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Boosting Widespread Adoption of Sustainable Agriculture – New Metrics and the Role of Science

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Adapting to new climatic, social, and environmental realities demands deep and massive transformative changes in how humans manage, perceive, and relate with terrestrial and aquatic productive systems. In India, agriculture production is challenged by degraded soils, scarce and contested water, fragmented and degraded seminatural habitats, social conflict, and more frequent extreme events. Existing political will is enabling the adoption of sustainable agriculture. However, the pace and the extent of the adoption of promising strategies, practices, and approaches for achieving sustainable and resilient agriculture remains sparse. Accelerating a socially just transformation to sustainability in India requires a new systems-oriented, multidisciplinary, human well-being-centered research agenda. Specifically, the new agenda can expand, contest and reevaluate agriculture performance' in terms of how is evaluated and measured at the farm and landscape level. The new evidence will be critical for learning, innovating and re-designing sustainable, multifunctional and resilient agricultural landscapes.

Introduction

All base resources that maintain human populations and the economy (e.g., soil, water, terrestrial and aquatic biodiversity) are under threat, and have degraded at an alarming rate and level, cascading into widespread environmental crises and social inequalities (Martin *et al*., 2020). Therefore, radical societal and economic transformations are essential to achieve sustainability as committed to and envisioned (Pascual *et al*., 2022). This transformation includes recasting how humans relate, manage, and envision the role of agriculture (production of food and non-food products, livestock, fisheries, and forestry) in achieving multiple Sustainable Development Goals and global commitments

Accelerating the transformation and widespread adoption of sustainable agricultural systems country-wide is, therefore, a tremendous task that some countries started to embrace. For example, the Indian government is committed to transforming its agricultural land, and better managing its terrestrial and aquatic genetic resources through multiple mechanisms; including multilateral environmental agreements, enacted legislation, national biodiversity targets, and concrete action plans (NBA, ICAR-Bureax and ABC, 2020). Yet, translating existing political will into accelerated crosssectoral and multilevel action for redesigning sustainable agricultural farms and landscapes remains challenging.

Multiple alternative approaches and practices to conventional agriculture can play (and are playing) a critical role in achieving healthy terrestrial and aquatic systems (Gupta *et al.,* 2021, Jones *et al.,* 2021, Leal *et al.,* 2020). These alternative and sustainable approaches share some commonalities, such as a) integrating traditional and scientific knowledge, b) putting farmers' wellbeing at the center to redesign aquatic and terrestrial agricultural systems that mobilize less or null external input use (including water), c) embedding more agricultural biodiversity in the farm, and landscape level, and d) retaining and restoring remanent patches of seminatural habitat (Gupta *et al.,* 2021). Despite multiple lines of evidence, adopting these actionable alternative approaches and practices remains rare and conventional agriculture still dominates (Gupta *et al.,* 2021).

Conventional agriculture played a crucial role in overcoming the challenges during the 60s by converting India's food availability from scarce to abundant (Kumar foreword in Gupta *et al.*, 2021). Conventional agriculture

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research, planning, and performance assessment remains heavily centered around yields thus neglecting impacts beyond the field (e.g. landscape or watershed level) and beyond the agriculture sector (e.g. human health, environment, economy). This myopic vision to assess the performance of agricultural systems brought about disastrous social and environmental consequences, which are poorly accounted for in current economic and political models. In India, the severity and extent of degraded soils, contested water use across sectors, depleted groundwater reservoirs, fragmented and degraded natural habitats, and environmental conflict raise the urgency to rapidly move from unsustainable to sustainable agriculture production (Fig. 1).

As such, the transition towards sustainable agriculture production demands an environment of political will at national and global level and a new research agenda that better captures the comparative advantage of multifunctional, sustainable, and resilient agricultural systems. Ideally, this new research agenda will facilitate identifying local and context-relevant solutions that particularly supports small, subsistence, vulnerable, and marginal farmers to thrive and flourish in healthy and resilient ecosystems (EcoNetwork, 2022). This will require systems-level, multidisciplinary, and human wellbeing -centered research (EcoNetwork, 2022). Likewise, the new research agenda should question and challenge how agriculture performance is measured including what gets measured or considered in performance assessments. Here we elaborate on two specific questions that can push the role of science in guiding decision-making and actions towards a socially just transformation to sustainability in India.

Future Prospective and Concrete Action Points

What gets Measured – Making the Invisible, Visible

Wild and domesticated biodiversity are the invisible engineers of terrestrial and aquatic ecosystems. However, wild biodiversity is rarely monitored in agricultural landscapes, and domesticated biodiversity is rapidly disappearing from our plates and fields, leaving humans with limited genetic resources for future use (Jones *et al*., 2021, Dulloo *et al*., 2021, Leal *et al*., 2020). Maintaining and fostering diversity is a critical principle in attaining resilience and adaptability (Biggs *et al*., 2015). Hence, efforts to better capture the spatial and temporal dynamics of terrestrial and aquatic genetic resources (e.g., multi-taxa assessments) in agriculture-dominated landscapes are crucial for establishing the connection between sustainable agriculture / biodiversity/ ecosystem functioning/ resilience.

Agriculture is also understood to be much more, such as “good food,” “identity,” “happiness,” “tradition,” “autonomy”, “resilience”, etc. Hence, developing, testing, and validating new metrics that capture sustainable agriculture’s ignored but highly relevant contributions to human wellbeing is key. For example, a study in Brazil shows that integrated interventions contribute more, and positively to multiple locally relevant aspects of human wellbeing than siloed interventions (e.g. land sparing strategy) (Carmenta *et al*., 2022).

Similarly, agriculture’s spillover effect on other sectors are often ignored. For example, un-sustainable crop production is compromising the 9.71 million tonnes per year of inland fish pro-duction due to pollution, sedimentation, water ab-straction, obstruction of river flows by dams, and im-paired environmental flows, among other pressures (ICAR-NBFGR and ABC, 2020). Hence, under-standing how terrestrial and aquatic managed systems interact is also critical for promoting syner-gistic multisectoral (e.g. agriculture, natural resources, human health) efforts, and collectively contribute towards achieving multiple objectives; such as, biodiversity conservation, nutritious and sustainable crop, livestock, forestry, and fisheries production.

Overall, re-designing agricultural land for resilience, multifunctionality and sustainability will require long-term and country-wide monitoring efforts a) tracking species, varietal and landrace diversity in productive systems (terrestrial and aquatic), b) capturing agriculture impacts beyond material aspects, and c) accounting for spillover effects across sectors. A network of landscapes with contrasting adoption levels of sustainable agriculture practices will enable innovation, cross-learning and advancing quantifying the comparative advantage of multifunctional and resilient agriculture against business as usual.

How Aquatic and Terrestrial Productive Systems Performance is Measured

Agriculture performance is often assessed through simplistic or static metrics such as yields, which keenly fall short of capturing the wide range and long-term contributions to people and nature from multifunctional and sustainable agriculture (Tittonell, 2014). A wide

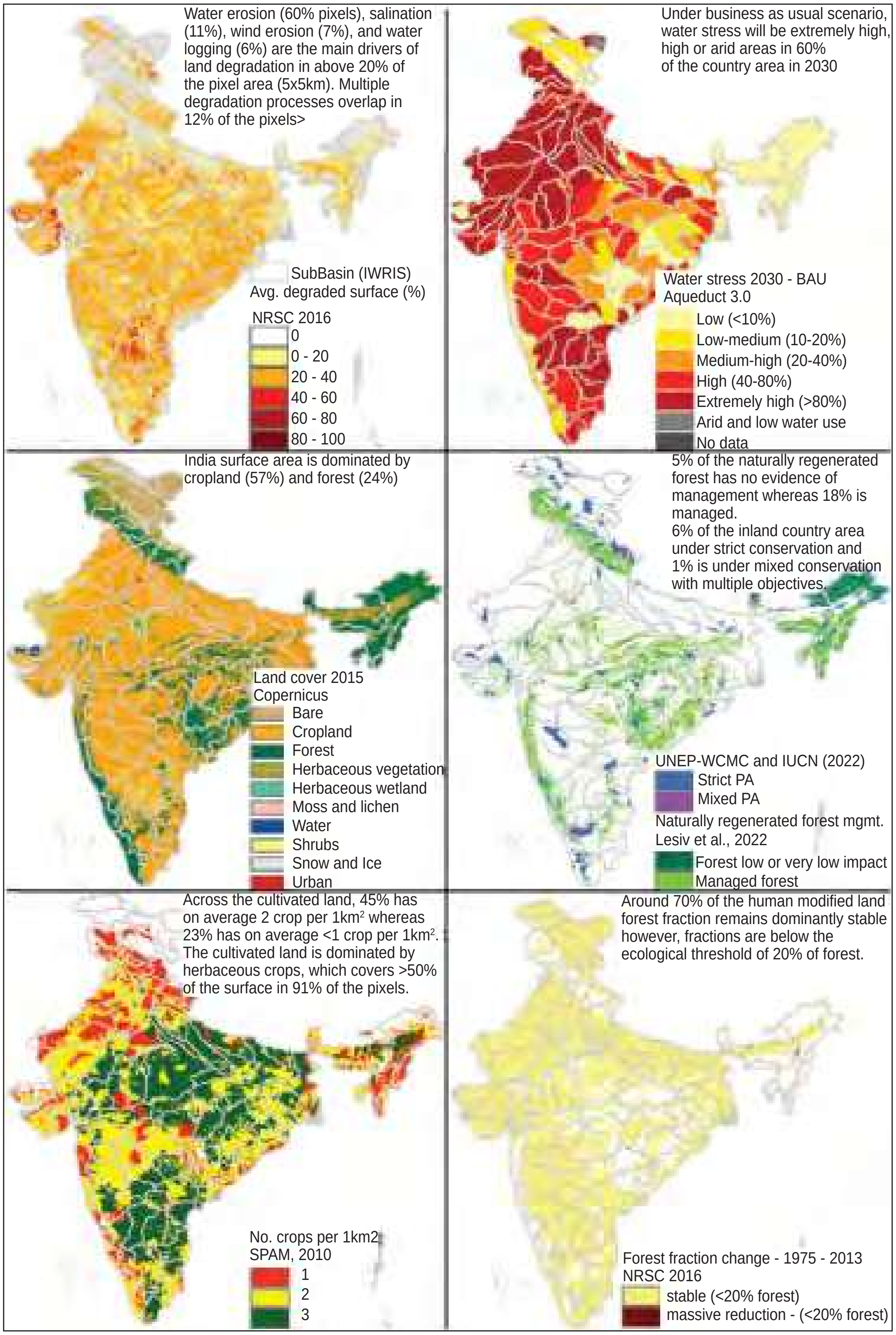

Fig. 1. Indian maps showing the severity and the urgency to move towards sustainable agriculture. In 2019, Indian agricultural land shared 4% of the global agricultural land area but contributed 11% of the global agriculture gross production and 16% of captured freshwater fisheries worldwide (India, 2nd largest global aquaculture producer) (FAOSTAT, *FishStatJ*, 2022). Social aspects are also critical but less commonly mapped, however, see in https://ejatlas.org/ well-documented social-environmental conflicts often related to unsustainable agriculture. Hence, maintaining a viable economy and nourishing 17% of the global population without water, soil, biodiversity and in conflict with people and nature is a dead end.

range of promising holistic metrics exist but more innovation is also needed. Testing and uptaking the most adapted metrics will depend on an iterative, participatory, and truly collaborative process across sectors and stakeholders to test, validate and adjust holistic metrics to the different socio and agroecological contexts as well as national goals and global commitments.

For example, land equivalent ratios better capture combined production in diversified fields (Letourneau *et al*., 2011), nutritional yield can capture nutritional contribution to humans (DeFries *et al*., 2015), crop diversity can capture stability of national food production (Renard and Tilman, 2019) or contributions to wild-diversity (Sanchez *et al*., 2022) to name a few. Other system-level metrics, although less developed, are also critical to measure the effectiveness of certain practices at the farm and landscape level in mitigating extreme events (e.g., hurricanes, HoltGiménez *et al*., 2002), or maintaining healthy terrestrial and aquatic wild and domesticated populations; along with the ecosystem services and resilience these communities provide (Gamez-Virues *et al*., 2015, Feit *et al*., 2021, Bailey and Buck, 2016).

Overall, heading and maneuvering towards the de-sired socially just transformation to sustainability re-quires new holistic metrics that enable decision-makers to take timely, well-informed, and locally relevant decisions. How those, or new holistic metrics score India's efforts to transition remains an open question that a new research agenda could soon answer.

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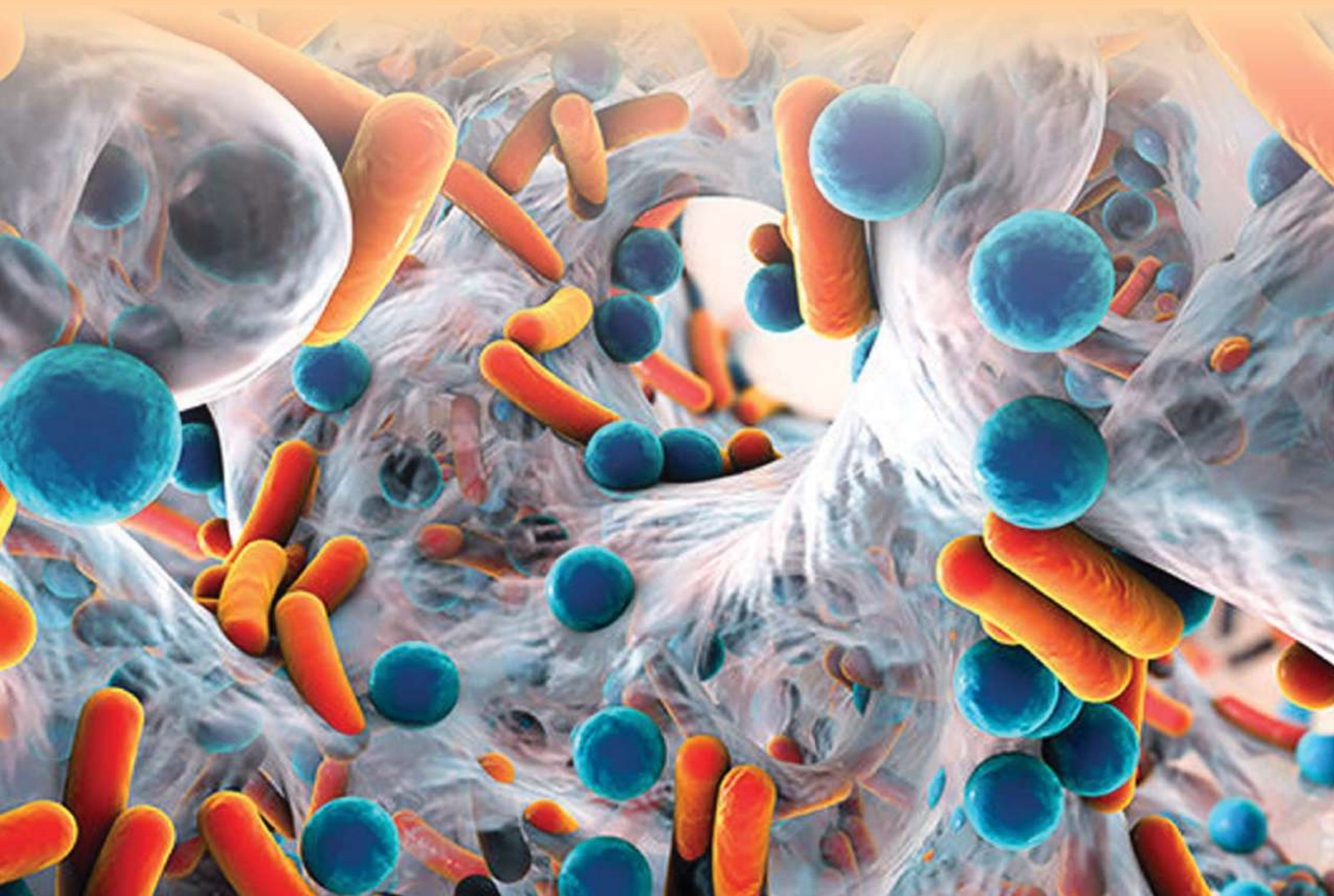

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