Possible impact of different scenarios of climate change on the formation of some ecosystem services in the Azov-Black Sea region

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Abstract. To estimate possible changes for some economical branches in South Ukraine which use the nature resources, three scenarios of climate changes were reviewed: increase of temperature and increase of precipitation; increase of temperature and decrease of precipitation; decrease of temperature and increase of precipitation. Impact on the Azov Sea ecosystems under these three scenarios was considered in respect of changes in salinity and temperature of water that consequently effects on ichthyofauna and fish industry. Trends of fish suffocation are also described. Agricultural risks induced by pests (on an example of the locust) under extreme high temperatures in a spring-summer season were discussed, with identification of possible distribution sites of the pest. The research carried out in the framework of the project “Building Capacity for a Black Sea Catchment Observation and Assessment System supporting Sustainable Development” (2009-2013) of the 7th Framework Programme

1. Introduction

As a rule, the researchers now understand ecosystem services as the quite wide range of the forms of the use of the functions of ecosystem, based on the need of the society to use the natural resources in the sparing mode which will not lead the natural processes and the individual ecosystems to depletion [1–4]. Biodiversity has been and remains as one of the most difficult service which is amenable to research and forecasting. At the same time, the climatic changes influence on significantly both biodiversity as a whole, its individual components, and the welfare (well-being) of the person, which he receives on the basis of biodiversity [5, 6]. And if the influence of the climatic changes directly on the individual aspects of diversity is in the focus of the scientific research today [7–9], so the assessment of the influence of such changes on ecosystem services in the Ukraine has been studied weakly yet.

On this background, realizing the need to move forward on the path to the solution of the actual problems of management of natural, semi-natural and artificial ecosystems, there have
been arisen the views which the authors have tried to express in the article. Dialectically, these views are not new, and they suggest gradually moving from the particular to the general, including the individual ecosystems or their composite biota in the research cycle, on the example of which it can be traced the possible qualitative and quantitative changes reliably that reflect on the socio-economic consequences of the exploitation of bio-resources of these ecosystems inevitably.

We have been made the attempt to present such consequences on the example of ecosystems and the individual elements of biota, which are significantly separated from each other at first sight, which have been the most studied, and the consequences of the exploitation of these resources can change the accents of ecosystem services. To such ecosystems, the use of resources by human “lies on the surface” and forms the significant services for the economy, we have attributed the ecosystem of the Sea of Azov with its historically established fish resources, the ecosystem of the Delta of the Danube, where renewable storage of building reed has become the important branch of the economy, the zonal steppe ecosystems and their surrogate derivatives such as agroecosystems that will change inevitably under the influence of the different scenarios of the impact of climate. The presented results of the research will help people who make decision in the questions of the use of nature during the formation of the strategy of the sustainable development of the region.

It should be noticed, the importance of finding solutions for the management of individual ecosystems requires an understanding of trends in the climate change and the transformation in the biocenoses structure.

Previous studies [10–12], which were focused on finding management solutions did not always take into account these aspects and could not become effective tools for ecosystem restoration. Also, in many similar solutions the impact of climate was considered quite generally and used stereotypical statements about the negative effects of climate change.

In this paper, we aimed to demonstrate various aspects of climate impact in a fairly wide region at the individual components level of ecosystems.

2. Material and methods
This work uses series of monitoring observations for the period 2009 – 2012. In addition, we studied available retrospective data on the Azov Sea ecosystem and changes in this sea ichthyocoenoses, as well as the data on the Danube Delta intrazonal ecosystem and production of its key species – the reed *Phragmites australis* which forms the delta landscapes. Geobotanical survey was performed in 2010 – 2011 on monitoring plots in zonal (steppe) and intrazonal (meadow) vegetation communities of the Azov Sea Region; preliminary predictions for these communities were made. For some ecotone ecosystems of the Azov Sea Region there was developed a prognostic scenario on dynamics of an agricultural pest, the locust (*Locusta migratoria* L., *Acrididae, Orthoptera*).

Analysis of changes in the Azov Sea ecosystems is based on main trends of hydrometeorological conditions, taken from specialized sources [13], and information of the National Climatic Data Center (NCDC) [14].

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Dynamics of reed communities in the Danube Delta was studied from 1998 to 2011 by common methods of geobotanic survey, along census routes, in permanent and half-permanent plots [15–17]. A method of test and control was used to reveal impact of the winter reed harvest on the vegetation condition. Transects for the survey were made from outer edge of the island to the inner part, each 500 m along the perimeter, with GIS coordinates affixment, and control
mowing of vegetation in $1 \ m^2$ in areas with different ecological conditions of growth (constant underflooding, prolonged or periodical underflooding or no underflooding).

Morphometrical parameters of the reed were studied in testing and control areas, and in areas of commercial harvest. For the all observation period over 700 descriptions of vegetation were made, 475 survey mowing on $1 \ m^2$ were cut, over 2500 plants and more than 8500 morphometrical parameters were measured, among them the total vegetation mass from $1 \ m^2$ (including the reed mass, number of reed stalks, their height and diameter, number of flowering and pest-damaged plants, etc.)

Steppe and meadow communities were monitored in 2010−2011, from the third decade of June to the third decade of October in control plots of the North Azov Region. Phytomass of communities were measured in 213 sample plots (each 30 to 100 $m^2$) in zonal steppe communities, and in 45 sample plots in intrazonal meadow communities. Description of areas was given according to standard geobotanic methods [17, 18]. Exposition and steepness of slopes, general microrelief, types of soil and their characteristics were fixed. Qualitative ratio of species in plots was determined by 5-point Braun-Blanquet cover-abundance scale. Phytomass of meadow biotopes was evaluated by mowings of vegetation within $1 \ m^2$ plots. The mown phytomass was weighted by electronic scale with $1 \ g$ accuracy.

The abundance of the locust *Locusta migratoria* L. (*Acrididae, Orthoptera*) was estimated by census routes method (44 censuses in 2010 − 2012), in 3 permanent plots located in the North Azov Region. The calculations used a relative abundance per $1 \ km$ of the route. Larvae and swarms were estimated as number of individuals per $1 \ m^2$.

In literature, there are no unequivocal views about scenarios of climatic changes. In various geographic areas these changes manifest themselves differently. In addition, they are amplified by human interference and nature management. The analysis of hydrometeorological data in the Azov Sea Basin gives a possibility to determine several, the most probable for the region, scenarios of climate changes:

(i) increase of temperature and increase of precipitation;
(ii) increase of temperature and decrease of precipitation;
(iii) decrease of temperature and increase of precipitation.

3. Results and discussion

**Azov Sea ecosystems.** Main trends of climate changes for the Azov Sea ecosystem are the following:

(i) Increase of average annual air temperature at the sea coastal meteostations for the last 30 years by $0.42−0.55^\circ C$ per each 10 years;
(ii) Increase of average annual water temperature by $1 ^\circ C$ for the last 50 years;
(iii) Decrease of salinity for the southern coast by $2.28g/l$, and for the northern coast − $2.67g/l$ for the last 30 years.
(iv) Sea level rise with the average rate of $2.11 \ cm/year$

These changes of basic parameters have provoked a succession dynamics of main hydrobiological indices of the ecosystem.

Increase of precipitation and, correspondingly, the volume of river drainage is a major determinant of salinity. It influences on fish productivity, forming the food base in the former decades, increase of salinity in the Sea of Azov brought about the appearance of the comb jellyfish *Mnemiopsis leidyi* which greatly undermined zooplankton biomass and affected productivity of most short-cycle fish species European anchovy (*Engraulis encrasicolus*) and Azov Sea sprat (*Clupeonella cultriventris*).
For the Sea of Azov, we can forecast the changes of fish communities and general indices of fish productivity according to three above-mentioned scenarios. These scenarios can have a noticeable impact on socio-demographical situation in the region.

1\textsuperscript{st} scenario will lead to decrease of salinity due to increased drainage of the rivers. This scenario is the closest to present conditions. Increase of air temperature will bring about increase of water temperature. As it was mentioned above, this trend will lead to further desalinization of the Azov Sea. Currently, the sea salinity is 10.2 \( g/l \) which is typical for a natural (before the construction of Tsymlyansky Hydrocomplex) condition of the sea.

Further decrease of salinity up to 9.5 – 10 \( g/l \) will not lead to any considerable changes in ichthyofauna structure. The European anchovy and Azov Sea sprat will remain to be dominating commercial species and current trend of their number growth will continue. The increase of stocks of these fish species will assist to improvement of socio-demographical situation in the industry. The increase of their catch will promote the growth of work places in extractive and processing fish industries. An important element of the development of fish extraction enterprises will be a possibility to catch fish using a fixed net in coastal waters without special vessels and trawls. It can assist to the development of small business in the coastal villages.

Decrease of salinity lower than 9 \( g/l \) will be critical for the Azov Sea ecosystem because under these conditions a majority of Ponto-Caspian species cannot live. In this case it is possible essential changes in the structure of communities negative for fish productivity and fish industry on the whole.

Increase of temperature to some degree will compensate the considerable freshening of the sea at the expense of evaporation from water surface. Especially strong evaporation may be observed in mouth zones of Molochny Liman and Sivash. Intensively evaporating, these water bodies will bring a great part of salts into salt balance of the sea.

An important consequence of increase of temperature will be increase of the frequency and area of suffocation phenomena. The combination of high summer temperatures and the calm lead to stratification of water and rapid decrease of the oxygen dissolved in lower water layers. The oxygen reduction lower than 3 \( mg/l \) results in mass mortality of bottom fish species – mostly gobies in present conditions (round goby \textit{Neogobius melanostomus}, bullhead \textit{Neogobius fluviatilis}, goad goby \textit{Neogobius fluviatilis}, Syrman goby \textit{Neogobius syrman}, etc.) (figure 2).

Analyzing the long-term hydrometeorological data [13], increasing frequency of high temperatures without wind conditions combination leads to water stratification and a critical decrease in dissolved oxygen. Linear trends of average monthly wind speed values calculated for the period 1945 – 2006 made it possible to identify significant trends in wind speed decrease in all seasons of the year for most points on the coast of the Sea of Azov. On the northern coast of the Sea of Azov, there are statistically significant negative linear trends (with values from \(-0.16 \) to \(-0.33 \) m/s over 10 years).

Also noteworthy is the warming of the surface water layer in the summer season, mainly in August. The highest significant coefficients of linear trends (0.051 – 0.087 °C/year) have been identified over the past 30 years on the entire sea coast [13]. In recent years (1986, 1992, 2001, 2007, 2008), the water temperature in August is significantly higher than long-term climatic values, and the entire sea area is occupied by strongly heated waters with a temperature of 27 – 28.5°C.

As for the socio-economical situation in the region, acceleration of such phenomena will lead to the following negative consequences: decline in fish stocks of bottom fish species; decrease of profitability of fish industry because of worsening of the production, e.g. even alive gobies captured in pre-suffocation period are lower in price; worsening of aesthetical and recreational potential because of mass discard of dead fish at beaches of the region.

Official data of the Azov Special Fish Protection Service show a trend of increase for the duration of suffocation phenomena and the volume of dead fish (figure 2).
Figure 1. Gobies on the Berdyansk beaches (photo http://www.brd24.com).

Figure 2. Summarized annual length of fish suffocation strip in the Sea of Azov during 2002-2011.
2nd scenario (increase of temperature and decrease of precipitation) will lead to increase of salinity due to increase of evaporation from water surface. This condition of the sea already was in the period of 1960 – 1980s. The only difference of that period was that the reduction of river drainage had anthropogenic reasons. In that period the sea salinity reached 14 g/l which is again possible in case of decrease of precipitation and increase of temperature in the region. In this situation a negative role of the jelly-like organisms in formation of food zooplankton will grow which will further result in reduction of stocks of the anchovy and Azov Sea sprat. In these conditions number of jobs in fish-extracting and fish-processing industries will considerably reduce because of decrease in fish catches. An alternative commercial species may be the so-iuy mullet (*Liza haematocheilus*) (it is an euryhaline species and in case of increasing salinity its number may grow). However, it should be noted that the number of work places connected with the so-iuy mullet catching is fewer than in case of catching and processing of the anchovy and Azov Sea sprat. That is why this scenario will apparently bring about the tension in fish industry of the region.

3rd scenario will lead to decrease of salinity and air temperature. It will be similar to the first scenario, with salinity as a main factor.

In the last decade main commercial groups of fish species have been already changed. Thus, to-date valuable sturgeon species (*Acipenseridae*) are lost, the pike-perch (*Sander lucioperca*), the turbot (*Psetta torosa*) and many freshwater species. At the same time, decrease of salinity and reduction of jelly-like organisms lead to increasing stocks of the European anchovy and Azov Sea sprat and positive trend of the round goby [19].

**Intrazonal ecosystems of the Danube Delta.** The reed harvest in the Ukrainian Danube Delta is one of the important economical branches of the region since it is harvested in winter when a part of the local people is unemployed, and this type of activity acquires a crucial importance.

Observation of the reed condition in 2011 – 2012 allows to make a careful prognosis for the development of this type of activity. In 2011 and 2012 the flood in the Danube Delta was so low that water could not reach inner parts of islands and *plavni* ecosystems stayed almost all time without water. Only Stensovko-Zhebriyansky Plavni were inundated during all the vegetation period. This fact influenced the reed development and its general productivity. This factor was also added by other climate features of the year 2012. A prolonged winter 2011/2012 with quite low temperatures resulted in mortality of the wintering reed buds and delay of vegetation phase. The long cold winter and short spring were followed by the hot summer with occasional rains. The vegetation phase delayed 2 – 3 weeks compared to average annual terms, and the phase of reed’s flowers formation started in mid August. Over the whole territory of the Danube Delta the reed came into a flowering phase being much lower in height that that of all the preceding years. Changes touched also such indices as the reed diameter and density per 1 *sq.m*.

All of it affected the reed productivity in the whole territory of the Danube Delta. In August-September 2011 fires destroyed thousands of *ha* of *plavni* vegetation on a considerable part of delta islands. On these territories the reed development started already in 2 – 3 weeks after the fire. By the early December 2011 the reed had grown only to 0.3 – 0.5 *m*. There was no formation of young wintering buds in these territories so the reed parameters in the sites of summer fires of 2011 were even worse that in those where there had been no fires or they had been in winter.

Over the all territory, vegetation of the reed in 2012 came out from deeper buds of roots that reflected in the number of stalks, their height and diameter.

Climate changes will have an essential impact on the success of reed harvest. The observed rise of Black Sea level and increased frequency of wind-driven water level fluctuations may result in increase of water level in the secondary delta of Kilia Branch of the Danube Delta, reduction of the reedbeds surface area and increase of cattail-reed associations.
Trend of decrease of flood water level in the Danube will lead to expansion of saline meadow and marshy-meadow communities on high ridges, with low percentage of the reed. In case of hot summer also the increase of fires frequency is expected. It will lead to changes in vegetation and formation of a marshy-meadow communities. This process of meadow formation in plavni is already observed on considerable areas of the Kilia Delta. The fires will change the cell membrane structure of the reed due to accumulation of ash constituents in soil which make parenchyma thinner, and the stalk more fragile. The latter will substantially reduce its commercial value.

Increase of summer temperature even by 1.5 − 2.0°C will bring about the shifts in timing of the reed development, especially transition into a winter phase. During 2009 − 2012, especially in winter 2011, the phase of leaf fall was practically absent and this substantially disrupted the terms of starting the reed harvest. It started only in early December, and the work was more expensive because of additional costs connected with cleansing the stalks from leaves when sorting and packing the reed for export.

As for positive trends in reed communities in terms of the reed harvest it is only the increase of the ecosystem mineralization due to the rise of the Black Sea level. The reed, growing in brackish areas, ripens more quickly and its stalks are stronger and adherent which increase its commercial value.

Taking all the above-mentioned into account we can make the following conclusions according to influence of climate changes on socio-economical conditions of residents of the region in connection with the reed harvest. Not stable qualitative characteristics of the reed require for a manual labour when sorting out the stalks. Therefore, the use of woman’s work and especially elderly people will grow. Increase in the demand for manual labour will result in prolongation of the working period for almost the whole year.

Shortening of the harvest period directly in plavni as a result of delaying leaf fall and considerable fluctuation of water level will lead to survival of only powerful harvesting companies which will be equipped with “Seiga” combines. Increase of a portion of the cattail-reed communities will result in a new activity of local people - winter cattail harvest of the which is already appearing at the labour-market.

4. Changes in some zonal and intrazonal ecosystems of the azov sea region

According to the results of the monitoring in the North Azov Region in 2010 − 2011, we have noticed a meadowification trend of steppe communities due to increase of phytoecenotic role of *Elytrigia repens, Cynodon dactylon* (on dark- and light-chestnut low fertile soils). In addition, retrospective data for the period 1952 − 2011 show a clear phytomass increasing trend for steppe communities with the dominance of *Stipa capillata*. Phytomass growth is a direct consequence of increasing amount of precipitation and air temperature. If this trend of increasing precipitation and air temperature continues it may lead to meadowfication of southern steppes.

Meadow vegetation communities take an insignificant portion within the studied section of the coast, and changes in their structure cannot cause any serious economic effects. Though, at the local level, changes of the meadow communities productivity can have a substantially effect on productivity of pastures and hayfields. Thus, for two years of observation (2010 − 2011) phytomass of meadow communities with the dominance *Elytrigia repens* in monitoring areas had a positive trend: from 4.2 to 22.0%.

In case of the 1st scenario (increase of air temperature and decrease of precipitation) the productivity of *Puccinellia gigantea* meadows can reduce 2 − 3 times. Respectively, number of grazing cattle or volume of haymaking will be also 2−3 times reduced. With average productivity of these communities as 40 − 50 kg/ha of green mass and market price of hay in the region as 1 UAH, loss because of lack of forage (for a single mowing) would be equal from 500 to 520 thou. a year (e.g. monitoring plot at the right coast of Molochnyi Liman). In meadow communities of
Elytrigia repens the productivity can drop 6 – 7 times, and the loss will be about 80,000 UAH.

In case of the 2nd scenario (increase of air temperature and increase of precipitation) the productivity of meadow coenoses can rise by 20 – 30%. In this case the overall commercial volume of hay can increase to from 600 to 750 – 800 thou. UAH/year (total for monitoring plots of Molochny Liman and Syvashik Bay).

At the present time, a major profitable type of activity in steppe areas is the cattle raising.

In case of the above-mentioned 1st scenario (increase of air temperature and decrease of precipitation) and dominating processes of desertification, the productivity of steppe areas can reduce 4 – 7 times in feather grass-fescue and fescue-feather grass communities. Respectively, heads of grazing cattle or volume of haymaking will be also 4 – 7 times reduced. With average productivity of feather grass-fescue and fescue-feather grass communities as 200 – 300 kg/ha of green mass and market price of hay in the region as 1 UAH, loss because of lack of forage (for a single mowing) would be equal from 450 to 550 thou. a year (control plot “Novopetrovsky”) and 850 – 950 thou./year for the Sivash monitoring area.

These consequences will be especially dramatic in Sivash Region where the hay-making is a major kind of use of vegetation resources. According to our observations the mowing takes place two times a vegetation season (May-June and the second half of August). In this case, we cannot exclude a possibility of steppe areas to be ploughed up as an alternative for haymaking or transition to sheep grazing which can successfully feed on low productive pastures. The sheep grazing will be even more destructive than ploughing and will greatly accelerate desertification.

Reducing productivity of steppe areas will probably be compensated by up-to-date techniques of the crop-growing including green forage crops (lucerne, esparcet, etc.). For Novopetrovsky area one of the solutions can be allocation of low productive steppe areas for building country cottages and recreation facilities.

In case of the 2nd scenario (increase of air temperature and increase of precipitation) and dominating processes of meadowfication, the productivity of feather grass-fescue and fescue-feather grass communities can rise nearly 2 times due to their transformation in couch grass beds and reach to 5600 – 5800 kg/ha. Respectively, heads of grazing cattle or volume of haymaking will become also 2 times greater. In this case the overall commercial volume of hay can rise to 1300 thou. UAH/year (control plot “Novopetrovsky”) and to 2000 thou. UAH/year for the Sivash monitoring area.

5. Insects of ecotone systems

The situation in the Azov-Black Sea Region, observed in 2010 – 2012, are connected with extreme high temperatures in the spring-summer period, and except for direct increase of air temperature and drought of soil, it leads to the considerable reduction of the watering area of near-water habitats and creates very favourable conditions for transformation of the locust (Locusta migratoria L.) in the gregarious (invasion) form. This situation is worsened with embankment and regulation of most rivers flowing into the limans of the Azov and Black Seas. River banks, lake shores and sea coasts with reed and sedge thickets (particularly Phragmites australis) are the main habitat for this species. Such sites are often surrounded by the steppes and agrocoenoses which potentially are in the most dangerous situation. Long-term observations show that potentially the most dangerous localities of the locust in Ukraine are the Danube River Delta and lower reaches of the rivers entering into the eastern part of the Azov Sea (figure 3).

The solitary form of the migratory locust prefers wild crops (e.g. the reed and Elytrigia). Gregarious forms during the first few days after hatching start to form concentrations (“clouds”) which density can reach to 80,000 larvae/m² for the 1st age and 7,000 larvae/m² for the 5th age. These clouds can move for a relatively large distances (marching “clouds”). In case of rare vegetation cover, the clouds of 5th age larvae can cover up to 3 km a day. The gregarious imagoes form swarms circa in 10 days after getting winged. In spite of the single form, the
individuals of the gregarious form can eat plants of many families when they are far from their breeding area or when the preferred forage is lacking i.e. can considerably change their food preferences in almost unlimited range. Every individual of the locust eats 300 to 500 g of green forage during its life including in the diet almost all agricultural crops, fruit trees, hayfields and pastures.

In 2012 the locust invasion has seriously damaged agricultural lands in south regions of the Russian Federation. But appearance of the locust outbursts at the Ukrainian Black Sea coast is only a question of the time. The situation with its harm to agriculture is worsened by imperfection of means of struggle against the locust, above all different pesticides. Implementation of new and high-effective chemical (hormonal) and biological means of struggle which will also entail the rise of financial costs for the harvest protection.

During monitoring of the locust indicator species, the changes in phenology of other species of insects were also recorded. In this respect, the year 2012 was characterized by an unusually early start of a very warm season, and terms of imago emergence for a majority of night Macrolepidoptera were ahead of normal time at least 14 – 16 days. Some representatives of this group demonstrated even more substantial time advance – up to 1.5 months in the light crimson underwing *Catocala promissa* (Noctuidae; Lepidoptera). The early start of a 2012 warm season was added by a prolonged period of the warm and dry weather.

These examples give an additional confirmation that phenological responses include not only a shift of insect development at the start of the season to earlier terms but further changes in phenology. Thus, phenophases, connected with the end of seasonal development, on the contrary, usually shift to later dates. It leads to prolongation of a period of active development, including that for pests, which can provide extremely negative socio-economic effects.

6. Conclusions
   (i) The global changes of climate cause the fluctuations of the natural conditions which determine the vital processes and the state of the individual species, grouping, ecosystems. At the same time, all existing scenarios have negative changes and they differ only in the large-scale negative transformations and the terms of the occurrence of the number of threats. Generaly, climate change affects the quality and availability of ecosystem services
in the Azov-Black Sea region.

(ii) For the Azov-Black Sea region, the climatic changes lead to changes not only at the level of the transformation of grouping, but also exert influence on the socio-economic conditions of the region. It has been investigated that changes of the salinity of the Sea of Azov, the increase of the water temperatures leads to suffocation phenomenon of resource species of fish and the decrease of the general fish productivity. It should be noted, according the official data during the period 2002−2012 in the summer there is a tendency to increase both the length of hypoxia phenomena and the volume of dead fish. These changes significantly affect the productivity of commercial fish stocks and threaten to reduce jobs in the region.

(iii) In Delta of the Danube, where as the result of the increase of the summer temperature by 1.5 − 2.0°C there is the dislocation of the terms of the development of reed and its transition to the winter phase, which leads to no leaves loss until harvest. Unstable quality characteristics of reeds require manual labor when sorting stems. It leads to the additional costs for the processing of the important building materials, and, accordingly, it affects the profitability of laying-in of reed.

(iv) The amount of precipitation determines the state of meadow grouping in the basins of the small rivers of Pryazovia and can affect significantly the productivity of pastures and hayfields. So, for two years of the observations (2010 − 2011) the phytomass of meadow grouping with dominance of Elytrigia repens in the zones of monitoring has had the positive dynamics: from 4.2 to 22.0%. It determines the profitability of stockbreeding in the region and affects significantly the socio-economic development of rural areas.

(v) Extremely high temperatures in spring and summer period, except the direct increase of the temperature of air and soil drought lead to the significant decrease of humidity, which creates the favorable conditions for the transformation of locusts (Locusta migratoria L.) in herd (invasive) form. The mass development of this species can affect significantly agriculture of the southern regions of the Ukraine. In general, it should be noted that the different scenarios of the climatic changes affect the quality and availability of ecosystem services in the Azov-Black Sea region.

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References
[1] Brown T C, Bergstrom J C and Loomis J B 2007 Natural Resources Journal 329–376 URL https://www.fs.fed.us/rm/pubs_other/rmrs_2007_brown_t001.pdf
[2] Grime J P 1997 Science 277 1260–1261 URL https://doi.org/10.1126/SCIENCE.277.5330.1260
[3] Karimi A, Yazdandad H and Fagerholm N 2020 Ecosystem Services 45 101188 ISSN 2212-0416 URL https://doi.org/10.1016/j.ecoser.2020.101188
[4] Valencia Torres A, Tiwari C and Atkinson S F 2021 Ecosystem Services 49 101267 ISSN 2212-0416 URL https://doi.org/10.1016/j.ecoser.2021.101267
[5] Schippers P, Abarca E L, Verboom J, Wamelink G W, Claire C V, Boer W, Harvey J A, Essens T, Grashof-Bokdam C J, WallisDeVries M F and Cobben M M 2021 Biodivers Conserv 2885–2906 URL https://doi.org/10.1007/s10531-021-02241-4

[6] Verma A K 2021 International Journal of Biological Innovations 3 331– 337 ISSN 2582-1032 URL https://doi.org/10.46505/IJBI.2021.3213

[7] Albouy C, Leprieur F, Le Loc'h F, Monquet N, Meynard C N, Douzery E J and Mouillot D 2015 Ecography 38 681–689 URL https://doi.org/10.1111/ecog.01254

[8] Harrison S, Spasojevic M J and Li D 2020 Proceedings of the National Academy of Sciences 117 4464–4470 URL https://doi.org/10.1073/pnas.1921724117

[9] Urban M C 2015 Science 348 571–573 URL https://doi.org/10.1126/science.aaa4984

[10] Chernichko I, Aleksandrov B, Dyakov O, Kichuk I, Emud M, Voloshkevich A, Krylov N, Podorozhny S, Dubyna D, Voloh A, Chernichko R, Siokhin V and Tkachenko V 2002 Vision of the Danube Delta URL https://wwfeu.awsassets.panda.org/downloads/danube_delta_vision_rus.pdf?206062/Danube-Delta-Vision

[11] Consultancy W, Overmars W and Ebert S 2007 Danube Delta: a natural gateway to Europe Ecology and Economy in Harmony URL https://wwfeu.awsassets.panda.org/downloads/vision_doc_280107_final.pdf

[12] Demchenko V O, Vinokurova S V, Chernichko I I and Vorovka V P 2015 Environmental Science and Policy 37–47 URL https://doi.org/10.1016/j.envsci.2014.08.015

[13] Ilyin Y P, Fomin V V, Dyakov N N and Gorbach S B 2009 Hydrometorological conditions of the seas of Ukraine (Research and Production Center “Ecosy-Hydrophysics”)

[14] National Centers for Environmental Information URL https://www.ncei.noaa.gov/

[15] Alexandrova V D 1969 The classification of vegetation (Nauka)

[16] Mirkin B M 1984 The results of science and technology 5 139–232

[17] Walter G 1982 General Geobotany (Mir)

[18] Golubev V N and Korzhenevsky V V 1985 Methodical recommendations on the geobotanical study and classification of the Crimea vegetation State Nikitsky Botanical Garden

[19] Stepanenko S and Pol'oviy A M 2018 Climate risks of functioning of branches of economy of Ukraine in the conditions of climate change (Odessa State Ecological University) ISBN 978-617-7711-22-2