Unpacking Land Degradation Neutrality (LDN), An Emerging Paradigm to Conserve Land Systems' Sustainability in the 21st Century? Meta-analysis of Challenges and Opportunities

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ABSTRACT

The UN Sustainable Development Goals specifically note the growing importance of land degradation management and mitigation strategies, advocating for global collaboration and innovative research and policy outlook. In this reflective summary, we synthesize the current worldview (post-2000) on land degradation neutrality (LDN), an emerging concept in the field of environmental sustainability that advocates a dynamic balance between degradation and restoration, to ensure no net loss in productive land resources. We first introduce the LDN Causal Framework (theoretical framework of LDN), followed by the Logic Model – guideline for on-ground LDN method implementation (comprising preparatory activities, followed by Integrated Land Use Planning (ILUP), and LDN Response Hierarchy (Avoid-Reduce-Reverse)). We draw attention to growing concerns about LDN technical problems*:* restore vs. rehabilitate; selecting indicator variables, and establishing a baseline. In the final section, we reflect on the social-ecological aspect of LDN – harnessing participatory action (multi-stakeholder engagement) and gender mainstreaming. Overall, LDN presents an umbrella vision for environmental regeneration and land capital management, that requires seamless integration of natural with social sciences, the policy with law, and requires strategic community mobilization.

INTRODUCTION

The 1992 Rio+20 Earth Summit identified Land Degradation as an imminent threat to global sustainable development initiatives (Sterk et al. 2016). Land degradation, negatively impacts about 40% of the total global landmass (Veron & Paruelo 2018), compromises livelihood opportunities of about 3.2 billion people, with an estimated annual reduction of about 10% of global gross products in biodiversity and ecosystem services (IPBES 2018). Between 1998 and 2013, nearly 20% of the Earth's vegetated land surface experienced persistent declining trends in productivity - apparent in 20% of global croplands, 16% of forest lands, 19% of grassland, and 27% of rangeland (UNCCD 2017). A prime driver of land degradation is unregulated growth in industrial agriculture (iPES Food 2016) - input-intensive crop monocultures, coupled with industrial-scale feedlots. Such intensive farming operations aggravate soil degradation (a) physically (erosion and compaction), (2) chemically (salinization and acidification), and (c) biologically (destruction of soil organic matter) (Fig. 1) that collectively threatens land systems' sustainability

(long-term delivery of goods and services), and ecosystem functioning (Keestra et al. 2018). Macro-scale outcomes of land degradation include soil productivity loss (Tang et al. 2016), competition for scarce resources (UNCCD 2017), human displacement (Cherlet et al. 2018), and climate change, to name a few (Amiraslani & Caiserman 2018, IPBES 2018). The importance of land degradation is acknowledged by the United Nation's Sustainable Development Goals (SDG Target 15.3). The global cost of land degradation could reach €420 billion annually (UNCCD 2013). Mounting need to protect land-based natural capital has led to the development of innovative ideas, including Land Degradation Neutrality (LDN) – a rapidly emerging concept that vies for a state whereby the quantity and quality of land resources, necessary to support ecosystem functions and services, remain stable (or increase) within specified temporal and spatial scales, without compromising existing food/water/energy security (Akhtar-Shuster et al. 2017; UNCCD 2016a).

However, till date, LDN has been an elusive concept (due yet to lack of adequate and targeted research), and a
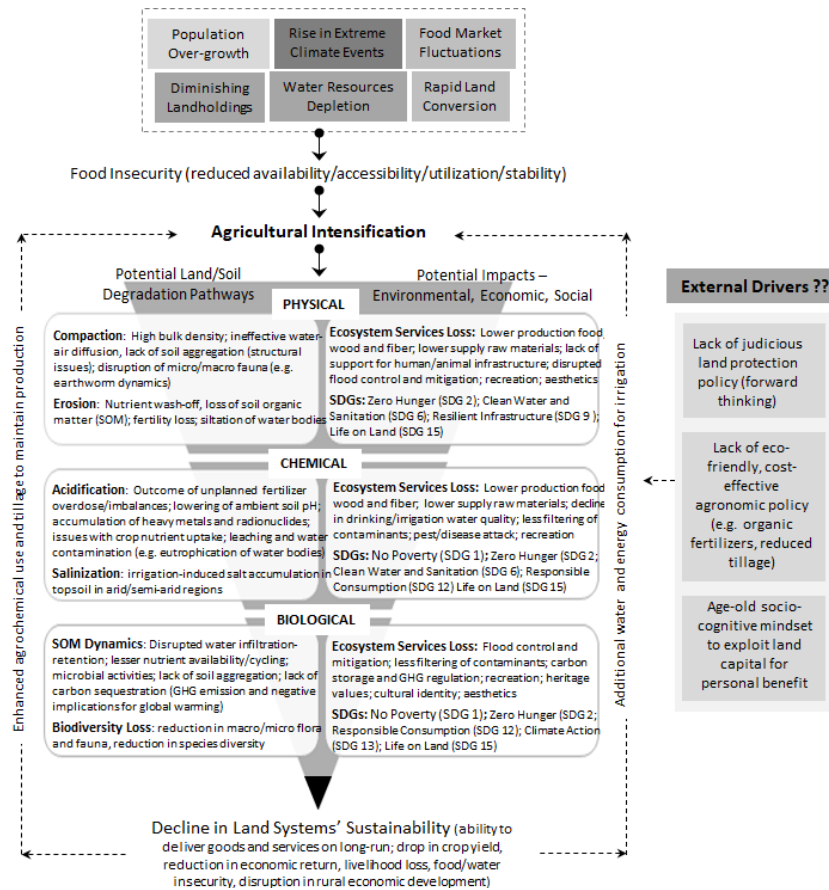
Fig. 1: Simplified depiction of interlinks between food insecurity, agricultural intensification, and major land/soil degradation pathways, with potential eco-environmental and social impacts on ecosystem services and Sustainable Development Goals (SDG). (adopted and modified from Keestra et al. (2018))

challenge to attain as it demands a thoroughly integrative vision, melding multiple development spheres, within a sound institutional structure and right political will (Cowie 2020, UNCCD 2014). In this reflective discourse, we aim to synthesize and present, to the relevant authorities (environmental and land systems' managers), ideas from global literature, to (i) outline core tents of LDN, (ii) emphasize the need to integrate natural with social sciences (stakeholder participation and gender empowerment) to turn theory into practices; and (iii) reflect on challenges vis-a-vis future opportunities to maintain land/ecosystem sustainability (ability to deliver goods and services on long-term). A subsidiary idea is also to showcase the structural, legal, and policy requirements to strive for LDN in future.

MATERIALS AND METHODS

A comprehensive literature search was performed across different databases and search engines including SCOPUS, PubMed, Science Direct, Springer Link, Blackwell, and Social Citation Index, Web of Science (WoS), EconLit, JSTOR, Google Scholar, etc. using a variety of keywords/ search phrases (detail given below). In addition to peer-reviewed journal articles, the search also included working papers, white papers, dissertations, newspaper articles, book chapters, grey literature, and any other technical reports/notes from government/non-government organizations published between January 2000 and July 2020. References cited in the literature were cross-searched and important studies were collected in full text.

A systematic literature search was conducted using the following search phrases:

- Category I : 'industrial agric*'; 'agric* intensi*'; 'agric* diversi*'; 'irrigat* agric*', 'agric* subsid*', 'till*'; and 'fertilizer'

- Category II: 'soil erosion*'; 'soil compact*'; and 'soil salin*'

- Category III: 'restor*', and 'rehabilitat*'

- Category IV: 'stakeholder participation'; 'stakeholder dialogue'; 'multi-stakeholder *'; and 'participatory *'
- Category V: 'Gender*'; 'women' and
- Category VI: Various combinations of Category I – V.

The '*' includes any extension of a word/phrase that precedes or succeeds to target a wider spectrum of topics and maximize the number of hits.

LDN: Theory and Practice

LDN is often equated with Zero Net Land Degradation (ZNLD), under which the extent of degraded land is expected to decrease or at least, remain stable over a definite time period (Stavi & Lal 2015). To understand the core tents of the LDN vision, however, the authorities (land and environmental systems' managers) should be cognizant about the multidimensional linkages between the drivers (natural or anthropogenic) of land degradation and their physical manifestations across a well-defined space-time continuum. In other words, there is a need to locate LDN within a cause-effect web - the LDN Causal Framework. Such introspective appraisals are more critical because of growing climatic anomalies and rapid socio-demographic shifts that endanger land capital in multiple ways.

LDN Causal Framework: Theoretical Underpinnings

The framework links five generic elements: Drivers (D); Pressures (P); State of land degradation (S); Response (R);
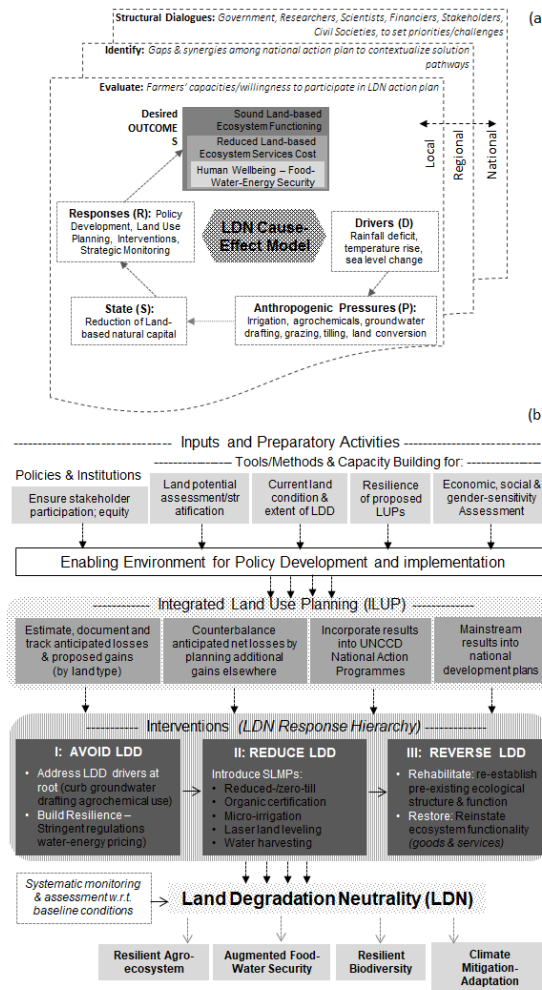

Fig. 2: (a) LDN Causal Framework (adopted from Cowie et al. (2018)) and (b) the genric workflow design involving LDN Logic Model (adopted from Orr et al. (2017)).

and Outcomes (O) over multiple spatial and temporal scales (Fig. 2a) (Cowie 2020). Elements 'D' and 'P' denote the biophysical and anthropogenic drivers of land degradation, respectively; while the 'R' term denotes Sustainable Land Management Practices (SLMPs). LDN causal framework offers a theoretical guide to understand how eco-environmental and human components overlap (Opakara et al. 2018), such as:

I.   Perceptions about broader environmental issues on arable land (e.g. drought, flood, heat waves, sea-level rise etc.)

II. Contextual knowledge to link specific farming practices (groundwater-sourced irrigation, deep tillage, agrochemical application) with ecosystem parameters.

III. Adaptive capacity; ability to plan suitable response actions to adjust to such changes (SLMPs). This is also complemented by the level of governmental support systems.

(I) and (II) embodies the 'D' and 'P' components in the causal framework, while (III) denotes the 'R' (Fig. 2a)'. The 'O' term underscores human wellbeing, realized by (i) rejuvenation of ecosystem services (ii) improving natural resources conditions while operating within the biophysical limits of land systems, (iii) reduction in ecosystem services costs (increasing availability/accessibility), and (iv) judicious allocation of land resources for various purposes. The LDN, unlike the traditional view of halting land degradation completely, which seems unrealistic, advocates a dynamic balance between the rate of land degradation and remediation (Orr et al. 2017):

–   Maintain and improve sustainable delivery of goods and services in long run

–   Increase the resilience of population reliant on land-based natural capital (train/equip them with context-relevant adaptive skills)

–   Harness synergies with other social, economic and environmental initiatives

–   Institute responsible and inclusive land governance.

LDN Logic Model: Putting Idea into Action

Existing LDN literature advocates a generic workflow structure, comprising of three broad stages of systems' action: (1) conducting input and LDN preparatory analysis, (2) developing integrated land use plans (ILUP), and (3) understanding choice of interventions (Cowie et al. 2018) (Fig. 2b). The LDN Logic Model begins with input and preparatory analysis (Cowie et al. 2018, Orr et al. 2017):

–   Assessment of initial land degradation status

–   Evaluation of existing land tenures

–   Realistic estimation of land capacities to deliver desired ecosystem services

–   Assessment of land stratification (types and extent of vegetative cover)

–   Level of maximum resilience potentially achievable.

The next stage is the ILUP design:

–   Realistic estimation of potential gains-losses due to proposed land use programs (loss in one location should be counterbalanced by gains in others)

–   Strategic integration of the proposed land use programs with other sustainable development paradigms as a complementary action strategy

–   Identifying strategic means to integrate it with the national sustainable development agenda

The final stage calls in land-based interventions, centering on the LD Response Hierarchy, founded on three principles:

–   AVOID: adopting pre-emptive regulation/planning to keep land degradation processes at bay

–   REDUCE: resorting to various SLMPs to curb impacts of different human activities

–   REVERSE: develop restoration or rehabilitation projects to assist in the recovery of already degraded land to rejuvenate ecosystem functions.

Avoiding land degradation should be the first priority, followed by reducing degradation, while restore/rehabilitate, to reverse degradation. The latter is more appropriate for land already degraded.

LDN IMPLEMENTATION: TECHNICAL CONCERNS

Rehab or Restore?

Rehabilitation encompasses a set of measures that aim to reinstate ecosystem functionality, focusing on sustainable/ equitable provisions of goods and services (McDonald et al. 2016). On the other hand, Restoration seeks to re-establish pre-existing ecological structure and functions, including biotic integrity. The choice of action depends on careful deliberation on (1) types and magnitude of drivers of land degradation; (2) long-term land potentials; (3) land management history; (4) snowballing pressure on land capital (unregulated natural resources extraction); and (5) climatic conditions, to name a few. However, the authorities should bear in mind that neither rehabilitation nor restoration can return degraded ecosystems to the pre-disturbance configuration in the short/medium term (Maron et al. 2015), and thus, pre-emptive action (avoid land degradation) is the most desired strategy. Authorities should also realize that

response to any 'corrective' intervention is a slow process and follows mostly a non-linear trajectory - perceptible changes in ecosystem parameters are only observed after a certain threshold point is reached, over a certain period of time (Bestelmeyer et al. 2015).

Selecting LDN Indicator Variables

There are three prime indicators, to monitor progress towards achieving LDN (Sims et al. 2019, UNCCD 2016b): (i) land cover and changes; (ii) land productivity; and (iii) carbon stocks. These indicators are applied in a 'one out, all out' approach: where any of the indicators show significant negative change, it is considered a loss, and conversely, if at least one indicator shows a positive trend and none shows a negative trend, it is considered a gain (UNCCD 2017). However, for more practical and local applications, there should be more targeted parameters (e.g. groundwater levels, streamflow, precipitation, soil organic matter content, cation exchange capacity etc.) (Tilahun et al. 2018). Indicators should be identified by (i) combining ground-level survey with remotely sensed observation (e.g. satellite imagery), and (ii) active consultation with local communities, rather than solely relying on external specialists who, most times have little familiarity with local conditions, and come with pre-conceived notions (Opakara et al. 2018).

Establishing Baseline

The baseline represents a standardized frame of reference (initial value of each LDN indicator variable) against which neutrality achievements/failures are assessed within a suitable timeframe (Cowie et al. 2018). Broad steps include:

1. Setting LDN target (realistic; based on the current level of land degradation)

2. Identification of indicator variables (stakeholder consultation to include local/traditional knowledge of ecosystem parameters)

3. Systematic monitoring with the help of local communities (inflow and outflow patterns of land-based natural stocks).

The baseline for each indicator variable should be computed over an extended timeframe (averaging values over decadal-scale; statistically accounting for temporal variability), instead of 'conventional' single-point-in-time approach (Orr et al. 2017)

SOCIO-ECOLOGY OF LDN: HUMAN-NATURE INTERACTIONS

Growing advocacy worldwide to implement LDN principles is to adopt a *socio-ecological* lens (Ostrom 2009), consciously apportion environmental systems into two mutually

reinforcing domains of development and action: (1) ecosystem-based and (2) society- and economy-based (Okpara et al. 2018). The latter is founded on two key policy approaches: (i) harnessing participatory engagement – multi-stakeholder dialogue, and (ii) women's strategic, active, and purposeful involvement.

Multi-Stakeholder Dialogue

Strategic implementation of LDN systems' governance calls for structural dialogues between multiple agencies: a platform comprising of actors ranging from local to national levels- with diverse perceptional, educational, and technical backgrounds; diverse expectations and priorities (Amiraslani & Caiserman 2018). Such a carefully designed multi-stakeholder platform increases opportunities for a coordinated action network (harnessing synergies in actions) that acknowledges different claims/demands on land capital while reconciling the needs and consumer demands (UNCCD 2015). Current global literature (Kust et al. 2017), indicates that participatory action helps to:

– Promote awareness about land restoration/rehabilitation

– Inspire sense of shared responsibilities towards land systems protection (viewing land as common-pool resources for mutual benefits)

– Develop means to remove legal, institutional, social barriers/conflicts to work towards a common and mutually re-assuring goal

To develop a participatory action plan, the authorities will need to (i) identify and reach out to all interested parties/stakeholders and indoctrinate them to LDN principles; and (ii) strategically engage them at all stages of decision making (Fig. 3a) (IUCN 2018). The stakeholders must adopt voluntary responsibilities (time-bound targets) to contribute meaningfully to land-based projects, with minimal conflicts. However, it will require an 'enabling' environment for the stakeholders. According to Verburg et al. (2019), the authorities need to deliberate on three ideas: (i) respecting farmers' perceptions, about the mode of LDN systems' operation (are the farmers apprehensive of outcomes?), (ii) systems' inadequacies (is there enough infra, knowledge, finance?), and (iii) expectations of the system (will LDN curtail farmers' incomes?) (Fig. 3b). Along similar lines, Crossland et al. (2018) suggested certain systems' checks: (i) negotiating priorities and incentivizing farmers' actions towards LDN, (ii) devising contextual solutions to problems, and (iii) co-production of knowledge (basing LDN assessment on local farmers' inputs).

Last but not the least, for the developing rural economies, there should be conscious deliberation on behalf of the authorities, to safeguard small/marginal holders' interests - LDN strategy implementation (targets, methods,

timeframe) should not endanger livelihood opportunities of this less-endowed and already vulnerable population, and/or evict them from their lands, in the name of land 'restoration/ rehabilitation' (IUCN 2018). Additional benefits might be realized by promoting farmers' social networks to disseminate new paradigms (e.g. optimize deep tillage, controlled/ planned agrochemical use, water-efficient crops, irrigation tariffing) (Chaudhuri et al. 2020a).

Harnessing Gender Responsivity

The value (urgency) of gender mainstreaming in LDN strategy implementation is yet fully acknowledged, with inadequate policy attention (Okpara et al. 2019). Lower access to productive resources; lack of information, technology, and extension services; lower awareness levels; patriarchal outlook; and ulterior political dynamics, still keep a vast cross-section of the women workforce from participating in environmental initiatives around the world (Chaudhuri et al. 2021a, 2018, Chaudhuri & Roy 2017). Okpara et al.

(2018) urged for developing targeted and context-relevant socioeconomic interventions for (1) safeguarding women's land rights (tenure); (2) creating legal provisions to enhance the ability to exercise land rights freely (ability to sell/lease out); (3) ensuring equitable access to all productive resources; and (4) developing targeted financial packages to rightfully compensate women for their contributions. In this regard, Mor (2019) has shortlisted certain socioeconomic indicators that might be used to assess gender inequality (Fig. 4). In rural societies, women are more tied to land-based natural capital (in charge of the collection of water/fuelwood/fodder/herbs/fruits), and thus land degradation affects them disproportionally (UNCCD 2017). Broad measures could include (Global Mechanisms 2019):

– Developing strategic sensitization programs to make women (farmers) aware of new cropping systems (tools, seeds, irrigation, harvesting practices)
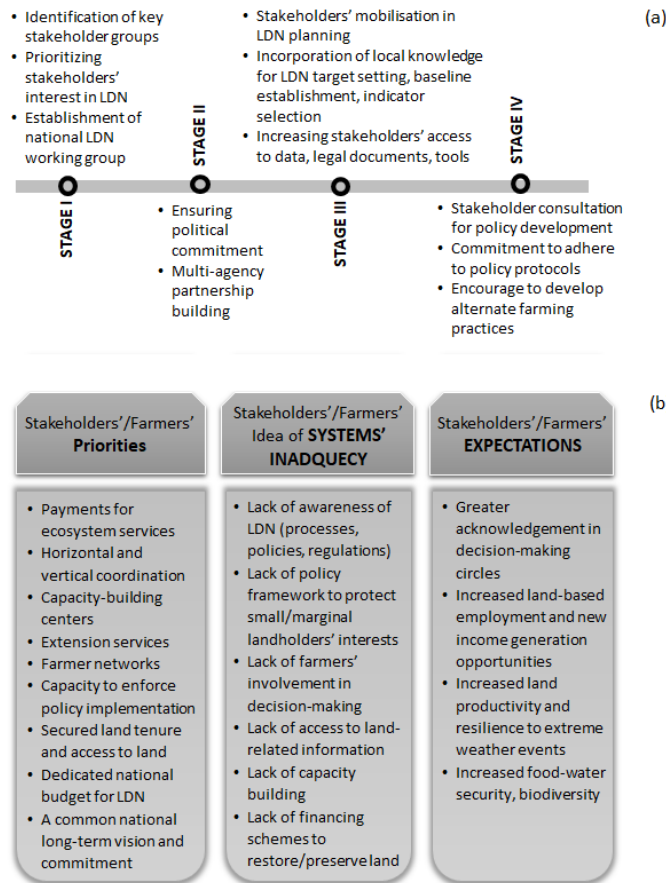– Helping women's groups get connected through information networks

Fig. 3: (a) Main stages of developing a functional participatory action framework that respects stakeholders'/farmers' priorities; and (b) current institutional systems' inadequacies for the same (adopted from Verburg et al. (2019)).

Gender Responsive LDN Theme	Potential Checklist for Authorities
Creating an Enabling Environment for Women in Land-based Projects	• Are women actively participating in land-based project development meetings (restoration/rehabilitation)? • Are women holding influential positions in decision-making circles (e.g. manager, lead farmer, entrepreneur)? • Are women part of self-help groups, information networks? • Are there legal provisions to promote and protect women's interests in land-based projects?
Women Equally Reaping of the Benefits of Land-based Projects as Men	• Are the women benefitting from organized workshops and skill-development initiatives? • Can women freely access latest tools and resources? • Are women actively participating in main policy discussions? • Are women-headed households land project beneficiaries? • Can women accessing financial schemes (loans, subsidies)?
Women's Ownership Status of Productive Asset base (land, livestock, tools)	• Do the women possess legal land documents? • Do they have equal rights as men to sell/mortgage/use land whenever necessary? • Are women aware of land rights/tenure issues (and changes therein) and associated redress mechanisms? • Do women own other productive assets?
Women's Level of Access to Resources and Inputs for Land-based Projects	• Do women have access to (i) improved seeds/saplings/fertilizer/fodder; (ii) agricultural extension services; (iii) climate-smart agriculture/technology; (iv) information/data • Is there land earmarked for restoration under LDN to women to use their own discretion to rehabilitate?

Fig. 4: Thematic survey to assess women's empowerment/involvement in land/environmental projects (could be expressed in terms of relative percentages of women, wherever applicable) (adopted from Mor (2019))

– Making legal and institutional provisions for women to participate in, and contribute to, land research and development activities

– Increasing the number of women personnel in the extension services

In this regard, the authorities may also want to consult the guidelines developed by the International Union for Conservation of Nature (Table 1) (IUCN 2018).

CONCLUSION

The LDN approach supports multiple sustainability paradigms, including food/nutritional security (SDG 2: Zero Hunger), livelihood and income (SDG 1: No Poverty), terrestrial biodiversity (SDG 14: Life on Land), and (SDG 5: Gender Inequity), to name a few (Stavi & Lal 2015). Moreover, the LDN falls in line with the Aichi Biodiversity Targets (Target 5: reduce habitat loss/degradation close; Target 7: sustainable management of areas under agriculture and forestry; Target 14 and 15: safeguarding essential ecosystem services and harnessing resilience, increasing carbon stocks, restoring degraded ecosystems) (IUCN 2015). LDN could even become a critical component to the Sendai Framework for Disaster Risk Reduction 2015-2030 (Priorities 2 and 3: strengthening disaster risk governance) (UN 2015). The incorporation of LDN in national development agendas could also bolster emission reduction efforts (SDG 13: Climate Action). Collectively, the successful implementation of LDN offers a milieu of opportunities to the authorities (environmental and land systems' managers) that could be critical in days ahead to brace up against 'unpredictability' (e.g. climatic anomalies), while bolstering food-water-energy security programs, and diversifying rural livelihood-income opportunities.

On-ground implementation of LDN should be planned within a participatory engagement framework, marked by strategic cross-linking of multiple development domains, agencies and actors (Table 2). It requires a robust institutional structure, stable finance (Public-Private Partnerships), social capital building, and technology support (Fig. 5). A major obstacle, however, will be to ward off political influences, which almost always take the populist path, and argues against any stringent intervention (Chaudhuri and Roy, 2019). Environmental reforms are vehemently repealed, branded as "anti-farmer", "anti-poor by regional/local parties to win electoral battles (Chaudhuri et al. 2021, 2020b).

To that end, we urge the authorities to adopt an integrative vision:

Table 1: Best practices to ensure women's participation in LDN projects (adopted from IUCN (2018))

Proposed Objective	Potential Method Implementation Action Plan
Women leading initiatives as major stakeholders in the land-based projects	• Engaging with NGOs and public sector offices with prior experience and equipped with ideas/techniques/manuals • Organizing focused group discussions (FGDs) with women to assess their expectations, aspirations. capacities • Conducting regular capacity-building workshops (hands-on demonstrations) to train and equip women • Mobilizing women's self-help groups towards LDN projects
Harness women's financial capacities	• Enabling women to access credits micro/mesoscale enterprises and formal banking sector • Identifying means to directly transfer credits/support to women without intermediary stage (not via husband/male family members) • Incentivizing the public and private sectors to source their raw material directly from women • Training women for value-added production • Developing new/alternate income generation opportunities from various land-based projects
Voluntary Guidelines on the Responsible Governance of Tenure (VGGT)	• Recognize women's land tenure right by ensuring a non-discriminatory LDN work plan • Safeguard legitimate land tenure rights against all potential threats (maintain equity, justice, human dignity by all means) • Prevent disputes, conflicts, and corruption by practicing transparency and accountability in the LDN systems' approach
Sensitizing success stories	• Using social/print/electronic media to sensitize success stories women leadership roles in various land/environmental projects
Gender-responsive knowledge products	• Elaborating studies/research/consultancies to incorporate gender-responsive ideas • Engaging reputed gender specialists to provide guidance and directions for LDN design • Circulating to national gender/women's experts/advocacy groups for inclusion of women in land-based projects
Gender message included in training and awareness events/campaigns	• National gender focal point and gender working group draft standard gender message • Include gender analysis as a requirement in the Terms of Reference (TORs) of LDN • Fact sheet on gender and restoration

– Identify ongoing environmental initiatives that would directly patronize LDN systems' thinking and implementation

– Found LDN on principles of equity, inclusivity, fairness and transparency (pro-poor; gender-sensitive)

– Incorporate LDN into mainstream rural economic development agenda

– Identify all potential stakeholders
  • Acknowledge priorities and capacities
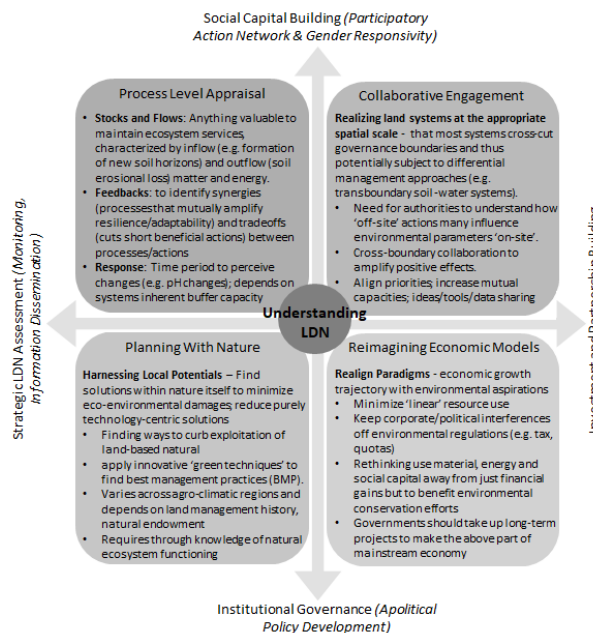 • Identify means to harness synergies (develop grievance redress protocols)

Fig. 5: Conceptual underpinning of LDN strategy development (concepts adopted from Keestra et al. (2018); authors' own illustratifon)

Table 2: Key developmental domains to maximize LDN benefits (adopted from IUCN (2015))

Development Domain	Key Areas of Emphasis
Strengthening natural resource governance and land tenure security	• Ensuring equitable rights of men and women to access land • Special LDN targets for lands not legally titled and/or land where indigenous peoples or ethnic minorities hold customary rights • Ensuring environmental justice and social protection to curb the risk of out-migration of the native population due to LDN projects • Implementing principle of free, prior, and informed consent when setting LDN targets and strategy implementing methods • Ensuring equity at the lowest practical and accountable level of the institutional governance system • Incorporating traditional/indigenous knowledge at every level of LDN systems' design
Integrating LDN with other Development initiatives	• Harnessing synergies between LDN actions/targets and other initiatives (biodiversity, carbon sequestration, climate action) • The full range of sustainable land management and restoration approaches, thereby leveraging other sectors and stakeholders as implementation actors • Evidence-based LDN target-setting using integrative vision (environment, agriculture, water, energy, climate, humans) • Restoration opportunities are decided based on the existing state of the land, the potential for restoration/rehabilitation, the cost-benefit ratio of LDN actions planned, threats to the native population
Collecting more evidence for LDN achievement (Monitoring and reappraisal of LDN targets over time)	• Disseminating open-sourced data to research communities on the state of land degradation, restoration, rehabilitation • Strategic monitoring and evaluation for adaptive management • The above includes selection, monitoring, and assessment of appropriate biodiversity indicators and analysis of multiple ecosystem services thereof • Scale-up of best management practices, evidence-based, accounting for cost-benefit of interventions on the full range of ecosystem services

- • Conduct strategic sensitization/outreach/promotion programs (assurance about food-water-energy security and dispelling myths about income loss)

– Deploy dedicated extension service agents (preferably by choosing individuals from local population – good communication skill; impartial attitude; aware of local expectations vis-à-vis grievances; demonstrated commitment to environmental causes; well-connected in community and influential)

– Ramp up technology support system (on-ground and remotely sensed)

– Choose local indicator variables using local wisdom/ experience

– Design novel monitoring and data reporting systems; train chosen individuals from local communities to assist in the process

REFERENCES

Akhtar-Schuster M., Stringer, L., Erlewein, A., Metternicht, G., Minelli, S., Safriel, U. and Sommer, S. 2017. Unpacking the concept of land degradation neutrality and ad- dressing its operation through the Rio Conventions. J. Environ. Manage., 195: 4-15.

Amiraslani, F. and Caiserman, A. 2018. Multi-stakeholder and multi-level interventions to tackle climate change and land degradation: The case of Iran. Sustainability, 10(6): 1-17. DOI:10.3390/su10062000.

Bestelmeyer, B.T., Okin, G.S., Duniway, M.C., Archer, S.R, Sayre, N.F, Williamson, J.C. and Herrick, J.E. 2015. Desertification, land use, and the transformation of global drylands. Frontiers Ecol. Environ., 13(1): 28-36.

Chaudhuri, S., Roy, M., McDonald, L.M. and Emendak, Y. 2021a. Coping

Behaviours and the concept of Time Poverty: a review of perceived social and health outcomes of food insecurity on women and children. Food Security. 13: 1049-1068.

Chaudhuri, S., Parakh, D., Roy, M. and Kaur, H. 2021b. Groundwater-sourced Irrigation and Agro-power Subsidies: Boon or Bane for Small/Marginal Farmers in India? Groundwater for Sustainable Development. 15(100690). DOI: 10.1016/j.gsd.2021.100690.

Chaudhuri, S., Roy, M., McDonald, L.M. and Emendack, E. 2020a. Reflections on farmers' social networks: A means for sustainable agricultural development? Environ. Dev. Sustain., 23(3): 2973-3008. DOI: 10.1007/s10668-020-00762-6

Chaudhuri, S., M. Roy, L.M. McDonald and Y. Emendack. 2020b. Water for all (Har Ghar Jal): Rural water supply services (RWSS) in India (2013-20180, Challenges and Opportunities. International Journal of Rural Management. 16(2): 254-284.

Chaudhuri, S. and Roy, M. 2019. Irrigation water pricing in India as a means to conserve water resources: Challenges and Potential future directions. Environ. Conserv., 46(1): 99-102.

Chaudhuri, S., Roy, M. and Jain, A. 2018. Appraisal of WaSH (Water-Sanitation-Hygiene) infrastructure using a composite index, spatial algorithms and sociodemographic correlates in rural India. J. Environ. Informat., 35(1): 1-22.

Chaudhuri, S. and Roy, M. 2017. Rural-urban spatial inequality in water and sanitation facilities in India: A cross-sectional study from household to national level. Appl. Geog., 85: 27-38.

Cherlet, M., Hutchinson, C., Reynolds, J., Hill, J., Sommer, S. and von Maltitz, G. (Eds.). 2018. World Atlas of Desertification, Publication Office of the European Union, Luxembourg.

Cowie, A. 2020. Guidelines for Land Degradation Neutrality: A Report Prepared for the Scientific and Technical Advisory Panel of the Global Environment Facility, Washington D.C.

Cowie, A.L., Orr, B.J., Sanchez, V.M.C., Chasek, P., Crossman, N.D., Erlewin, A., Louwagie, G., Maron, M., Metternicht, G.I., Minelli, S., Tengberg, A.E., Walter, S. and Welton, S. 2018. Land in balance: The scientific conceptual framework for land degradation neutrality. Environmental Science and Policy. 79: 25-35.

Crossland, M., Winowiecki, L.A., Pagella, T. and Hadgu, K. 2018. Implications of variation in the local perception of degradation and restoration

processes for implementing land degradation neutrality. Environ. Develop., 28: 42-54.

Global Mechanisms. 2019. Land Degradation Neutrality Transformative Projects and Programmes: Operational Guidance for Country Support. UNCCD, Bonn, Germany.

IPBES. 2018. Summary for policymakers of the assessment report on land degradation and restoration of the intergovernmental science-policy platform on biodiversity and ecosystem services. In: R. Scholes, L. Montanarella, A. Brainich, N. Barger, B. ten Brink, M. Cantele, B. Erasmus, J. Fisher, T. Gardner, T. G. Holland, F. Kohler, J. S. Kotiaho, G. Von Maltitz, G. Nangendo, R. Pandit, J. Parrotta, M. D. Potts, S. Prince, M. Sankaran and L. Willemen (eds.). IPBES Secretariat, Bonn, Germany, p.44.

iPES Food. 2016. From uniformity to diversity: a paradigm shift from industrial agriculture to diversified agroecological systems. International Panel of Experts on Sustainable Food Systems. https://www.ipes-food.org/_img/upload/files/UniformityToDiversity_FULL.pdf

IUCN. 2018. A review of land degradation neutrality process. International Union for Conservation of the Nation. Gland, Switzerland.

IUCN. 2015. Land Degradation Neutrality: Implications and Opportunities for Conservation. International Union for Conservation of the nation. Gland, Switzerland.

Keestra, S., Mol, G., De, Leeuw, J., Okx, J., Molenaar, C., De, Cleen, M. and Visser, S. 2018. Soil-related sustainable development goals: Four concepts to make land degradation neutrality and restoration work. Land, 7(4): 133. Doi: 10.3390/land7040133.

Kust, G., Andreeva, O. and Cowie, A. 2017. Land degradation neutrality: Concept development, practical applications, and assessment. Environ. Manage., 195(1): 16-24.

Maron, M., Bull, J.W., Evans, M.C. and Gordon, A. 2015. Locking in loss: Baselines of decline in Australian biodiversity offset policies. Biol. Conserv., 192: 504-512.

McDonald, T., Gann, G.D., Jonson, J. and Dixon, K.W. 2016. International Standards for the Practice of Ecological Restoration-Including Principles and Key Concepts (first edition), Society for Ecological Restoration (SER), Washington, D.C.

Mor, T. 2019. A Manual for Gender-Responsive Land Degradation Neutrality Transformative Projects and Programs. UN Women, IUCN.

Okpara, U.T., Stringer, L.C. and Akhtar-Schuster, M. 2019. Gender and land degradation neutrality: A cross-country analysis to support more equitable practices. Land. Degrad. Develop., 30(11): 1368-1378.

Okpara, U.T., Stringer, L.C., Akhtar-Schuster, M., Metternicht, G.I., Dallimer. M. and Requier-Desjardins, M. 2018. A socio-ecological systems approach is necessary to achieve land degradation neutrality. Environ. Sci. Policy, 89: 59-66.

Orr, B.J., Cowie, A.L., Sanchez, V.M.C., Chasek, P., Crossman, N.D., Erlewein, A., Louwagie, G., Maron, M., Metternicht, G.I., Minelli, S., Tengberg, A.E., Walter, S. and Welton, S. 2017. Scientific Conceptual Framework for Land Degradation Neutrality. A Report of the Science-Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany.

Ostrom, E. 2009. A general framework for analyzing sustainability in social-ecological systems. Science, 325: 419-422.

Sims, N.C., England, J.R., Newnham, G.J., Alexander, S., Green, C. and Held, A. 2019. Developing good practice guidance for estimating land degradation in the context of the United Nations Sustainable Development Goals. Environ. Sci. and Policy, 92: 349-355.

Stavi, I. and Lal, R. 2015. Achieving net-zero land degradation: Challenges and opportunities. J. Arid Environ., 112: 44-51.

Sterk, G., Boardman, J. and Verdoodt, A. 2016. Desertification: History, causes, and options for its control. Land Degrad. Dev., 27: 1783-1787.

Tang, Z., An, H., Deng, L., Wang, Y., Zhu, G. and Shangguan, Z. 2016. Effect of desertification on productivity in a desert steppe. Sci. Reports, 6: 27839. DOI:10.1038/srep27839.

Tilahun, M., Singh, A., Kumar, P., Apindi, E., Schauer, M., Libera, J. and Lund, H.G. 2018. The Economics of Land Degradation Neutrality in Asia: Empirical Analyses and Policy Implications for the Sustainable Development Goals. https://www.eld-initiative.org/fileadmin/pdf/Asia_Report_EN.pdf

UNCCD. 2017. Global Land Outlook: First Edition. United Nations Convention to Combat Desertification, Bonn, Germany. http://www2.unccd.int/sites/ default/files/documents/2017-09/GLO_Full_Report_ low_res.pdf

UNCCD. 2016. United Nations Convention to Combat Desertification. Report of the Conference of the Parties on its twelfth session, held in Ankara from 12 to 23 October 2015. Part two: Actions. ICCD/COP(12)/20/Add.1.United Nations Convention to Combat Desertification, Bonn.

UNCCD. 2015. Climate Change and Land Degradation: Bridging Knowledge and Stakeholders. United Nations Convention to Combat Desertification, 3rd Scientific Conference, 9-12 March, Cancun, Mexico

UNCCD. 2013. United Nations Convention to Combat Desertification. The Economics of Desertification, Land Degradation, and Drought: Methodologies and Analysis for Decision-Making. In Proceedings of the UNCCD 2nd Scientific Conference, Bonn, Germany, 9-12 April 2013.

Verburg, P.H., Metternicht, G., Allen, C., Debonne, N., Akhtar-Schuster, M., Inácio, da Cunha, M., Karim, Z., Pilon, A., Raja, O., Sánchez Santivañez, M. and S€nyaz. A. 2019. Creating an Enabling Environment for Land Degradation Neutrality and its Potential Contribution to Enhancing Well-being, Livelihoods and the Environment. A Report of the Science-Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany.

Veron, S.R. and Paruelo, J.M. 2010. Desertification alters the response of vegetation to changes in precipitation. J. Appl. Ecol., 47: 1233-1241.