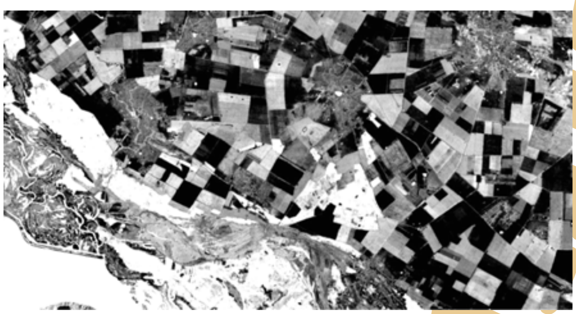

Fig. 5 : Image of calculated NDMI in Landsat data, 1992

complex, high utilization of natural resources, and considerable anthropogenic pressure on the environment (Kushnirenko, 2009).

Kanivske reservoir was constructed in 1974 on Dnipro river. It is located between highland on the right bank and lowland on the left bank and has an area of 675 km^2 with total capacity of 2.63 km^3. It is a typical reservoir in Ukraine, constructed on plain land, with average of 4 meters, maximum depth of 21m. Over 20 villages were moved during its construction, and it was selected as a typical object of reservoir impact on land use under the climatic conditions present in the area.

For studying the environmental impact of reservoir on landscape Landsat legacy imagery from June to July, in 1975, when the reservoir was finished and began to work, the environmental impact of the reservoir was not sufficient yet; in 1992, it was on high performance, and in 2002 and 2010 (presently) were used.

Necessary preprocessing was made, and the data imported to the open-source geoinformation software Quantum GIS (QGIS 1.8 Lisboa), which was used to provide necessary geoprocessing procedure. After digitization of Dnieper map from scanned topographic map, using vector geoprocessing tools in QGIS, the following buffer zones from reservoir were built: 1km, 5 km, 10 km, 25 km, and 50 km; to estimate reservoir impact on land use of adjacent territory (Fig. 2 and 3).

Normalized Difference Moisture Index (NDMI) was calculated to estimate moisture by imagery data:

NDMI = [IR band - SWIR band] / [IR band + SWIR band].

It is used widely by the environmental scientists to estimate moisture from MODIS and especially Landsat imagery (Goodwin *et al.,* 2008; Lin *et al.,* 2011; Bogdanets, 2012). A lot of features can be defined visually on the images (Hansen, 2005; Wang *et al.,* 2009), however, in general cases it is hard to obtain high resolution imagery for an intended evaluation, but medium resolution allows to analyze complex mixed-classes objects and areas as a landscape-in-continuum (Weng and Lu, 2009).

Results and Discussion

On the lower left bank of Dnipro river the impact of reservoir on soil moisture was sufficient enough than on the right bank, which depends on geological and geomorphological conditions, the effect took place at 1 km, 5 km and even the slighter effect at 10 km distance. At 25 km-buffer zone its impact was much less, and, in 50 km buffer, no reliable impact of moisture increase was detected in the reservoir. So, attention was focused on the left bank of the reservoir.

At 1 km buffer zone a lot of channels and ponds were located, many were constructed in 1970's according to the engineering project to prevent land waterlogging; specific type of plants - meadow grasses - were found here, mostly on swampy, soddy and meadow soils. They formed wetlands in conjunction with flooded lands – a unique and important part of the landscape.

At 5 km zone from the reservoir, the character of land use changed, soil cover was still represented by meadow, meadow chernozem and other glayed soils with high level of ground water domination. Because of high risk of waterlogging, the most widespread land cover types were pastures, grasslands and forests with places for recreation, however, arable land was relatively rare. On the high right bank the level of ground water was low and arable lands also played a dominant role (Fig.4).

At 10 km zone the risk of waterlogging was relatively low, arable lands were occupied mainly by vegetable and technical crops, and the share of forests was extremely low. At 25 km buffer zone there was a typical agricultural landscape of Ukrainian Forest Steppe zone, with very high share of arable land, divided by lines of trees. Mostly cereal crops were grown on local fields, but also some impact of wetness from underground was coming from the reservoir and could be observed especially in lowland soil cover.

Calculated NDMI (Fig.5) showed that moisture level of the surface depended on distance from the reservoir at places where there was no other reliable source of surface water (irrigational channels, small rivers, lakes, ponds, etc.). This effect was observed at 1-5 km buffer zone, at 10-25 km zone it gradually decreased, and at 25-50 km zone it was not observed. This is in conformity with the findings of several authors (Vendrov, 1976; Starodubtsev, 2004), but according to the calculations moisture effect was visible even at 10 km buffer zone.

Comparing development of the landscape from 1975 to 2010, the evident land cover and land use changes took place. Many of them, such as movement of flooded forests, pastures and grasslands were connected with the reservoir activity, others, such as changes in the ratio between arable lands from one side, and pastures and forested lands from the other, moving cropland in 10-25 km zone from 5-10 km zone in 2002-2010 have mainly economic reasons. Compared to 1975, in 1992 the share of arable land increased, but it restored and even decreased in 2002 and 2010. The reason is economic trend in Ukraine and the state policy of decreasing the share of arable lands for harmonization of landscape component by withdrawing to pastures, forests, etc. However, in the investigated areas in the agrilandscapes results of classification of Landsat data showed that the share of forested land was less than 1%, that's the reason to look on the land use structure and measures preventing wind and water erosion in agrilandscapes, and ways to achieve sustainable landscapes with minimizing risk of land degradation.

Veldkamp and Lambin (2001) emphasized that, the proxy variables, which are easier to measure spatially (e.g. distance to a road or a town), are often used for deeper underlying driving forces (e.g. influence of markets).This shift from driving forces to proximate causes, for data convenience, might obscure causality. Subtle land-cover or land-use modifications, e.g. related to changes in cropping patterns, input use or tree density of forests, also need to be taken in to account in addition to the more easily measurable land-cover conversions. Moreover, land-use change models need to account for the endogeneity of variables such as land management technologies, infrastructures or land-use policies. These are also concerned with the land-water interaction in landscape with large water bodies and material presented on waterlogging and land use.

Changes in the hydrological regime of the rivers and the processes taking place in the coastal zone of the reservoirs are reflected on land cover structure, wildlife and micro-climatic conditions. GIS analysis of remotely sensed data of land cover and land use near large water reservoirs shows important role of ground water on landscape components near the reservoir, than its impact is minimized quickly by the distance. Up to 5-10 km there's sufficient impact of groundwater, slight impact observed up to 25 km from the reservoir. However, it depends on individual conditions of the territory. As compared to 1975, in 1992 the share of arable land increased, but it restores and even decreased in 2002 and 2010. The share of forested land is less than 1%, that's the reason to revise measures preventing wind and water erosion in agrilandscapes, and ways to achieve sustainable landscapes with minimizing risk of land degradation.

That's a starting point for land planners in typical conditions of Forest-Steppe zone near large water bodies to achieve balanced land use.

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