ISSUE ON LAND DEGRADATION IN KAZAKHSTAN

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Abstract
The scientific article is dedicated to the pressing issue of land degradation, which is observed and studied by the global scientific community, including Kazakhstani scientists. The classification and study of the state of degraded territories are of paramount importance as they are linked to further monitoring of the problem, determining the financial costs of implementing protective measures, and promoting sustainable development of these landscapes. It has been established that more than 90% of agricultural lands in Kazakhstan are subject to degradation processes, and this indicator varies depending on the type of land and their spatial distribution.

When monitoring pastures, data from the Terra and Aqua satellites were used to determine the degradation of pastures. Based on the results of comparing the degree of damage to pastures obtained by remote methods and on the basis of ground surveys, it was found that the reliability of the correct determination of a weak degree of damage corresponds to 75%, an average degree of damage - 85% and a severe degree of damage - 90%.

The authors of the article propose a classification of Kazakhstan's lands according to the Intergovernmental Panel on Climate Change and identify types of land degradation in Kazakhstan according to the «Wocat». The identified patterns of degradation processes in the territory of Kazakhstan are classified according to the Intergovernmental Panel on Climate Change levels. Directions for enhancing the sustainability of agricultural lands are determined based on classification criteria. The materials of this scientific research are recommended for use in land resource management and the development of agro-, phyto-, and agroforestry measures aimed at increasing the sustainability of desert agro-landscapes in Kazakhstan.

Key words: land degradation indicators; land productivity; soil organic carbon; land resource assessment; normalized vegetation index; Earth's remote sensing; land use.

Basic position and Introduction
Land degradation neutrality - one of the objectives of Sustainable Development Goals: by 2030, it is required to restore the degraded lands and soils, including the lands affected by desertification, drought and floods, and achieve a neutral balance in relation to degradation of lands [1].

Since the early of the 2000s, the global environmental changes have occurred on the Earth, the qualitative and quantitative indicators of land used in agricultural production have changed. Therefore, Land degradation neutrality is crucial in sustainability research.

According to the Food and Agriculture Organization of the United Nations, more than 66.0% of ploughland in Kazakhstan is vulnerable to erosion of varying degrees [2, 3, 4, 5].

In accordance with the Government order, in 2021, the Land Cadastre and Technical Inspection of Real Estate Departments performed work to monitor agricultural land [6, 7]. It has been found from 2000 to 2021 there was a decrease in the humus level by 12.0-33.8% on chestnut, chernozem soils of Akmola, Kostanay, Aktobe, East Kazakhstan, West Kazakhstan regions. The
physical and chemical soil characteristics of arable lands have deteriorated: granulometric and microaggregate composition, dispersion, hydrological constants, acidity. The density of the plough layer, mainly of medium density requires the measures aimed at loosing the subsurface layer of these soils. The farm areas in Atyrau, Mangystau, Kzyl-Orda, Turkestan and Zhambyl regions are characterised by overgrazing and degradation of plant cover [6, 7].

The examination of regional characteristics of indicators caused by the climate change and intensive economic activity is very necessary to take measures to reduce land degradation.

**Materials and Methods**

The United Nations Convention to Combat Desertification [8] adopted three Sustainable Development Goals indicators (15.3.1) for land degradation monitoring and assessing:

1. Soil cover;
2. Land productivity;
3. Carbon stocks above and below the soil surface soil organic carbon parameter. [1]

To determine the level of land degradation, a period of 10–15 years is taken into account [1]. The unit of measurement for the indicator "soil cover" is the spatial extent (ha or km2), expressed as a share (as a percentage) of degraded land in the total land area.

With respect to the land productivity indicator, the data can be obtained and calculated from earth observations by (remote sensing of the earth) using the Normalized Difference Vegetation Index (Normalized difference vegetation index).

The soil organic carbon indicator is calculated based on soil depth and volume density data determined for each deep soil layer (depth 0–30 cm) and subsoil [1].

The interpretation of these indicators should include the regional ecological and socio-economic conditions of study areas.

The purpose of the research is to analyze indicators for monitoring and assessing of land degradation that affect (Land degradation neutrality), to clarify future (Land degradation neutrality) trends for (sustainable development goals) achievement 15.3.1.

To achieve the main goal of the research, we should do the following:

- to establish the relationship between (Land degradation neutrality) indicators, land rehabilitation and (sustainable development goals);
- analyze (Land degradation neutrality) indicators for monitoring and assessing land degradation in Kazakhstan.

**Object of research**

According to the "Consolidated analytical report on the condition and use of Kazakhstan land for 2021", agricultural land makes up 97.4% of the total area of agricultural land, including: ploughland 22.9%, perennial plantations - 0.05%, fallow - 1.7%, hayfields - 2.01%, pastures - 70.7% [6]. They are located in 10 natural zones and pre-determine the development of a wide range of areas of agricultural production. The largest area of agricultural land (37.6%) is occupied by the desert zone with gray and gray-brown soils. In the dry steppe zone on chestnut soils
and semi-desert zone, they occupy 24.9% and 15.4%, respectively. The steppe zone on chernozem soils occupies 10.7% of all agricultural land in the country [7].

**Results**

Land cover and its qualitative changes are indicative of the important factor, since they contain the first signs of vegetation decrease or increase, ecosystem fragmentation and transformation of land resources. It is also used in the interpretation and consideration of the other two indicators.

Land classification Level 1 is based on the categories of (International Plant Protection Convention) Procedure Manual [1]. Land classification Level 2 is based on the land cover classification, which is used by Food and Agriculture Organization (Land Cover Meta Language) for a unified approach to defining the soil class. If the country's national land-use classification system is not consistent with levels 1 and 2 classes, the land-use classifications need to be combined or split to match the classes presented in the Manual (Table 1).

Table 1 - Hierarchical classification of land cover according to International Plant Protection Convention [1]

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest area</td>
<td>Forest trees</td>
</tr>
<tr>
<td>Meadowland</td>
<td>Grassland and and native grasses</td>
</tr>
<tr>
<td></td>
<td>Shrubs, heathland</td>
</tr>
<tr>
<td></td>
<td>Sparse lands</td>
</tr>
<tr>
<td></td>
<td>Climatic climax communities and mosaics</td>
</tr>
<tr>
<td>Ploughland</td>
<td>Medium and large-sized unirrigated grassy farm fields</td>
</tr>
<tr>
<td></td>
<td>Medium and large-sized irrigated grassy farm fields</td>
</tr>
<tr>
<td></td>
<td>Permanent crops, agricultural plantation</td>
</tr>
<tr>
<td></td>
<td>Agricultural communities and mosaics</td>
</tr>
<tr>
<td>Moorland</td>
<td>Open moorland</td>
</tr>
<tr>
<td>Settlements</td>
<td>Urban areas and related economically developed areas</td>
</tr>
<tr>
<td>Other land</td>
<td>Barren land</td>
</tr>
<tr>
<td></td>
<td>Permanent snow cover and glaciers</td>
</tr>
<tr>
<td>Water</td>
<td>Inland waters, coastal waters, seas</td>
</tr>
</tbody>
</table>

The nearest to the categories of (International Plant Protection Convention) Procedure Manual is the classification of lands into categories, which has the basis of their intended purpose [5, 6]. Table 2 shows the classification of land in Kazakhstan in accordance with (International Plant Protection Convention) Procedure Manual.

Table 2 - Classification of land in Kazakhstan, given in accordance with IPPC Procedure Manual
<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest area</td>
<td>specially protected natural areas, forest fund lands</td>
</tr>
<tr>
<td>Meadowland</td>
<td>grassland</td>
</tr>
<tr>
<td></td>
<td>hayfields</td>
</tr>
<tr>
<td></td>
<td>perennial plantations</td>
</tr>
<tr>
<td></td>
<td>wild land</td>
</tr>
<tr>
<td>Ploughland</td>
<td>ploughland, incl. irrigated</td>
</tr>
<tr>
<td></td>
<td>non-agricultural land</td>
</tr>
<tr>
<td></td>
<td>lands of settlements</td>
</tr>
<tr>
<td></td>
<td>industry, transport, communications and other land of non-agricultural</td>
</tr>
<tr>
<td>Moorland</td>
<td>Land reserve</td>
</tr>
<tr>
<td>Settlements</td>
<td>Water reserve land</td>
</tr>
</tbody>
</table>

Note: compiled by the authors

The qualitative condition of land on large areas in the Republic of Kazakhstan is complicated by the presence of signs that adversely affect their fertility [7]. Agricultural land with negative signs accounts for about 80.0% of the land (Figure 1).

The "National report on the state of the environment and on the use of natural resources of the Republic of Kazakhstan for 2020" provides the following figures: "... in the whole country, the ameliorative group with uncomplicated negative signs is 19.4%, with negative signs to a weak degree - 20.1%, and in a medium and strong degree - more than 60%." [6]. The following conclusion is drawn: "... As a result of the transformation of agricultural lands, there is a qualitative change in the composition of ploughland, mainly due to the withdrawal of its low-productive part from the semi-desert light chestnut zone and the development of new ploughland in the steppe chernozem and dry steppe chestnut zones, and also in the piedmont regions of the republic, where the most productive lands are located [6].
The various types of land use result in the certain forms of land degradation [1]. Table 3 shows the types of land degradation in the field of natural resource conservation according to (World Overview of Conservation Approaches and Technologies).

Table 3 - Comparative characteristics of land degradation types

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Water erosion - loss of topsoil and erosion of ploughed layer</td>
<td>Vulnerable to water erosion (eroded) from the total area of eroded lands occupy an area of 4.9 mln ha or 2.3% of agricultural land</td>
</tr>
<tr>
<td>Wind erosion of soils - loss of top soil</td>
<td>Vulnerable to wind erosion (wind-eroded) - 24.2 mln ha 127 or 11.3% of agricultural land</td>
</tr>
<tr>
<td>Chemical soil damage - reduced fertility and reduced organic matter content</td>
<td>Pollution with oil and oil products is observed on an industrial scale. During the period of activity of the uranium mining industry on the territory of Kazakhstan, about 200 mln tons of radioactive waste were generated. Soil pollution with heavy metals - Emissions into the atmosphere, solid and liquid waste from industrial enterprises, energy, military-industrial...</td>
</tr>
<tr>
<td>Description</td>
<td>Example</td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Physical soil damage - mining, construction</td>
<td>- 243.4 thousand ha of land disturbed during the construction of industrial facilities, linear structures and other entities, during the development of deposits of useful minerals</td>
</tr>
<tr>
<td>Water degradation - the decrease in the quality of surface water caused by wastewater from large entities of agribusiness industry, the ingress of industrial, waste water and used water into rivers</td>
<td>- non-compliance with the size of water-conservation zone, - formation of spontaneous household landfills, - sewage waters of industrial and agricultural facilities, placement of residential and industrial facilities on the banks of river beds, - accidents at sewerage facilities</td>
</tr>
<tr>
<td>Biological degradation – threatened animals and plants</td>
<td>- 387 plant species are included in the Kazakhstan Red Data Book as rare or endangered due to the irrational use of natural resources. - The spread of highly dangerous pets with numbers above the economic injury level can lead to a loss of 15-30% of the crop yield</td>
</tr>
</tbody>
</table>

Note: compiled by the authors

All types of land degradation are also peculiar to Kazakhstan land resources.

Land productivity means the biological productivity of land, the source of all food, fiber and fuel necessary for human activity [1].

Net Primary Land Productivity can be calculated from the indicator for large areas using remote sensing of the earth techniques. The most practicable currently is the use of vegetation indices for (net primary land productivity) proxy indicators [1]. The Normalized Difference Vegetation Index (Normalized difference vegetation index) is the most commonly used vegetation index.

Kazakhstan ranks 5th in the world in terms of pasture land and only 30% of which is currently used. To inspect the large-scale processes in pastures associated with vegetation for a number of technical characteristics, Terra/Aqua-MODIS remote sensing system is used. The most informative for determining the average grass-cover thickness are (Normalized difference vegetation index) and (Soil-adjusted vegetation index) indices. Almost all vegetation indices actively respond to changes in plant biomass, as well as to changes in the density of vegetation of natural pastures from 60% or more.

To determine the state of pastures with low projective cover (0-20%) and, accordingly, low productivity, it is advisable to use the red range of the red spectrum in combination with the (Normalized difference vegetation index) index. According to the measurements obtained, a red value
above 0.15 indicates low productivity or overrun of the analyzed pasture areas. These stages of pasture degradation are noted during ground surveys, and then tracked on satellite images, as well as during automated processing of satellite images (Figure 2).

Figure 2 - Field surveys of pastures in Aktobe region

To verify (calibrate) remote sensing data, we planned field surveys. For example, in 2020, according to remote sensing data, the state of pastures in the Aktobe region is generally assessed as bad and very bad. This is due to the location of the area: a desert and semi-desert natural zone. The maximum hot and dry summer did not contribute to the development of green vegetation.

Our surveys of pastures in the Magnistus region in 2018-2020 also confirm that the lack of available water sources and the destruction of water supply facilities has led to an increase in the processes of desertification of the territories. Vegetation cover is experiencing a strong anthropogenic impact, forage plant species are decreasing, which causes degradation of pastures (Figure 3).

Figure 3 - State of pasture vegetation in Mangistau
areas according to ground-based observations in 2020 (Shetpe village)

Based on the results of comparing the degree of damage to pastures obtained by remote methods and on the basis of ground surveys, it was found that the reliability of the correct determination of a weak degree of damage corresponds to 75%, an average degree of damage - 85% and a severe degree of damage - 90%. (Figure 4)

We have established that the main degraded areas fall on the share of the South-Western region of the Republic of Kazakhstan, where desert pastures are located. The lack of accessible water sources and the destruction of water supply facilities led to an intensification of desertification processes in the territories, especially the Aral Sea region, the Betpakdala desert, Saryarka, and the Moyunkum sands.

Remote sensing provides calibrated, quantitative, repeatable and inexpensive information over large areas that can be duplicated or refined by ground data. Remote sensing provides important information about soil erosion, and the appropriate processing of satellite images can be no less important factor in the prediction of erosion processes than ground-based observations.

Table 4 shows an example of one of the accepted soil and vegetation cover degradation classifications.

<table>
<thead>
<tr>
<th>Degree</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very weak</td>
<td>Very weak erosion, the process is just beginning and has no clear signs, traces of mineral deposits are visible in places of accumulation of rainfall.</td>
<td>1</td>
</tr>
</tbody>
</table>
Pasture degradation is a gradual change in the plant community under the influence of excessive or long-term pasture load. During pasture degradation in steppe ecosystems, we noted the following four stages: feather grass - forb (weak and moderate degradation); fescue (moderate degradation); wormwood sheep fescue (most severe degradation); complete degradation (degraded bare land with single oppressed weeds). These stages of the pasture degradation are observable in ground surveys and then monitored on satellite images. On cattle passes, around summer and winter camps and around settlements, and in some places even on large areas of pastures, completely knocked out, highly sparse grass stands are formed, consisting mainly of weeds, as in the area of the village of Shetpe, Mangistau region. This stage of the degradation is clearly visible on satellite images of various scales, and also it manifests itself in the spectral signature of the earth's surface.

Thus, the land degradation as a long-term decline in the ecosystem function and the productivity can be assessed using the long-term remote sensing data of the Normalized Difference Vegetation Index.

The next indicator is (soil organic carbon) - a general indicator of soil quality, which is the main carbon storage in the terrestrial ecosystems and regulates the soil productivity. Thus, soil organic carbon runoffs are not only of local importance, but also of global significance due to their role in the global carbon cycle.

Soil organic carbon is strongly influenced by the agricultural production, agricultural land structure and land management practices. The productive capacity of soils depends on these factors. The maintenance of the normal level of soil organic carbon is necessary to maintain or improve soil health and is directly mentioned in the strategic documents of Global Environment Fund [9].

Based on the literature data, scientists have established a large contribution of pasture lands to the global accumulation of soil carbon, but they also noted that there is uncertainty about grazing in such territories. In this regard, the study of soil organic carbon for pasture lands of the territory of the Republic of Kazakhstan is one of the
main tasks in the global climate agenda, and geospatial data, along with ground-based studies, will help solve the problem of constructing mathematical dependencies between the studied indicators in the shortest possible time.

**Discussion**

In opinion of many scientists there is certain relationship between soil organic carbon levels and yields. The article “Soil Potential for Climate Change Mitigation through Carbon Sequestration” says that “Firstly, organic fertilizers will bring not only carbon but also nutrients to the soil. Therefore, the increase in cropping productivity can be associated with the presence of additional nutrients, and not with the improvement in soil quality due to soil organic carbon. Secondly, soil organic carbon stocks can be expected to rise in the well-managed agricultural systems that increase yields, as experimentally found in Rasool et al. studies (2007), Zingore et al. (2007) and Kukaletal. (2009). On the contrary, if the introduction of alternative management techniques leads to lower crop yield, this may negatively affect soil organic carbon stocks (Ogle et al., 2012). Due to the variety of possible chemical, biological and physical factors preventing yield potential from being realised, soil organic carbon content escalation is an important safeguard against crop failure from soil perspective, moreover it can be the best strategy for restoration of fertility in degraded lands, for example when the moisture-holding capacity is the main limitation of crop yield (Bruce et al., 1995)” [10].

**Conclusion**

As part of the Sustainable Development Goals, countries aim to achieve land degradation neutrality by 2030, in which the quantity and quality of land resources remain stable or increase over certain time and space scales. In order to achieve this sustainable land management methods are required to be introduced to increase the sustainable provision of ecosystem goods and services for population life support.

Our research shows that land productivity indicators obtained from satellites are successfully detected by means of sustainable land management methods on primary productivity, here-with these indicators serve as important elements of the monitoring and assessment tools needed to track the condition of land in order to guarantee the neutral balance to land degradation, since only the technologies with more than a 10-year implementation period show statistically significant improvements [11].

In the course of a series of studies, we substantiated natural sounding as an information basis for planning the sustainable development of regional agricultural systems based on the use of the agro-resource potential of the territory, analyzed the level of gross regional product in the agricultural industry based on the integration of statistical, spatial and temporal approaches and indicators of sustainable development, an information system has been developed for compiling dynamic models of the input-output balance using the method of economic cybernetics.

As a result, the best direction of development for carrying out transfor-
mations in the territories based on do-

cumestic priorities, demand and agro-re-

cource potential allows the presence of

the SDGs in the regional programs of

socio-economic development [12].

In 2022, the first carbon polygon

was created in Kazakhstan, located in

Zholtaptyk aul, Zhelezinsky district,

Pavlodar region. The projects being de-

veloped at this polygon are based on

new technologies for capturing, trans-

porting, processing and sequestering

carbon. In addition, the scientists ana-

lyze the territory to calculate the bi-

ological mass, species composition of

plants and soil conditions using un-
manned systems and ground equip-

tment.

The scientists around the globe

came to the common scientific conclu-

sion: we must strive to increase the

area of recultivated land, reduce the

area of degraded land in order to

achieve land degradation neutrality and

reduce trade-offs between land degra-

dation neutrality and other Sustainable

Development Goals in the future [13,

14, 15, 16].

We have an opportunity to

achieve the land degradation neutrality

by 2030 only if we move on the sophis-
ticated solutions based on the analysis

of socio-economic and ecological sys-

tems using concepts such as nature-

based solutions.

Information on financing

The article includes studies on the topic of program-targeted financing of sci-

entific and technical progress BR10764919 “Research on impact of government pol-

icy in the agricultural sector on the development of cooperative processes in the agro-

industrial complex, sustainable development of rural areas and food security gover-

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Түйін
Ғылыми мақала дүние жүзілік ғылыми қоғамдың, ата жатқандан, қазақстандық ғалымдар бакылап, зерттеп жүрген жердің тозуының озекти мәселесіне арналған. Деградацияға ұшыранған ауамдардың жай-құйын жіктеу және зерделеу мәселелері аса маңызды болып табылады, өйткені олар проблеманы өдан ері бақылаумен, табиғатты қорғау шараларын жәзеге асыруға қаржылық шығындарды анықтаумен және осы қаржы шаңыр шараларың.
К ВОПРОСУ О ДЕГРАДАЦИИ ЗЕМЕЛЬ В КАЗАХСТАНЕ

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Аннотация

Научная статья посвящена актуальной проблеме деградации земель, наблюдаемой и изучаемой мировым научным сообществом и, в частности, казахстанскими учёными. Вопросы классификации и изучения состояния деградированных территорий являются первостепенными, так как связаны с дальнейшим мониторингом проблемы, определением финансовых затрат на осуществление охранных мероприятий и придания этим ландшафтам устойчивого развития. Установлено, что сельскохозяйственные угодья в Казахстане более чем на 90% подвержены деградационным процессам и этот показатель варьируется в зависимости от вида угодий и их пространственного размещения.

При мониторинге пастбищных угодий для определения деградации пастбищ использовались данные спутников Terra, Aqua. По результатам сравнения степени повреждения пастбищ, полученных дистанционными методами и на основе наземных обследований, было выявлено, что достоверность правильного определения слабой степени повреждения соответствует 75%, средней степени повреждения — 85% и сильной степени повреждения - 90%.

Авторами статьи предложена классификация земель Казахстана в соответствии с IPPC и определены типы деградации земель Казахстана в соответствии с WOCAT. Выявленные закономерности проявления деградационных процессов на территории РК классифицированы по уровням IPPC. Определены направления повышения устойчивости сельскохозяйственных земель с учётом классификационных признаков. Материалы научного исследования рекомендуются к использованию при управлении земельными ресурсами и разработке агро-, фито, лесомелиоративных мероприятий, направленных на повышение устойчивости пустынных агроландшафтов РК.

Ключевые слова: показатели деградации земель; продуктивность земель; органический углерод почвы; оценка земельных ресурсов;
нормализованный индекс растительности; дистанционное зондирование Земли; землепользование.