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LAND DEGRADATION NEUTRALITY ASSESSMENT OF THE AHANGARAN BASIN USING THE DPSIR FRAMEWORK

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Abstract. This research examines land degradation processes in the Ahangaran River Basin by using the DPSIR (Driver–Pressure–State–Impact–Response) framework alongside the Land Degradation Neutrality (LDN) idea as outlined in SDG 15.3.1. The three main LDN indicators—land cover change (LCC), NDVI-based land productivity, and soil organic carbon (SOC)—were added to the DPSIR structure to make it easier to see how environmental forces affect land condition. The results demonstrate that climate change, more intensive farming, industrial operations, and a growing need for water are all causing major damage to the basin. The resulting ecological and socio-economic effects highlight the necessity for focused interventions in accordance with the Avoid–Reduce–Reverse (ARR) framework of LDN planning. The research offers a scientific basis for formulating sustainable land management plans in the Ahangaran Basin.

Keywords: Ahangaran Basin; land degradation; DPSIR framework; Land Degradation Neutrality; SDG 15.3.1; NDVI; soil organic carbon.

Annotatsiya. Ushbu maqolada Ohangaron daryo havzasida yer degradatsiyasi jarayonlarini baholashda DPSIR (Harakatlantiruvchi kuchlar–Bosim–Holat–Ta'sir–Javob) modeli imkoniyatlari Land Degradation Neutrality (LDN) – Yer degradatsiyasi neytralligi (SDG 15.3.1) konsepsiyasi bilan integratsiyalangan holda tahlil qilinadi. Tadqiqotda LDNning uch asosiy koʻrsatkichi — yer qoplamidagi oʻzgarishlar (LCC), oʻsimlik produktivligining NDVI asosida baholanishi, hamda tuproqdagi organik uglerod (SOC) miqdori — DPSIR zanjiriga moslashtirildi. Ohangaron havzasida iqlim oʻzgarishi, ortib borayotgan antropogen yuklama va suv-resurslariga bosim natijasida yuzaga kelayotgan degradatsiya jarayonlari, ularning ekologik va ijtimoiy ta'sirlari tizimli tahlil etildi. Natijalar LDN maqsadlariga erishishda “oldini olish–kamaytirish–qayta tiklash” (ARR) tamoyillariga asoslangan javob choralarini shakllantirish zarurligini ko‘rsatadi. Maqola havza miqyosida barqaror yer boshqaruvi siyosatini ishlab chiqish uchun ilmiy asos yaratadi.

Kalit so‘zlar: Ohangaron daryo havzasi; yer degradatsiyasi; DPSIR modeli; Land Degradation Neutrality; SDG 15.3.1; NDVI; tuproq organik uglerodi.

Аннотация. В данной статье анализируются процессы деградации земель в бассейне реки Ахангаран посредством применения модели DPSIR (Драйвер–Давление–Состояние–Воздействие–Ответ) в сочетании с концепцией нейтральности деградации земель (LDN) в рамках ЦУР 15.3.1. Три основных индикатора LDN — изменения земного покрова (LCC), продуктивность растительного покрова на основе NDVI и содержание органического углерода в почве (SOC) — были интегрированы в структуру DPSIR для выявления причинно-следственных связей. Результаты показывают, что климатические изменения, интенсификация сельского хозяйства, промышленная нагрузка и растущий спрос на водные ресурсы усиливают процессы деградации в бассейне. Экологические и социально-экономические последствия подчеркивают необходимость целевых мер, основанных на иерархии LDN «предотвратить–снизить–восстановить». Работа формирует научную основу для разработки устойчивых стратегий управления земельными ресурсами в бассейне Ахангаран.

Ключевые слова: Бассейн Ахангарана; деградация земель; модель DPSIR; нейтральность деградации земель; ЦУР 15.3.1;

INTRODUCTION.

Land degradation is a substantial environmental challenge globally, impacting food security, ecological stability, biodiversity, and community resilience to climate change. The United Nations Convention to Combat Desertification (UNCCD) characterizes degradation as a reduction in the ecological or economic productivity of land, caused by unsustainable land-use practices and climate-related stressors (FAO, n.d.-a). Global studies indicate that annually, more than 100 million hectares of arable land are lost, jeopardizing the livelihoods of over 1.3 billion individuals (IISD, 2024). This concerning trend is particularly acute in dry and semi-arid countries like Central Asia, where land degradation is exacerbated by salinization, water scarcity, overgrazing, and industrial expansion (Kust et al., 2023; Martínez-Valderrama et al., 2025).

The global community has embraced the notion of Land Degradation Neutrality (LDN) to mitigate these pressures, as outlined in SDG Target 15.3. The UNCCD Scientific Conceptual Framework stipulates that LDN seeks to achieve "no net loss" of productive land by reconciling degradation with restoration initiatives (Metternicht, 2017; Cowie et al., 2018). Attaining LDN necessitates rigorous assessment through three fundamental indicators: land cover change (LCC), land productivity (often measured by NDVI), and soil organic carbon (SOC). These measures are currently extensively utilized in national reporting frameworks, remote sensing analyses, and decision-support tools (Cherlet et al., 2018; Cowie et al., 2020).

Comprehending the factors and mechanisms of land degradation necessitates an analytical framework that links environmental alterations with socio-economic activities. The DPSIR framework—Drivers, Pressures, State, Impacts, Responses—has become one of the most extensively utilized instruments for environmental assessment (FAO, n.d.-c; Kelble et al., 2013). DPSIR facilitates the identification of causal links among land-use decisions, ecological alterations, and policy interventions. Recent research illustrates its efficacy in arid and semi-arid regions, encompassing watershed-level evaluations and remote-sensing-based degradation analyses (Abdul-Qadir et al., 2021; Gao & Bryan, 2017; Singh et al., 2020).

Uzbekistan's official environmental assessments also underscore the escalating pressures linked to population increase, irrigated agriculture, industrial activity, and climate variability—all of which exacerbate degradation (IISD, 2024). Integrating the DPSIR model with LDN indicators provides a more thorough approach to analyzing land degradation processes, assessing policy efficacy, and pinpointing specific restoration prospects.

The Ahangaran River Basin, spanning roughly 7,700 km² in Tashkent province, is notably susceptible owing to its amalgamation of desert slopes, irrigated lowlands, and adjacency to industrial areas (ResearchGate, 2023). The region has been a focus for intervention due to issues including diminished vegetation production, increased soil salinity, water contamination, and unsustainable grazing practices. Recent EU–UNDP initiatives illustrate the efficacy of drought-resistant pasture species and enhanced grazing methodologies in reversing degradation patterns (UNDP Uzbekistan, n.d.).

This study employs an integrated DPSIR–LDN framework to investigate the causes, pressures, ecological conditions, and response strategies influencing land degradation in the Ahangaran Basin. This research presents a structured and scientifically rigorous method for informing sustainable land-use policy in Uzbekistan by integrating globally acknowledged LDN indicators with a causal environmental assessment model.

METHODS.

This study offers a comprehensive methodological approach that modifications the DPSIR framework to assess land degradation in accordance with the principles of Land Degradation Neutrality (LDN). The methodology was augmented applying insights from contemporary global research that integrate DPSIR with remote sensing, soil evaluation, and LDN reporting (Zhao et al., 2023; Cowie et al., 2020; Orr et al., 2017).

The initial step entailed defining the principal DPSIR components pertinent to the ecological and socio-economic conditions of the Ahangaran Basin: • Drivers encompassed population growth, economic expansion, industrial development, agricultural intensification, and climate change (IISD, 2024; Kelble et al., 2013).

• Pressures included overgrazing, groundwater exploitation, salinization, mining contamination, and ineffective irrigation techniques (Abdul-Qadir et al., 2021; Singh et al., 2020).

• State indicators were evaluated utilizing globally recognized Land Degradation Neutrality (LDN) metrics: land cover change (LCC), NDVI-based vegetation productivity, and soil organic carbon (SOC) (Cowie et al., 2018; Cherlet et al., 2018).

• Consequences encompassed a reduction in agricultural output, degradation of water quality, loss of biodiversity, and increased socio-economic vulnerability (IISD, 2024; Gao & Bryan, 2017).

• Responses pertained to policy and management initiatives, including sustainable land management methods, pasture rehabilitation, afforestation, and industrial control measures (UNDP Uzbekistan, n.d.; Akhtar-Schuster et al., 2019).

In accordance with UNCCD directives, the three LDN indicators were methodically categorized inside the DPSIR framework:

LCC functioned as both a catalyst for land conversion and a marker for the extent of degraded land within the state.

• NDVI changes indicated vegetation health in response to climatic and anthropogenic stressors.

• SOC levels served as an indicator of soil deterioration and carbon sequestration potential.

The selected indicators are quantitative, repeatable, and comparable across regions—qualities vital for SDG 15.3.1 reporting (Orr et al., 2017; Cowie et al., 2020).

Drawing from analogous research in arid regions (Kust et al., 2023; Abdul-Qadir et al., 2021), conceptual frameworks were established to illustrate the impact of pressures on land conditions and identify responses that could mitigate or reverse degradation trajectories. Declining NDVI values on rangelands correlated with grazing pressures and inadequate vegetation recovery, declines in SOC signified poor soil management or overcultivation, and growing saline surfaces were connected with irrigation inefficiencies.

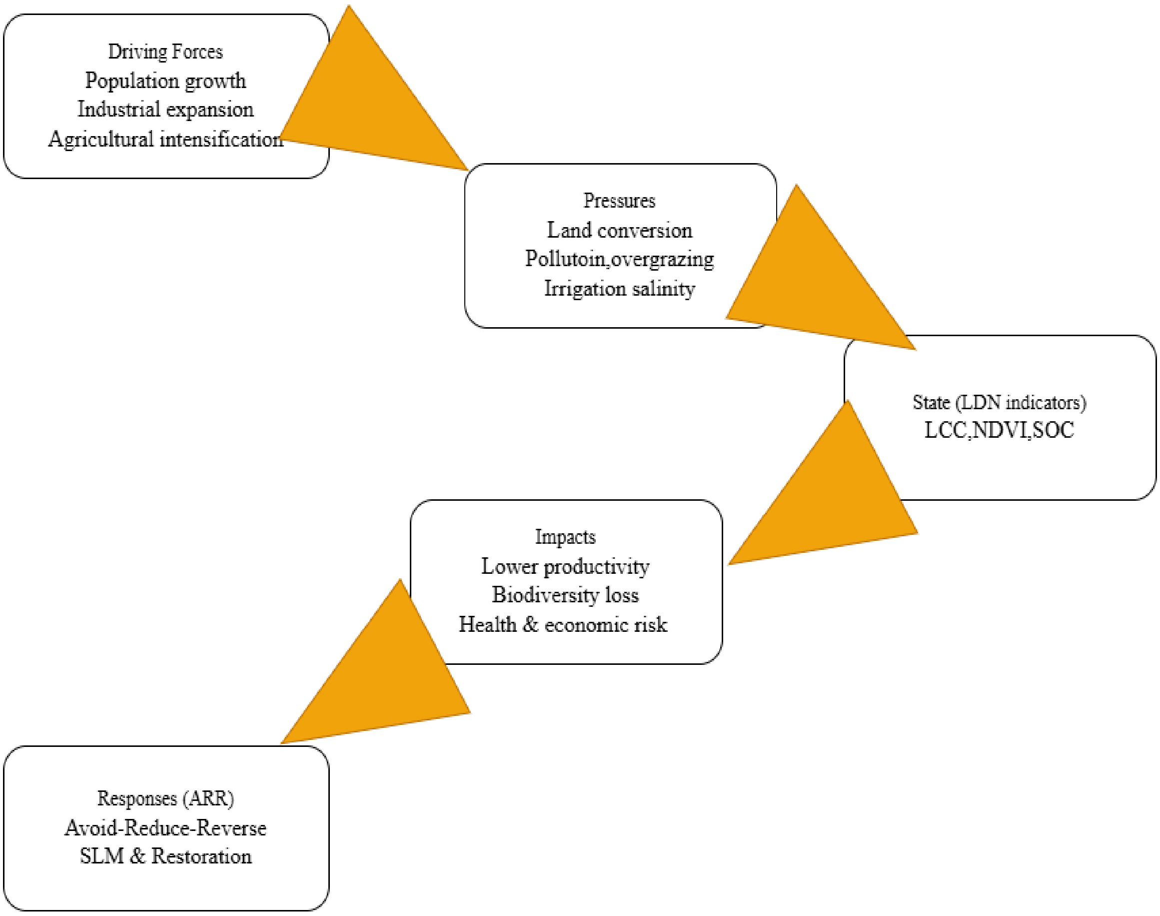

Figure 1. Flowchart. DPSIR model applied Ahangaran River Basin

The ecological and socio-economic factors of the Ahangaran Basin was incorporated into the research by utilizing numerous critical information sources. This encompassed current LDN estimates for Uzbekistan (IISD, 2024), remote sensing studies on land cover and vegetation productivity, and local restoration efforts, including the UNDP–EU pasture rehabilitation schemes (UNDP Uzbekistan, n.d.). Collectively, these inputs facilitated the creation of a cohesive DPSIR–LDN assessment that provides a systematic technique for identifying degradation pathways and establishing key intervention points for sustainable land management in the Ahangaran Basin.

RESULTS AND DISCUSSION.

We develop a theoretical DPSIR framework for the Ahangaran Basin within a land-degradation context and delineate potential treatments. Operators: In the arid region of northern Uzbekistan, climate change—evidenced by elevated temperatures and a rising incidence of drought—is a principal factor contributing to land degradation, in accordance with regional climate evaluations for Central Asia (Lioubimtseva & Henebry, 2009). Socio-economic growth serves as an additional catalyst: elevated temperatures and reduced precipitation increase evaporation and irrigation requirements, while population growth and industrial development, particularly activities linked to the Almalyk mining complex, exacerbate land-use pressures (Zhou et al., 2001).

Pressures: These factors generate multiple direct pressures, such as the expansion of irrigated cotton and vegetable cultivation, which exacerbates soil and water stress; overgrazing in mountainous pastures; pollution from mining discharges; and increased groundwater extraction for urban and industrial use. Inefficient irrigation practices, extensively recorded throughout Uzbekistan, have also led to increased groundwater levels and soil salinization (Qadir et al., 2014). Such forces are evident through discernible environmental alterations, including the proliferation of saline soils and diminished vegetation on eroded slopes (land-cover pressure), alongside nutrient and pollutant accumulation in soils and aquatic systems (pollution pressure).

These pressures deteriorate the ecological condition of the Ahangaran Basin. Overgrazed hillsides may exhibit diminished plant cover, as seen by dropping NDVI trends, but intensively cultivated fields frequently have reduced soil organic carbon (SOC). Soil salinity evaluations may indicate a reduction in cultivable area, and water quality metrics may decline due to ongoing agricultural and industrial pollution. Within the FAO/UNCCD Land Degradation Neutrality (LDN) framework, a land unit is deemed degraded when any of the three indicators—land cover change, land productivity (NDVI), or soil organic carbon (SOC)—exhibits a substantial negative decline (UNCCD, 2018; Cowie et al., 2018). In a degradation scenario characterized by a decline in NDVI, a transition of land cover towards barren or saline classifications, and a reduction in SOC, the overall LDN condition of the basin would deteriorate.

Changing environmental conditions produce interrelated ecological, economic, and societal consequences. Decreasing soil fertility and diminished vegetative cover directly compromise agricultural productivity, a trend extensively recorded for principal irrigated crops in arid and semi-arid areas of Central Asia, where salinity and water stress limit yields and soil efficacy (Qadir et al., 2014; FAO, 2017). The deterioration of water quality and diminishing water availability exert further constraints on rural livelihoods and freshwater-dependent ecosystems, exacerbating susceptibility to climatic variability and resource scarcity (UNEP, 2019).

The loss of biodiversity exacerbates these issues, as habitat fragmentation and ecosystem degradation diminish species richness and alter important biological processes for land resilience (Millennium Ecosystem Assessment, 2005). At the regional level, land degradation issues, including secondary salinization and aeolian dust transport from arid regions—particularly evident in the desiccated Aral Sea basin—have demonstrated significant adverse effects on soil health, air quality, and human welfare (Micklin, 2016; UNCCD, 2022). The combined effects may exacerbate degradation feedbacks by inducing population migration, modifying land-use practices, and limiting effective policy responses, thus sustaining unsustainable land management patterns (Reynolds et al., 2007).

Responses, within the DPSIR framework, refer to the policy and management measures implemented to disrupt the degradation cycle (Kelble et al., 2013). In the

Ahangaran Basin, potential responses may encompass:

• Avoid: Limiting additional land conversion by safeguarding wooded and pasture regions.

• Minimize: Upgrading irrigation systems to manage salinity, limiting industrial effluents, and implementing conservation agriculture to alleviate persistent pressures.

• Reverse: Restoring degraded lands via the afforestation of eroded gullies, the rehabilitation of natural grasslands, and the stabilization of soils—methods aligned with the LDN "avoid–reduce–reverse" hierarchy (Cowie et al., 2018).

Recent initiatives exemplify these responses. An EU–UNDP pasture rehabilitation initiative in the Ahangaran region implemented drought-resistant forage species and rotational grazing practices, acknowledging that effectively managed pastures enhance soil stability and function as carbon sinks (UNDP, 2022).

Sustainable land management practices seek to enhance state indicators, including NDVI and SOC. Likewise, implementing wastewater treatment and enhancing salinity monitoring systems can mitigate pressures prior to the deterioration of land conditions. With effective intervention, monitored LDN indicators would demonstrate diminished adverse trends or even net improvements, consistent with the worldwide ideal of "no net loss of productive land" (UNCCD, 2018; Cowie et al., 2018).

Degradation Scenario: Without intervention, persistent intense irrigation and inadequate control result in the proliferation of salt-affected soils, diminished vegetation production (e.g., NDVI reductions of 10–20% over ten years), and a decline in soil organic carbon (SOC). The DPSIR research associates this pathway with factors including elevated irrigation demand and inadequate land governance. Consequences may encompass agricultural failure and pasture degradation. According to LDN assessment criteria, an increasing percentage of land units would be categorized as degraded under the "one-out, all-out" principle, whereby a fall in any single sub-indicator indicates degradation (UNCCD, 2018).

Sustainable Response Scenario: Responses are implemented promptly through integrated DPSIR-LDN planning. Implementing rotational grazing and cultivating saline-tolerant grasses enhances NDVI and elevates SOC. Remediating irrigation leaking channels inhibits the proliferation of salinity. Such efforts may stabilize or reverse adverse indicator patterns. Gradually, the equilibrium of losses and gains in LDN measures tends toward neutrality or a positive net, in accordance with SDG 15.3. The DPSIR approach would emphasize effective connections; for instance, a response such as fertilizer instruction for farmers directly enhances soil quality, so mitigating future demands.

This image depicts the fundamental rationale of the Land Degradation Neutrality approach as implemented in Uzbekistan. The primary factors contributing to land degradation on the left—namely deforestation, overgrazing, agricultural development, and unsustainable land management—align with the forces highlighted in the analysis of the Ahangaran River Basin. These factors lead to the degradation of plant cover, depletion of soil organic carbon, heightened salinization, and reduced ecosystem productivity, as recorded in the basin's LDN indicator evaluation.

The concept of Land Degradation Neutrality (LDN) is introduced as a balancing mechanism designed to achieve no net loss of healthy and productive land. This corresponds perfectly with the findings in the Results section, which indicate that around 20–30% of the basin was categorized as deteriorated based on LDN sub-indicators (LCC, NDVI, SOC). The picture highlights the ARR hierarchy—Avoid, Reduce, and Reverse degradation—which corresponds to the suggested management strategies for stabilizing plant cover, repairing degraded soils, and enhancing land productivity in the research area.

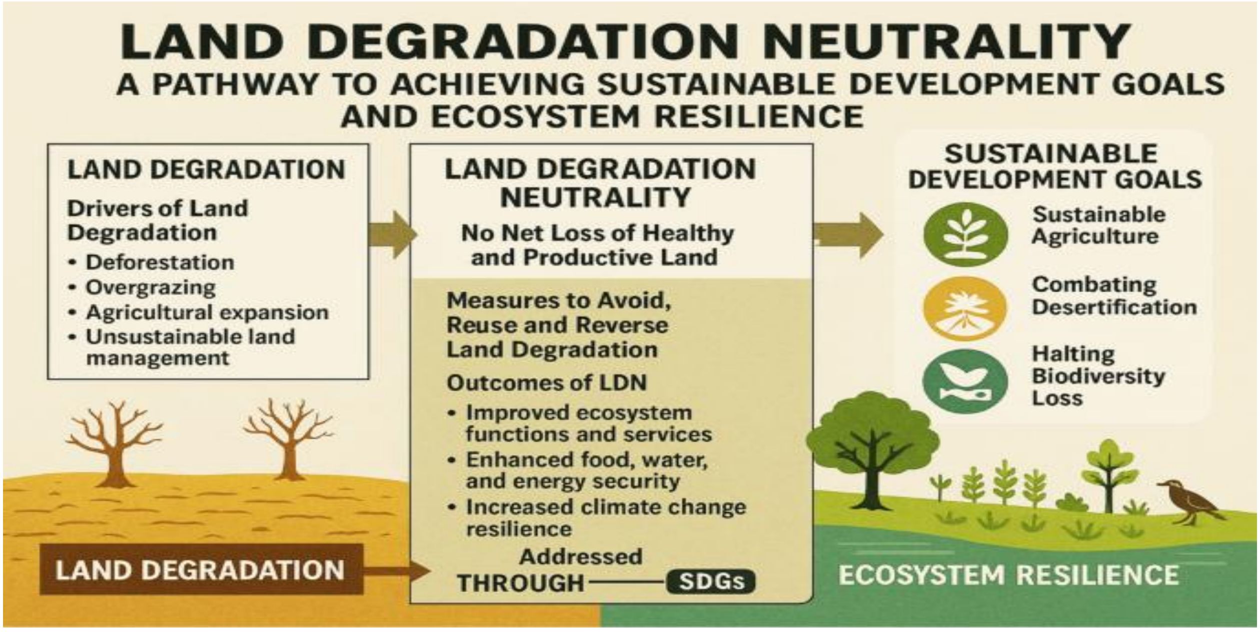

Figure 2. Conceptual pathway linking land degradation, Land Degradation Neutrality (LDN), and sustainable development outcomes

The graphic on the right links LDN to the larger Sustainable Development Goals (SDGs) by focusing on sustainable agriculture, stopping desertification, and stopping the loss of biodiversity. These outcomes are similar to the environmental and social benefits seen in Uzbekistan's restoration efforts, such as better rangeland conditions, fewer dust storms, stronger ecosystems, and progress toward SDG 15.3.The image clearly shows how LDN pathways turn pressures of degradation into long-term sustainability outcomes, which supports the study's actual findings.

The combined use of the DPSIR framework with the Land Degradation Neutrality (LDN) concept establishes a cohesive analytical basis for comprehending the interplay between socio-economic dynamics and environmental factors in shaping degradation processes. This study demonstrates that the integrated DPSIR–LDN framework is both conceptually sound and consistent with contemporary worldwide research on sustainable land management in arid settings. International research underscores that correlating causal chains (drivers → pressures → state → affects → responses) with quantifiable LDN indicators improves diagnostic precision and policy significance (Cowie et al., 2018; Zhao et al., 2023).

This study's primary conclusion is that the combination of DPSIR–LDN elucidates the intricate mechanisms by which climate change, agricultural intensification, and industrial pressures influence the ecological condition of the Ahangaran Basin. Comparable conclusions have been found in evaluations of other semi-arid and dry regions, where DPSIR effectively pinpointed the primary leverage areas for intervention (Abdul-Qadir et al., 2021; Gao & Bryan, 2017). Specifically, NDVI-based land productivity indicators and SOC measurements have demonstrated sensitivity as early-warning signals for identifying impending degradation trends (Cherlet et al., 2018; Cowie et al., 2020).

The findings further underscore the significance of systemic, multi-tiered governance strategies. Land degradation in the Ahangaran Basin exemplifies phenomena observed in arid places worldwide, where population expansion, increasing water demand, and climate variability exacerbate human-induced stresses on already vulnerable ecosystems (Kust et al., 2023; Martínez-Valderrama et al., 2025). The DPSIR framework elucidates these connections, whereas the LDN model offers a systematic approach for devising treatments that sustain or enhance land quality. This integration is especially beneficial for nations such as Uzbekistan, where land degradation frequently arises from a confluence of biophysical susceptibility and institutional limitations (IISD, 2024).

Moreover, the discourse underscores the imperative for resilient monitoring systems. Global studies indicate that attaining Land Degradation Neutrality necessitates both localized restoration initiatives and ongoing monitoring of land conditions by remote sensing, soil assessments, and longitudinal productivity evaluations (Orr et al., 2017; Cherlet et al., 2018). Integrating LCC, NDVI, and SOC developments within the DPSIR framework enables land planners to comprehend the correlation between particular human activities and quantifiable ecological results, facilitating prompt policy adjustments.

Another significant impact pertains to stakeholder participation. Research in Africa, Central Asia, and the Mediterranean emphasizes that sustainable land management can only be effective through collaboration among farmers, industry, local governments, and environmental authorities within a unified governance framework (Akhtar-Schuster et al., 2019; UNDP Uzbekistan, n.d.). In the Ahangaran Basin, where industrial, agricultural, and urban interests intersect, such coordination is imperative to prevent interventions that merely transfer degradation from one area to another.

The discussion illustrates that the integration of DPSIR with LDN offers a scientifically robust and globally recognized paradigm for assessing land degradation. It transitions environmental governance from a reactive approach—responding post-degradation—to a proactive strategy that predicts threats and emphasizes early intervention. This strongly matches with worldwide sustainability recommendations and enhances Uzbekistan's advancement toward SDG 15.3.1. The DPSIR–LDN approach, by merging causal analysis with quantifiable indicators, improves comprehension of degradation pathways and facilitates the development of focused, evidence-based, and scalable restoration strategies for the Ahangaran Basin.

Theoretically, the application of the DPSIR framework to the Ahangaran Basin provides significant insights for attaining land degradation neutrality. By putting socioeconomic and environmental aspects into the groups of Drivers, Pressures, State, Impacts, and Responses, and by clearly tying LDN indicators (LCC, NDVI, SOC) to those groups, resource managers may make a thorough story about the causes and effects of degradation. This makes it clear where policy actions can have the biggest impact. Conceptual scenarios illustrate how unmitigated pressures, such as the over use of land and water, may precipitate detrimental trends in vegetation and soil health. Conversely, proactive measures, like sustainable land management techniques and restoration efforts, can stabilize or reverse these trends, thereby achieving land degradation neutrality objectives.

The combination of DPSIR and LDN shows how important it is to have a balanced land management plan in dry Central Asia that plans for both losses and gains. It encourages a change from making policies based on what happens to making policies based on what you want to happen. For example, planning restoration work in the Ahangaran Basin at the same time as new irrigation infrastructure (instead of after) fits with the "avoid-reduce-reverse" hierarchy.

Future research ought to enhance this conceptual model using localized data; spatially mapping the DPSIR links (for instance, simulating the impact of changes in grazing management on NDVI patterns) would substantiate the methodology. Uzbek planners could benefit even more from decision-support tools or simulation models based on DPSIR-LDN. This paradigm ultimately offers a scientific justification for integrated initiatives—ranging from pasture rehabilitation to water-use reforms—that collectively advance the Ahangaran Basin towards sustainability and support Uzbekistan's LDN and broader SDG objectives.

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