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## PROFICIENCY IN THE CONCEPTUALIZATION AND ASSESSMENT OF LAND DEGRADATION: A REVIEW

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### SUMMARY

The presented study analyzes the international experience in conceptualization and assessment of land degradation in the context of achieving the Sustainable Development Goals (SDGs). It is a well-known fact that the traditional approach to differentiated interpretation of land degradation is insufficient and requires numerous adjustments. From ecological, economic, and social perspectives, the necessity of a comprehensive interpretation of land degradation needs substantiation. The importance of considering the close association of these aspects entails emphasis. In this study, the proposed land degradation underwent an analysis of the scale of degradation in the modern world. It was well noted that up to 40% of the planet's soils reached degradation to some extent, and the total degraded land areas amounted to about 15% of terrestrial lands. The said problem is most acute in developing countries. Giving specific attention is essential to sustainable land management, which can ensure the prevention of land degradation to achieve significant ecological, economic, and social benefits.

**Keywords:** Land and soil degradation, assessment of soil and land degradation, sustainable land resource management, soil resource management, development goals

**Key findings:** The water deficit condition at the flowering stage caused a significant reduction in yield and its components in maize. The silicon treatment 6 mM L<sup>-1</sup> concentration notably enhanced the grain and oil yields and carbohydrates.

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## INTRODUCTION

The relevancy of the land degradation problem gained determination by its scale and the growing threat it poses to sustainable development at the regional and global levels (Bogolyubov, 2023). Land degradation consequences are complex in nature and manifested in ecological, economic, and social spheres, exerting negative effects on the environment, the climate, the productivity of ecosystems, and food security (Muhlinina, 2024).

In mitigating the repercussions of land degradation, the global community has already undertaken active measures, including the adoption of Goal 15 within the framework of the UN Sustainable Development Goals by 2030 and the development of numerous national and regional programs. However, the effectiveness of these efforts primarily attained constraints from methodological challenges, mainly from terminological ambiguity (Eswaran *et al.*, 2001) concerning the concepts of 'soil degradation' and 'land degradation,' as well as associated concepts, such as desertification, erosion, and environmental pollution.

This uncertainty further complicates the classification and assessment of degradation processes. For example, interpretation of aridity, being a climatic characteristic, can be a type of soil degradation, while assessment may vary from measuring the extent of soil erosion to assessing the loss of ecosystem services (Prävālie, 2021). Further difficulties arise in the precise identification of the causes of land degradation, as well as in distinguishing the natural degradation—an inherent process in all natural systems—from human-induced degradation (Ajai, 2022).

In the present era, the international agenda has considerably shifted from documenting isolated symptoms of land degradation to setting measurable targets for combating and reversing it. Within this policy context, the concept of Land Degradation Neutrality (LDN), promoted under the United Nations Convention to Combat Desertification, frames land condition as a balance between the losses and gains in land-based natural

capital. It provides a common point of reference for achieving SDG target 15.3. Recent worldwide syntheses further emphasized that land degradation is a biophysical phenomenon and an emerging challenge that intersects with poverty, food security, and climate-related risks (United Nations Convention to Combat Desertification—UNCCD, 2012; Nkonya *et al.*, 2016; Secretariat of the Convention to Combat Desertification, 2022).

This important shift has viable methodological implications for research and monitoring. First, the assessments increasingly rely on harmonized proxy indicators (land productivity, land cover change, and soil organic carbon) that enable consistent reporting worldwide while recognizing the need to complement these proxies with field measurements and locally relevant socio-economic observations (Sims *et al.*, 2017, 2021). Moreover, a growing recognition indicates that the same drivers (increasing aridity and unsustainable agricultural intensification) can further trigger multiple degradation pathways, which requires an integrated framework capable of capturing trade-offs and co-benefits of sustainable land management (Dubovyk, 2017; Prävālie, 2021). Therefore, the synthesis of an international experience is crucial for clarifying the terminology and aligning assessment approaches with the multi-dimensional nature of land degradation within the SDG context.

In this regard, the purpose of this study sought to analyze the accumulated international experience in the conceptualization of land degradation, including the classification and determination of the scale of degradation processes in various regions worldwide. Likewise, it contributes to the prospects for future research on this issue.

## MATERIALS AND METHODS

The prospective study comprised a systematic review of the existing past studies on the conceptualization and assessment of land degradation problems. The gathering of relevant literature came from the different

databases, such as Scopus, Web of Science, and Google Scholar, using related keywords about land and soil degradation, desertification, sustainable land management, ecosystem services, and Sustainable Development Goals (SDGs). The keywords used in the search strategy included combinations of terms like “land degradation assessment,” “soil erosion and productivity,” “desertification drivers,” “remote sensing land degradation,” “neutral balance of land degradation (LDN),” and “sustainable soil management.”

By compiling the relevant data, the study identified key findings regarding the ecological, economic, and social dimensions of land degradation, as well as widely applied assessment methods, such as expert evaluation, field research, remote sensing, and various modeling approaches. The analysis also highlighted the gaps in current knowledge. These included the lack of unified definitions for land and soil degradation, insufficient integration of social and economic indicators, and methodological limitations of remote sensing in capturing the degree of land and soil degradation.

These formulated gaps point out the need for further investigations, particularly in the development of comprehensive and harmonized methodologies that integrate ecological, economic, and social aspects of land and soil degradation within the framework of the SDGs.

## RESULTS AND DISCUSSION

### Land degradation and its classification problems

From an ecological viewpoint, land degradation definition can be a decline in the normal functioning of biogeocenoses. Its core element is the edaphotope, a soil cover together with other parts of the lithosphere and hydrosphere within the geocenosis (Gorodyuk, 2014). It regulates nutrient cycles, helps maintain the biochemical composition of the atmosphere and hydrosphere, accumulates considerable organic matter, and supports key biospheric

processes (Jie *et al.*, 2002). Accordingly, land degradation may comprise damage to the edaphotope and other related components (climatopes, phytocenoses, zoocenoses, and microbiocenoses), expressed as biodiversity loss, disruption of carbon and nitrogen cycles, higher GHG emissions due to reduced soil carbon sequestration, and loss of water bodies and vegetation.

The classification of soil and land degradation can be as a global threat because it undermines essential soil functions and ecosystem stability (Jie *et al.*, 2002). The Millennium Ecosystem Assessment (2005) similarly emphasizes that land degradation reduces ecosystem capacity to deliver key services, with alarming impacts on human well-being. These findings support interpreting land degradation as a system-wide disruption of the edaphotope and connected biogeocenotic components.

From an economic perspective, land and soil degradation often mean the reduced capacity for crop production systems (Tsvetnov *et al.*, 2021), generating substantial losses and intensifying food-security risks (Crosson and Anderson, 2000; Millennium Ecosystem Assessment, 2005; Hamdy and Aly, 2014). Previous worldwide observations based on productivity losses reported annual damages of about USD 42 billion (Dregne and Chou, 1992), while the Food and Agriculture Organization of the United Nations (FAO) and Land Degradation Assessment in Drylands (LADA) reported the comparable figures of about USD 40 billion (Gupta, 2019; FAO, 2025). Declining productivity potential of soil reduces output, increases prices, and lowers farm incomes, especially in developing countries where the agricultural sector performs as a backbone of the economy (Gerber *et al.*, 2014; Barbier and Hochard, 2016).

Costing studies grounded in yield and productivity variations showed degradation creates macro-scale economic losses, and productivity decline became a meaningful indicator (Dregne and Chou, 1992). The economics of land and soil degradation synthesis further revealed that impacts extend beyond the farms to markets, incomes, and broader development outcomes, particularly in

land-dependent regions (Nkonya *et al.*, 2016). This further recognizes the use of productivity loss as a key characteristic for economic evaluation and monitoring.

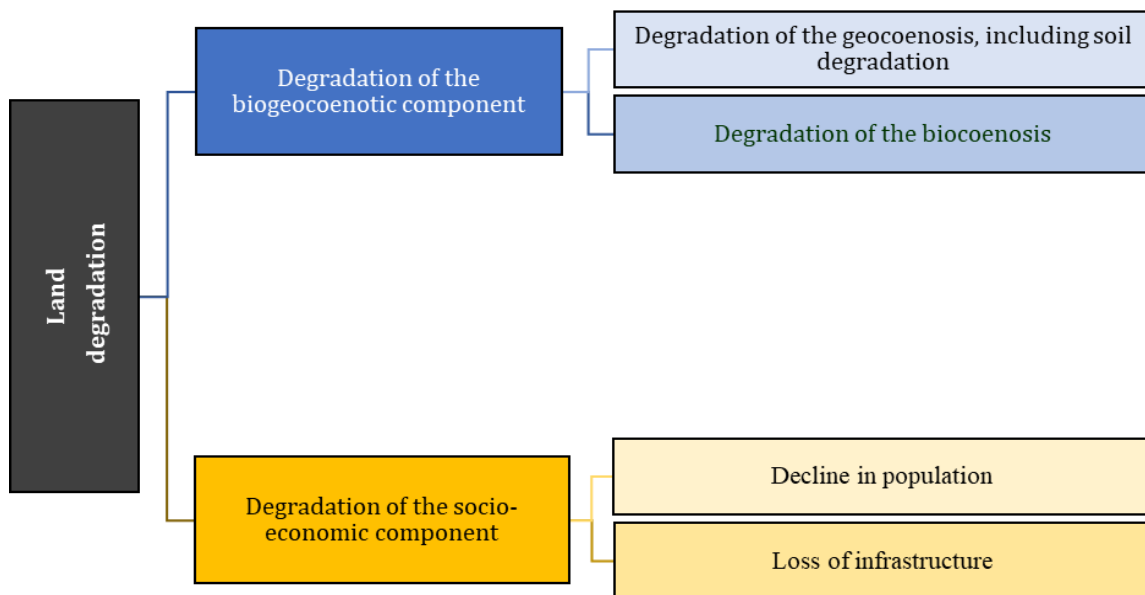
According to expert evaluations, the degradation of land and soil also affects social processes, including reduced recreational potential, food and job shortages, poorer health and life expectancy, shifts in real estate values and land use, and changing social attitudes (Bondarev and Radomyslsky, 2024). The social dimension often has reflections in declining rural quality of life and migration; for example, 'social desertification' can develop from the closure of community-forming enterprises (Fokin, 2016), where soils may remain suitable, but labor is no longer available to cultivate them.

Based on these ecological, economic, and social approaches, three key directions can be distinct bases for classification and assessment (Figure 1). This framework does not explicitly include 'desertification,' commonly defined as land degradation in arid, semi-arid, and dry sub-humid zones, which can refer to climate change and diverse human activities (United Nations Convention to Combat Desertification, 1994). Desertification

is therefore a special case of land and soil degradation, reinforcing the need to analyze degradation comprehensively and avoid treating its types in isolation.

### Factors of land degradation

At the local level, the key sources of soil degradation are irrational land use. These are monoculture farming, abandonment of crop rotation, excessive use of agrochemicals, uncontrolled livestock grazing, as well as deforestation, improper irrigation, and land pollution (Ajai, 2022). At the national level, land degradation incurs exacerbation with the insufficient effectiveness of state regulations, including gaps in the legal framework, weak enforcement and sanctioning mechanisms, inadequate funding of environmental protection measures, and the considerable impact of corruption and lobbying (Bondarev and Radomyslsky, 2024). At the global level, the main drivers are industrialization, urbanization, and globalization, accompanied by the expansion of agricultural production areas, deforestation, intensive exploitation of natural resources, and rising environmental pollution.



**Figure 1.** Main foci in the conceptualization of land degradation.

In light of the above discussion, the following proposed definition of land degradation can aim for sustainable development. Land degradation is the loss, under the influence of natural and anthropogenic factors, of the following. First, the biogeocoenotic component of land, including soil and biocoenotic elements; second, the socioeconomic component, the negative changes in the lives of the population living in the given territory, a decline in its size and well-being, and negative changes in the structure of settlements and infrastructure; and finally, a set of 'super-characteristics' derived by the biogeocoenotic and socioeconomic components, including biological and economic productivity of land, as well as other ecosystem services not directly related to productivity.

### Assessment of land degradation

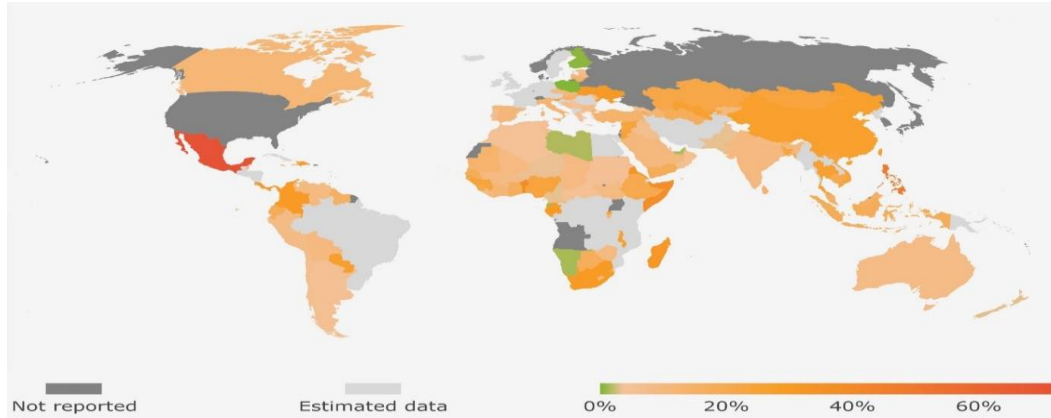
Before describing the global scale of land degradation, it is important to outline how its assessment took place. With no universal method applied, each case study differed by degradation types, scale, available resources and time, and assessment goals. Therefore, the current studies basically combine the expert judgments, land-user surveys, field monitoring, modeling, productivity-change analysis, and remote sensing (Taimi, 2008). Field approaches rely on in-situ diagnostic indicators, compared over time, and with results commonly processed using statistics and GIS to support modeling. For national to global assessments, remote sensing (RS) was the most widely used application due to its efficiency and consistency (Surovikina and Slabunova, 2021), enabling analysis of both biogeocoenotic variations, such as erosions (Wang *et al.*, 2024), and 'super-characteristics,' such as land cover and productivity dynamics (Dubovyk, 2017; Sims *et al.*, 2021). Remote sensing can also proxy socioeconomic change, such as nighttime lights (Nkonya *et al.*, 2016).

The major integrated example of the Land Degradation Neutrality (LDN) methodology entailed introduction from the United Nations Convention to Combat

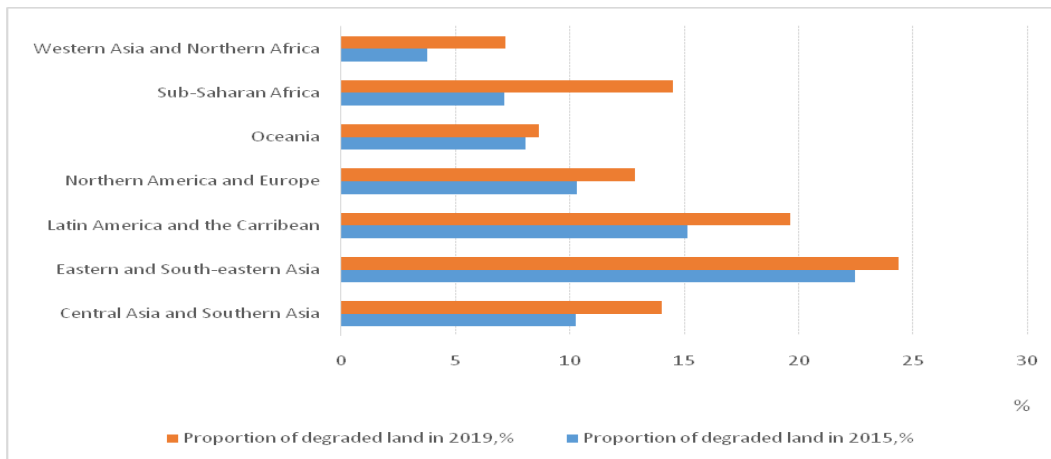
Desertification (UNCCD, 2012). It evaluates SDG 15.3.1 using three proxy indicators: land productivity, land-cover change, and soil organic carbon (0–30 cm) (Sims *et al.*, 2017), with the same also supplemented with national datasets to reflect regional specifics, and its key advantage was cross-country comparability (UNCCD, 2017). At present, no assessments exist that cover all manifestations of land degradation noted in Figure 1 simultaneously. The assessments carried out within the LDN methodology described above have come closest to this task. However, like most remote sensing-based approaches, it was insufficient in estimating degradation severity compared with field measurements and often emphasizes productivity more than other ecosystem-service losses. The socioeconomic dimension also remains insufficiently captured. According to available data, 1.56 billion hectares of land attained degradation (15.39% of the world's land area). This estimate was according to 167 studies, including national reports and the data from the UN Convention to Combat Desertification (UNCCD, n.d.-b) (Figure 2).

The UNCCD analysis based on individual world regions showed that the highest values of the indicator "share of degraded land relative to the total land area of the region" succeeded in their recording in East and Southeast Asia, as well as in Latin America and the Caribbean, reaching 24.39% and 19.64%, respectively, by 2019 (Figure 3) (UNCCD, n.d.-b). However, the most alarming situation was evident in Sub-Saharan Africa, where the share of degraded land was more than double during the said period (from 7.14% to 14.5%). Western Asia and North Africa, starting from a low base, also revealed a considerable increase in the share of degraded lands (from 3.78% to 7.19%). Central and South Asia showed moderate growth in the share of degraded lands (from 10.26% to 14.04%). However, in other regions, the indicators remain relatively stable.

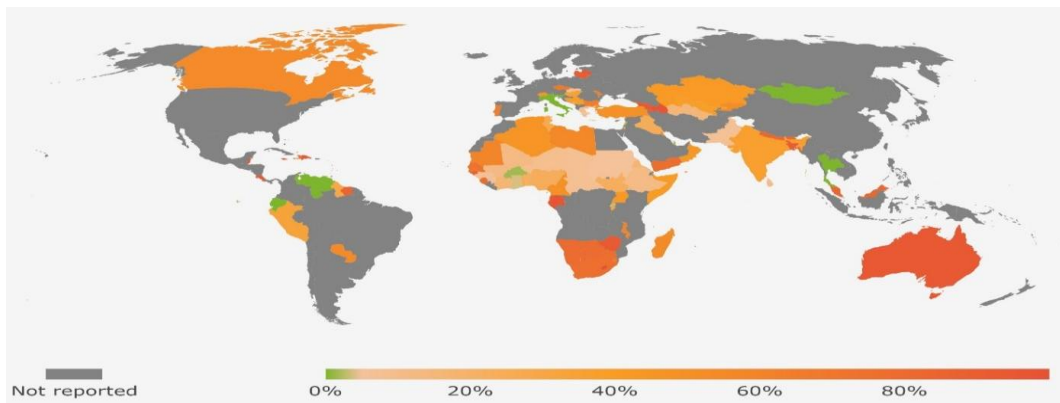
The UNCCD assessment of the spatial distribution of arid regions worldwide showed that arid conditions can be visible on all continents, and according to estimates from 2000 to 2019, affected land area reached 40% and 50% by this phenomenon (Figure 4). The



**Figure 2.** Share of degraded land relative to total land area (estimate for 2019) (United Nations Convention to Combat Desertification [UNCCD], n.d.b).



**Figure 3.** Dynamics of the share of degraded land by 2019 relative to 2015, by world regions (based on data of the United Nations Convention to Combat Desertification [UNCCD], n.d.b).



**Figure 4.** Share of land with arid conditions (2016-2019) (United Nations Convention to Combat Desertification [UNCCD], n.d.a).

latest assessment during 2016–2019 showed that arid conditions covered 3.29 billion ha (48.86% of land surface) (UNCCD, n.d.-a). Based on the lack of UNCCD data for some regions, the true problem scale was likely much greater than as reflected in official statistics. Africa and Asia appeared to be the most vulnerable in this respect, considering the area impacted (about 23 million km<sup>2</sup> on each continent). In terms of the extent of arid landscapes, Africa ranks second in the world (75%), after Australia, where arid zones occupy more than 90% of the territory. It was well noted that aridity makes the largest contribution to the development of land and soil degradation globally (Prävālie, 2021).

Undoubtedly, special attention should focus on the degradation of soil cover. Global assessments showed that 20%–40% of all soils worldwide are currently degraded (Secretariat of the Convention to Combat Desertification, 2022), affecting more than half of the world's population one way or another, and by 2050, no more than 10% of land will remain unaffected by significant anthropogenic pressure (Chotte *et al.*, 2019).

Soil erosion is one of the most important types of soil degradation (Mukhametov *et al.*, 2024). Erosion poses a serious threat to soil conditions, especially when the erosion rate exceeds the permissible threshold of 10 t/ha/year. Spatial data analysis enunciated that intensive soil erosion processes cover about 10 million km<sup>2</sup>, which is around 7% of the global land surface. Asia incurred the most effects from water erosion, followed by Africa. The most significant hotspot of intensive water erosion is China, where severely eroded lands occupy nearly 1.5 million km<sup>2</sup>, becoming 14% of the world's area affected by intensive water erosion. Next are the countries, such as Brazil (almost 1 million km<sup>2</sup>, 9%), Russia (about 900,000 km<sup>2</sup>, 9%), the USA (about 760,000 km<sup>2</sup>, 7%), and India (about 736,000 km<sup>2</sup>, 7%). One should also note that about 7% of the world's arable land receives simultaneous alterations from aridity and erosion.

The second most important factor of soil degradation is salinization worldwide (Muhlinina, 2024). About 2.6 million km<sup>2</sup>

(around 2% of the Earth's land surface) sustained influences from salinity. Salinization mostly occurs on all continents but is most widespread in Asia, where saline soils occupy about 1.3 million km<sup>2</sup>. Globally, four other major salinity hotspots are Australia (about 0.5 million km<sup>2</sup>, 19% of the world's saline soils), Kazakhstan (about 319,000 km<sup>2</sup>, 12%), China (about 307,000 km<sup>2</sup>, 12%), and Iran (about 300,000 km<sup>2</sup>, 12%).

The loss of soil organic carbon (SOC) is another critical factor of soil degradation. The SOC considerably affects numerous physical, biochemical, and biological soil properties and has direct links to soil fertility (Bogolyubov, 2023). Thus, the loss of SOC is crucial for the agriculture sector. At the same time, SOC losses are an accelerating factor in climate change, since soil carbon is the largest global carbon reservoir: numerous estimates suggested that about 1500 Pg C remain stored in the upper 1-meter soil layer (twice the amount of carbon in the atmosphere and roughly three times that in terrestrial vegetation), about 50% of which was stored in the top 30 cm of soil.

During the period of 2001–2015, recorded SOC loss reached over about 2.7 million km<sup>2</sup> (nearly 2% of the global land area). Major SOC loss hotspots include Brazil (about 412,000 km<sup>2</sup>, 15% of the total affected area), China (about 300,000 km<sup>2</sup>, 11%), Russia (about 289,000 km<sup>2</sup>, 11%), the USA (about 210,000 km<sup>2</sup>, 8%), Canada (about 115,000 km<sup>2</sup>, 4%), and Indonesia (about 83,000 km<sup>2</sup>, 3%). Collectively, these countries account for more than half of the total area modified by SOC losses since 2001 (Prävālie, 2021).

Another vital factor of land and soil degradation is vegetation degradation, in particular, deforestation (Smetanin and Kaci, 2024). An analysis of the indicator "forest area as a proportion of total land area" (SDG indicator 15.1.1) from 1990 to 2020, based on Our World in Data team (2023), revealed uneven trends across various world regions. Globally, during this 30-year period, forest cover gradually declined from 32.5% to 31.2% of land area. The most significant deforestation occurred in tropical regions—South America,

Africa, and Southeast Asia. For example, in Brazil, forest cover fell from 70.5% to 59.4% due to logging for agriculture and resource extraction. In Indonesia, forest cover dropped from 63.1% to 49.1% as forests bore clearing for oil palm plantations. Nigeria lost 17.5% of its forests, with forest cover decreasing from 29.1% to 23.7%.

Similarly, the forest cover in Europe, North America, and East Asia remained relatively stable and even slightly increased due to reforestation and the retreat from extensive agriculture (Secretariat of the Convention to Combat Desertification, 2022). For example, in the USA, forest cover increased from 33.1% to 33.9%, and in China, from 16.7% to 23.4%. In Russia, forest cover remained around 49.4%, and in Canada, around 38.7%. Some countries even stood out for successful examples of reforestation and forest conservation. In Vietnam, targeted policies increased forest cover from 30.2% to 47.2%. In Chile, the forest cover rose by 3.6% since 1990, reaching 24.5%.

Let us also consider the degradation of agricultural lands. The African continent is the region most affected by agricultural land degradation. Severe degradation was evident in 33 African countries, including Algeria, Ethiopia, Ghana, Kenya, Lesotho, Mali, Morocco, Nigeria, Tanzania, Tunisia, Uganda, and Zimbabwe. Overall, about 494 million hectares of land reached considerable degradation. By the type of land use, 18% of irrigated, 71% of rainfed, and 74% of pasture lands obtained a degraded classification (Hossain *et al.*, 2020).

In the United States, the problem of agricultural land degradation also showed high relevance. As of 2020, a significant share of agricultural land was subject to various forms of degradation. About 8.5 million hectares of land underwent erosion. Around 23% of irrigated land (about 4.2 million hectares) attained a declaration as saline. Pastureland, which covers more than half of the country's territory, is overgrazed (about 14.5% lightly overgrazed, 73.4% moderately, and 12.1% severely) (Brevik, 2022).

China, with its vast agricultural resources, faces serious soil degradation

challenges. The current area of agricultural land in China is between 120 and 140 million hectares. An estimate shows that more than 60% of these lands sustained various types of soil degradation, from moderate to severe conditions (Pretty *et al.*, 2007).

In Russia, agricultural land occupies 380.8 million hectares, which is 23.2% of the country's total area. According to Rosreestr, a significant part of Russia's agricultural land was degraded. About 70 million hectares were due to erosion and deflation, with more than 1 million hectares from desertification, and 6.3 million hectares comprise unconsolidated sands. Soil compaction was also prevalent on almost 40% of arable land and pastures (Fedorenko, 2024).

Serious agricultural land degradation also emerged in various regions of Asia, Latin America, and the Caribbean, affecting at least 20% of the total arable area (Smetanin and Kaci, 2024).

### **Measures to combat land degradation**

Combating land degradation requires coordinated efforts at three different levels: globally—international environmental cooperation, sustainable consumption/production, and climate action; nationally—robust land use and environmental legislation, better enforcement of standards, and incentives for eco-friendly agricultural technologies; locally—targeted solutions for specific degradation types through sustainable land management (SLM) (such as crop rotation, organic farming, and zero-tillage) plus farmers' training, extension services, and environmental protection education (Giger *et al.*, 2018).

Evidence showed that SLM/SSM can deliver both biophysical and socioeconomic benefits. Across 286 projects in 57 developing countries (~37 million ha; 12.6 million households), sustainable practices increased crop yields by ~79% on average, improved water-use efficiency, and enabled potential soil carbon sequestration of about 0.35 t C/ha/year; in 77% of projects, pesticide use fell by ~71% while yields still rose by ~42% (Pretty *et al.*, 2007). Beyond yield gains,

sustainable soil management helps reduce disaster risks (droughts/floods), lowers the fertilizer and pesticide costs, strengthens ecosystem services, and can develop considerable economic values via soil carbon sequestration, while healthy soils also support higher land values (Chotte et al., 2019).

## CONCLUSIONS

The traditional differentiated view of land degradation is insufficient for a full understanding and effective overcoming of land degradation as one of today's global problems. An analysis of international experience showed the conceptualization of land degradation should proceed simultaneously in three key dimensions of sustainable development: ecological, economic, and social. The presented analysis demonstrated that an important part of studying land degradation processes should include research on the degradation of the socioeconomic component of the 'land category,' as well as studies integrating ecological and socioeconomic aspects into a unified system. Therefore, it is necessary to identify indicators for analyzing land and soil degradations within the proposed framework, conduct assessments based on them, and ensure their standardization for different regions of the world.

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