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CAN REGENERATIVE DEVELOPMENT RECONCILE AGRICULTURAL PRODUCTIVITY AND ECOLOGICAL CONSERVATION? A PROBLEMATIZING LITERATURE REVIEW OF SMALLHOLDER AGRICULTURAL SYSTEMS

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ABSTRACT----------
Agriculture must produce sufficient food while maintaining the ecological systems on which production depends. However, efforts to increase agricultural productivity can place pressure on soil health, biodiversity and other ecological functions, creating a productivity–conservation tension. This tension is particularly important in smallholder farming systems, where agricultural production, household livelihoods and natural resources are closely connected. This review examines whether, and under what conditions, Regenerative Development can help address this tension. The study adopts a problematising literature review approach, guided by Ecological Economics, Social-Ecological Systems theory and Regenerative Development as complementary analytical perspectives. A Scopus search retrieved 1,093 records. Following deduplication, 1,077 unique records remained. After removing non-English records and non-qualifying items, 1,048 records proceeded to title and abstract screening. Of these, 1,020 were retained in the review corpus and examined through abstract-based thematic analysis. Subsequently, 37 publications were shortlisted for detailed examination, and 33 full texts were obtained. The analysis draws particularly on Bisht (2021), which examines smallholder farming systems in Uttarakhand, India, and Schreefel et al. (2022), which provides a contrasting commercial dairy-farm benchmark from the Netherlands. The findings indicate that the productivity–conservation tension is shaped by economic, ecological and institutional conditions, rather than by farm management alone. The Uttarakhand case highlights the importance of common resources, local ecological knowledge, crop diversity and household livelihoods in sustaining smallholder farming systems. The Dutch case shows that improving some soil functions can reduce farm productivity and income. The farm also needed to purchase more animal feed to compensate for lower grassland production. Together, these findings suggest that improvements in ecological conditions do not necessarily secure wider social and economic benefits. Smallholder transitions also depend on reliable market access, institutional support, collective resource management and fair access to resources and decision-making. The review suggests that agricultural success should be judged in three connected ways: protecting the environment; ensuring that smallholder farmers can maintain a decent livelihood; and providing diverse, nutritious food while protecting local control over food and farming. It concludes that Regenerative Development may provide a useful way to understand how agriculture can support both production and environmental protection. However, this depends on addressing the wider economic, social and institutional conditions that affect smallholder farmers. Further research is needed to understand how these relationships operate across different farming systems and social settings.

KEYWORDS: *Regenerative Development; Regenerative Agriculture; smallholder farming; productivity–conservation trade-off; Ecological Economics; Social-Ecological Systems; smallholder livelihoods*----------

1. INTRODUCTION

1.1 Background and Research Problem

Global agriculture faces major ecological and structural challenges. Decades of conventional, input-intensive industrial agriculture have achieved substantial increases in crop yields, but these gains have come at a cost to important agroecosystem functions (IAASTD, 2009; Poore & Nemecek, 2018). Agricultural production contributes to the depletion of arable land, disruption of natural biogeochemical cycles and substantial environmental damage. It is associated with approximately 25% of global anthropogenic greenhouse gas (GHG) emissions, one-third of terrestrial acidification and most global surface-water eutrophication (Poore & Nemecek, 2018). Beyond environmental degradation, conventional industrial agriculture has weakened the social and cultural connections between rural communities, land stewardship and food systems (Ikerd, 2019; Sandwell, 2019). These concerns highlight the need to examine alternative agricultural approaches, particularly in smallholder systems that support millions of rural livelihoods worldwide.

Reconciling the need for high agricultural productivity with the declining ecological capacity of agricultural soils presents a central challenge for sustainability science (FAO & ITPS, 2015; Poore & Nemecek, 2018). Global policy frameworks increasingly recognise the need for agricultural land to perform multiple functions, including producing food, sequestering carbon, purifying water and supporting biodiversity (European Commission, 2019b; United Nations, 2015). However, dominant agricultural practices continue to prioritise short-term production over long-term ecosystem integrity. This problematising review therefore moves beyond general descriptions of sustainable agriculture to examine the structural trade-offs, contradictions and gaps in evidence between yield optimisation and ecological conservation.

The effects of agricultural intensification and the feasibility of conservation transitions vary across social-ecological contexts. In the rainfed hill farming systems of Uttarakhand, India, smallholders manage diverse farming landscapes and depend on common property resources while facing socioeconomic pressures and out-migration (Bisht, 2021). In contrast, a conventional commercial dairy farm on peat soils in the Netherlands provides a benchmark for examining farm-level productivity–conservation trade-offs. Its average annual milk production was 21,384 kg ha^{-1}, while the reference scenario showed a nitrogen surplus of 258 kg N ha^{-1}. The study also identifies peat oxidation associated with drainage as an important environmental pressure in Dutch peat-soil farming systems (Schreefel et al., 2022). These contrasting cases provide a basis for examining the relationship between agricultural production and conservation across different farming contexts.

1.2 Research Question and Objectives

This review is guided by the following central research question:To what extent, under what conditions, and through what systemic trade-offs can Regenerative Development reconcile agricultural productivity with ecological conservation in smallholder farming systems?

To answer this question, the review pursues four analytical objectives:

1. **Deconstruct the Productivity–Conservation Paradox:** Examine how conventional measures of agricultural success can oversimplify performance and conceal biophysical degradation, nutrient leaching and declining ecosystem functions.
2. **Evaluate Theoretical Frameworks:** Synthesise principles from Ecological Economics, including biophysical limits to growth, externalised costs and natural capital, and Social-Ecological Systems theory, including system dynamics, institutional constraints and feedback loops, to explain the structural drivers of agricultural trade-offs.
3. **Critically Examine Regenerative Approaches:** Distinguish the systemic principles of *Regenerative Development* from the field-level management practices of *Regenerative Agriculture*. Evaluate empirical evidence from bio-economic models, such as Soil Navigator and FarmDESIGN, and smallholder farming initiatives against their theoretical claims.
4. **Reframe Agricultural Success:** Develop a broader understanding of agricultural success by integrating soil health and ecological integrity, smallholder livelihood viability, and community access to diverse and nutritious food, rather than relying solely on biomass yield.

2. REVIEW METHODOLOGY

2.1 Research Design and Review Approach

Following Alvesson and Sandberg (2020), this study adopts a problematising literature review to examine whether Regenerative Development can reconcile agricultural productivity with ecological conservation in smallholder farming systems. Rather than merely summarising existing research, the review critically examines the assumptions, concepts and theoretical propositions underlying the perceived productivity–conservation paradox through a structured process of literature searching, screening and analysis.

Three complementary perspectives guide the analysis: Ecological Economics (EE), Social-Ecological Systems (SES) and Regenerative Development (RD). EE examines the relationship between economic development, agricultural production and ecological limits; SES explores interactions between people, institutions, agricultural practices and ecosystems; and RD examines approaches that seek to move beyond reducing environmental harm towards improving ecological and social conditions. These perspectives serve as distinct analytical lenses. The review does not assume that RD provides a solution but critically examines its propositions, supporting evidence and enabling conditions.

2.2 Literature Search and Identification

Literature was retrieved from Scopus on 14 November 2026 using seven search strategies within the TITLE-ABS-KEY fields, covering publication years 2000–2027. The upper year limit extended one year beyond the search date to capture early-online articles; however, the retrieved records had publication years ranging from 2003 to 2026 (n = 1,093). The searches covered agricultural productivity, ecological conservation, smallholder agriculture and the three theoretical perspectives, using Boolean combinations of terms such as 'regenerative development', 'smallholder', 'productivity-conservation', 'ecological economics' and 'social-ecological systems'. The complete search strategies, including all seven search strings, are provided in the supplementary file deposited alongside the dataset in Zenodo. Following deduplication using DOIs, Scopus EIDs and publication titles, with author names and publication years used for corroboration, 1,077 unique records remained.

2.3 Eligibility Criteria and Screening

Publications were screened using five eligibility criteria. Criterion 1 required relevance to agriculture or managed agricultural landscapes, while at least one of the remaining four criteria, concerning productivity, theoretical perspectives, regenerative approaches or trade-offs, also had to be satisfied. A permissive inclusion approach was adopted, allowing publications to contribute to the conceptual, theoretical or empirical understanding of the review topic without requiring them to meet all five criteria. During screening, 32 records were initially excluded. Four were subsequently reinstated after their indirect relevance to smallholder systems was verified. The remaining 28 records were excluded, leaving 1,020 publications in the final review corpus.

2.4 Abstract-Based Analysis and Thematic Synthesis

All 1,020 included publications were examined using eight analytical questions:

1. How does the paper explain the relationship between human activities, agricultural production and ecological systems?
2. What assumptions does the paper make about economic development, agricultural productivity and ecological conservation? Are they compatible or conflicting?
3. What conditions, mechanisms or processes enable or constrain the achievement of both agricultural productivity and ecological conservation?
4. How does the paper explain the relationship between human development, agricultural productivity and ecological regeneration?
5. How does the paper relate to Social-Ecological Systems (SES), Ecological Economics (EE) and Regenerative Development (RD)? Does it support, challenge or differ from these perspectives?
6. What empirical evidence does the paper provide about agricultural productivity and ecological outcomes? Were both measured together?
7. What trade-offs, synergies, limitations, barriers and contradictions does the paper identify?
8. What does the paper contribute to understanding the productivity–conservation paradox in smallholder agricultural systems? What remains unexplained or uncertain?

Findings were extracted from available abstracts and bibliographic information, classified as Explicit, Tentative, not reported or not applicable, and linked to individual Paper_IDs. Publications were also classified by primary research category, publication type and relevance to smallholder agriculture. The findings were organised into thematic categories and critically synthesised to identify recurring assumptions, theoretical relationships, supporting and contradictory evidence, and emerging theoretical insights. These interpretations were considered preliminary and subject to full-text validation.

2.5 Selection of Publications for Full-Text Analysis and Case Studies

Following the abstract-based analysis, all 1,020 publications were assessed against five dimensions: theoretical importance, contribution to Regenerative Development, empirical relevance, critical value and smallholder relevance. Each dimension was scored from 0 to 3, giving a maximum total of 15. Scores were assigned using publication categories, research types, smallholder-relevance classifications and evidence from the abstracts, following predefined scoring criteria.

Selection was not based solely on numerical ranking. A coverage-based approach was also used to ensure representation across nine areas: Social-Ecological Systems theory, Ecological Economics, Regenerative Development, Regenerative Agriculture, agricultural evidence, explicit smallholder relevance, trade-offs and limitations, foundational theory, and policy context. Minimum coverage requirements were set for each area: three publications on Social-Ecological Systems theory, three on Ecological Economics, one on Regenerative Development, three on Regenerative Agriculture, eight providing agricultural evidence, four explicitly addressing smallholder agriculture, eight addressing trade-offs, limitations or contradictions, two contributing foundational theory, and one addressing policy context. These requirements guided selection alongside the numerical scores. The process first identified 21 publications that collectively covered all nine areas. A further 16 paradigmatic publications were included to strengthen representation of central Regenerative Development literature and relevant empirical cases, resulting in a shortlist of 37 publications. These publications fell into overlapping categories: 11 were categorised under Regenerative Development, 24 were empirical publications and 17 explicitly addressed smallholder agriculture. Scores ranged from 6 to 13, with a mean of 9.9 and a median of 10.

Full texts were obtained for 33 of the 37 shortlisted publications; the remaining four were unavailable for detailed examination. Bisht (2021) was selected as the focal smallholder case study, providing empirical insights into smallholder social-ecological dynamics in Uttarakhand, India. Schreefel et al. (2022) was retained as a contrasting commercial dairy-farm benchmark for examining farm-level bio-economic trade-offs on Dutch peat soils. These studies serve different analytical purposes and are not intended to represent the full diversity of smallholder or commercial agricultural systems. Schreefel et al. (2022) provides evidence on biophysical and economic mechanisms, but their relevance to smallholder contexts requires careful qualification. The remaining shortlisted publications provide conceptual, theoretical and empirical context for the analysis.

2.6 Full-Text Examination and Critical Synthesis

The full-text examination considered theoretical foundations, conceptual assumptions, research methods, empirical findings and implications for productivity–conservation relationships. The preliminary abstract-based synthesis provided an analytical guide for assessing whether the full-text evidence supported or qualified the initial interpretations. Particular attention was given to evidence of simultaneous improvements in agricultural productivity and ecological outcomes; the contribution of Regenerative Development in relation to Ecological Economics and Social-Ecological Systems theory; and the institutional, economic, social and ecological conditions influencing its application in smallholder systems. Bisht (2021) provides the focal smallholder evidence, while Schreefel et al. (2022) serves as a contrasting commercial dairy-farm benchmark for examining farm-level bio-economic trade-offs. These studies examine different dimensions of the productivity–conservation relationship and are not treated as directly comparable cases. The remaining shortlisted publications provide conceptual, theoretical and empirical context for interpreting the two studies and the wider productivity–conservation relationship.

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2.7 Methodological Limitations

his review is limited by its reliance on Scopus, the exclusion of non-English publications and the use of abstracts and bibliographic information for the initial analysis. Abstracts may not fully capture theoretical foundations, research methods or contextual findings. Furthermore, only 33 of the 37 shortlisted publications were available for full-text examination, meaning that some relevant arguments and evidence may not have been considered in detail. Empirical evidence on simultaneous improvements in agricultural productivity and ecological outcomes also remains uneven, particularly in research on Regenerative Development. These limitations are taken into account when interpreting the findings and drawing conclusions.

3. RESULTS

3.1 Understanding the Productivity–Conservation Paradox

The historical and policy framing of agricultural productivity and ecological conservation as opposing goals has created difficulties for smallholder farming systems. Conventional agricultural policies often encourage high-input production and short-term increases in output, while conservation frameworks may treat ecological restoration as a constraint on agricultural land use. This binary framing overlooks the ecological processes on which agricultural production depends and leaves smallholders facing difficult choices between maintaining their livelihoods and protecting the environment

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3.1.1 Productivity, Conservation and Their Relationship

Standard measures of agricultural productivity focus mainly on physical output, such as crop yield per hectare, dry matter production, and milk production per cow or unit of land area (kg milk ha−1 yr−1) (Sandén et al., 2019; Schreefel et al., 2022). Although these measures provide clear quantitative indicators of production, they do not capture several important ecological functions. These include non-market soil ecosystem services and changes in soil organic matter (SOM), subsoil water storage, biological pest suppression and soil microbial diversity (Bünemann et al., 2018; Schulte et al., 2014). In contrast, broader ecological assessments consider the capacity of land to support multiple soil functions, including primary productivity, climate regulation through greenhouse gas (GHG) mitigation and carbon sequestration, nutrient cycling, water purification and regulation, and soil biodiversity and habitat provision (Bünemann et al., 2018; Haygarth & Ritz, 2009; Schulte et al., 2014).

The relationship between agricultural management and environmental conditions depends on the practices used and the characteristics of the farming system. For example, Schreefel et al. (2022) show how nitrogen fertilisation and grassland management influence soil functions and environmental outcomes in a Dutch dairy system. Excessive mineral nitrogen inputs can reduce biological nitrogen fixation, increase nitrous oxide (N_2O) emissions, accelerate soil organic matter breakdown and increase nitrate leaching into water systems (Schröder et al., 2016; Wall et al., 2020). More broadly, land clearing, continuous grazing and drainage of organic soils, such as peatlands, can expose stored carbon to oxidation and release carbon dioxide (CO_2). These processes can turn natural carbon stores into sources of GHG emissions and affect soil functions such as water purification and habitat provision (Schothorst, 1977; Schreefel et al., 2022).

Table 1. Dimensions of Productivity vs. Conservation Measures

Metric Category	Standard Operational Metrics	Ecological/Systemic Blind Spots	Trade-Off Vulnerabilities
Agricultural Productivity	Crop yield (t ha^{-1} yr^{-1}); Dry matter yield (kg ha^{-1} yr^{-1}); Milk yield (L cow^{-1}, kg ha^{-1} yr^{-1}).	Ignores subsoil degradation, natural nutrient depletion, loss of biological soil structure, and off-farm environmental externalization.	Maximizing output triggers high external input costs, soil organic matter depletion, severe nitrate leaching, and N_2O emissions.
Nutrient Efficiency	Inorganic N applied vs. crop uptake; Feed conversion efficiency.	Overlooks biological N_2-fixation potential, soil microbial cycling dynamics, and off-farm embodied energy of synthetic inputs.	High mineral fertilization suppresses natural soil microflora and mutualistic legume N_2-fixation capacity.
Hydrological Function	Surface water drainage capacity; Irrigation throughput efficiency.	Neglects soil water storage capacity, natural filtration, groundwater recharge, and wetland buffering capacity.	Drainage of organic/peat soils drives rapid aerobic carbon oxidation, land subsidence, and degraded water purification capacity.
Biodiversity & Ecosystem Health	Aboveground yield uniformity; Species-specific pest eradication rates.	Excludes belowground microbial, fungal, and microarthropod biodiversity, native seed evolutionary potential, and eco-nutrition.	Monoculture cropping and synthetic agrochemical reliance collapse natural biological regulation, driving pest resistance and dietary simplification.

3.1.2 The Paradox in Smallholder Agriculture

Smallholder farming systems are particularly vulnerable to the productivity–conservation tension. In the rainfed mixed crop–livestock systems of Uttarakhand, India, farmers manage diverse agroecosystems but face structural pressures, including fragmented landholdings and limited market access (Bisht, 2021). More broadly, smallholders with limited resources may struggle to balance immediate food needs with long-term soil management, particularly when institutional support is weak (Pretty et al., 2006; Giller et al., 2021). Although traditional farming systems maintain high levels of agrobiodiversity, economic difficulties and limited livelihood opportunities can contribute to out-migration and land abandonment (Bisht, 2021; Adhikari et al., 2019).

Bisht (2021) reports that informal seed systems meet about 95% of the seed requirements of traditional hill farming communities. These systems depend on farmers producing, storing and reusing seeds, and help maintain local crop varieties. However, the study also identifies concerns about the availability of farmer varieties and the loss of landrace diversity in production landscapes. These findings highlight the importance of supporting local seed systems rather than assuming that greater use of external inputs will necessarily improve smallholder livelihoods. In contrast, the conventional Dutch dairy farm provides a commercial benchmark for examining farm-level productivity and environmental trade-offs. It produced an average of 21,384 kg of milk ha^{-1}, while its reference scenario showed a nitrogen surplus of 258 kg N ha^{-1}. Schreefel et al. (2022) also identify peat oxidation associated with drainage as an important environmental concern in Dutch peat-soil farming systems. The two cases illustrate different agricultural challenges and should not be treated as evidence of equivalent transition costs or livelihood outcomes.
Together, these cases show why agricultural production and environmental outcomes need to be examined in relation to the ecological, economic and institutional conditions of each farming system.

3.2 Economic and Ecological Perspectives: Ecological Economics

Ecological Economics provides useful concepts for understanding the productivity–conservation paradox by viewing agriculture as part of wider ecosystems with finite resources. Unlike conventional agricultural economics, which often treats natural resources as inputs that can be substituted or replaced, Ecological Economics recognises ecological limits and the dependence of agricultural production on natural systems. It also considers unpriced ecosystem services, the depletion of natural capital and non-linear changes in ecological systems.

3.2.1 Agricultural Development and Ecological Limits

From an Ecological Economics perspective, food production depends on finite natural resources and ecological functions, including soil organic carbon, biological nutrient cycling, water filtration and atmospheric regulation (FAO & ITPS, 2015; Poore & Nemecek, 2018). Conventional agricultural intensification can achieve short-term productivity gains while depleting natural capital and shifting environmental costs to society and future generations. Agricultural production also generates substantial environmental costs through nitrogen and phosphorus imbalances, soil degradation and atmospheric pollution (Poore & Nemecek, 2018). However, conventional farm accounting often excludes these costs because many ecosystem services are not reflected in market prices. This can create a misleading picture of economic efficiency (Ikerd, 2019).

These ecological changes can also affect smallholder livelihoods. Bisht (2021) reports that wild plant foods, comprising 30–40 species, traditionally supplement seasonal household diets. The loss of these resources can reduce dietary diversity and increase reliance on purchased foods, potentially raising household food expenditure.

3.2.2 Challenging Assumptions About Agricultural Productivity and Environmental Conservation

A common assumption in modern agriculture is that improved technologies and farming inputs can increase crop yields without causing environmental damage (IAASTD, 2009). However, farm-level modelling shows that improving environmental conditions can also create challenges for agricultural production and farm income.

For example, Schreefel et al. (2022) used the Soil Navigator and FarmDESIGN models to examine how changes in farm management could improve soil functions on a conventional Dutch dairy farm. Under the improved management scenario, three of the five soil functions reached high capacity: nutrient cycling, biodiversity and habitat provision, and climate regulation. Primary productivity declined from high to medium capacity, while water purification and regulation improved from low to medium capacity. The management changes included stopping mineral nitrogen fertilisation, replacing slurry with solid manure, reducing organic nitrogen fertiliser inputs and establishing herb-rich grasslands containing approximately 30% white clover (*Trifolium repens*) (Schreefel et al., 2022).

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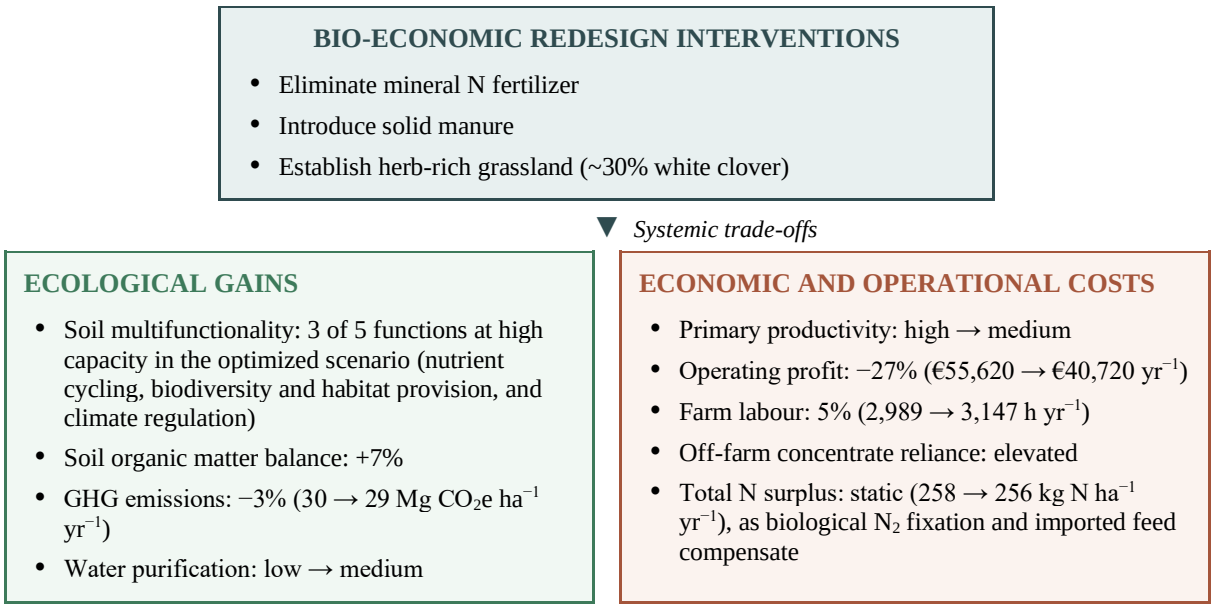


Figure 1. Trade-offs of the bio-economic redesign of a Dutch peat-soil dairy farm using Soil Navigator and FarmDESIGN. Values from Schreefel et al. (2022).

As shown in Figure 1, these changes improved the soil organic matter balance by 7%, increased climate regulation capacity from medium to high, and reduced reported farm-level greenhouse-gas emissions by 3%, from 30 to 29 Mg CO_2e ha^{-1} yr^{-1}. However, they also involved economic and practical trade-offs:

- Primary productivity declined from high to medium because the reduced nitrogen fertilisation was considered insufficient to maintain the previous production level.
- Farm operating profit decreased by 27%, from €55,620 to €40,720 per year.
- Farm labour requirements increased by 5%, from 2,989 to 3,147 hours per year (Schreefel et al., 2022).

The farm's nitrogen surplus changed very little, from 258 kg N ha^{-1} yr^{-1} in the reference scenario to 256 kg N ha^{-1} yr^{-1} under improved management. The authors linked this small reduction mainly to increased purchases of concentrate feed and higher biological nitrogen fixation (Schreefel et al., 2022). Although mineral nitrogen fertiliser was eliminated and organic nitrogen fertiliser was reduced, the model included biological nitrogen fixation of 172 kg N ha^{-1} yr^{-1} in the herb-rich grassland, compared with zero in the reference grassland. This rate applies to the herb-rich grassland, not the whole farm. The farm nitrogen balance also includes purchased feed, manure, fertilisers, atmospheric inputs, biological nitrogen fixation and farm products. However, the study does not provide a complete breakdown of these flows for both scenarios. The contribution of each component to the small change in nitrogen surplus therefore remains uncertain.

These findings also highlight the potential environmental effects of farming decisions beyond the farm itself. As primary productivity declined, the farm purchased more concentrate feed to meet the animals' nutritional needs (Schreefel et al., 2022). This dependence on purchased feed may shift some environmental pressures to the regions where the feed is produced, although the study does not measure these wider impacts. Similarly, the reported reduction in greenhouse-gas emissions is based on a farm-level model indicator that includes emissions from livestock, manure, fertilisers and diesel, as well as fertiliser and pesticide production and use. The study does not clearly establish whether emissions from producing purchased concentrate feed are included. The reported reduction should therefore not be interpreted as a complete assessment of the farm's total environmental footprint. This case illustrates why agricultural sustainability needs to be assessed beyond the farm boundary, taking account of farm inputs and wider supply chains.

3.3 Understanding Smallholder Farming Systems: Social-Ecological Systems

Smallholder farming systems can be understood as complex, adaptive social-ecological systems in which biophysical processes, such as soil functions, hydrological flows and crop genetic diversity, interact with human institutions and practices, including land tenure, household labour allocation, local knowledge and market networks. These interactions create feedbacks that influence agricultural production, ecological conditions and livelihood outcomes. The following section examines these relationships through the case of smallholder farming communities in Uttarakhand, India, while recognising that their characteristics and constraints may differ from those of smallholder systems in other geographical and institutional contexts.

3.3.1 Smallholder Farming Systems in Uttarakhand as Social-Ecological Systems

The resilience of smallholder social-ecological systems depends on interactions among household labour, livestock, crop diversity, local ecological knowledge and informal governance institutions. Evidence from Uttarakhand, India, shows how local environmental and institutional conditions shape different farming systems across mountain landscapes (Bisht, 2021; Figure 2).

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Figure 2 presents three agro-ecological settings described by Bisht (2021), which are interpreted in this review as distinct types of smallholder social-ecological systems.

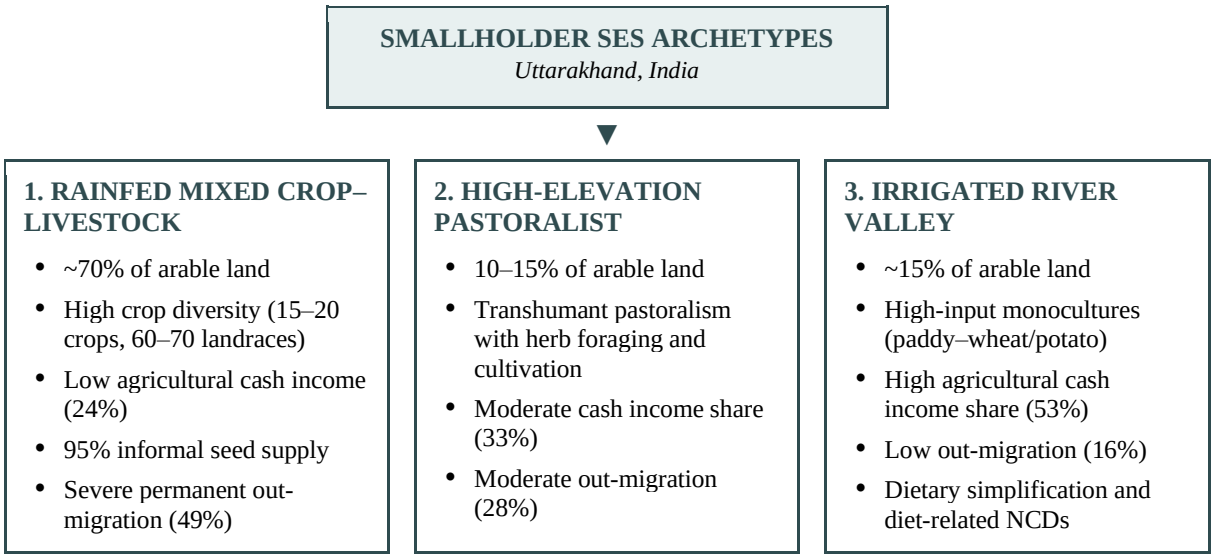


Figure 2. Smallholder social-ecological system archetypes in Uttarakhand, India. Adapted from Bisht (2021).

1. **Rainfed Crop–Livestock Mixed Farming Landscapes:** Representing approximately 70% of total arable land, these systems are based on subsistence-oriented mixed cropping. Households maintain high landrace diversity, with 15–20 crops and 60–70 traditional varieties per site. They rely heavily on informal seed systems, which provide approximately 95% of their seed supply, and achieve around 80% food self-sufficiency. However, agriculture contributes only 24% of household cash income. These systems therefore face considerable economic pressures and high permanent out-migration, reported in 49% of households, contributing to land abandonment (Bisht, 2021).
2. **High-Elevation Nomadic Pastoralist Systems:** Accounting for approximately 10–15% of arable land, these high-altitude transhumant systems, managed primarily by *Bhotia* and *Shoka* communities, combine sheep and goat pastoralism with specialised cultivation and the collection of valuable wild medicinal herbs. These include *Allium stracheyi* (Jambu/Faran), *Angelica glauca* (Gandhrain) and *Carum carvi* (Kala jeera). Commercial herb sales contribute 33% of household cash income, providing an additional source of income. Permanent migration is reported in 28% of households (Bisht, 2021).
3. **Irrigated River Valley Systems:** Comprising approximately 15% of arable land, these systems feature high-yielding paddy–wheat or paddy–potato rotations supported by surface irrigation and mineral fertilisers. Agriculture contributes 53% of household cash income, while permanent out-migration is reported in 16% of households. However, crop specialisation is also associated with reduced dietary diversity and a moderate-to-high incidence of diet-related non-communicable diseases (NCDs) (Bisht, 2021).

These systems also illustrate the importance of the traditional CPR–Crop–Livestock relationship in rainfed farming landscapes. Common property resources provide forest biomass and grazing fodder to support household livestock. Livestock, in turn, provide draught power, milk for household consumption and sale, and manure that helps maintain soil fertility in crop production. According to Bisht (2021), increasing human pressures and declining institutional support have contributed to the degradation of common property resources and the contraction of livestock herds. Reduced livestock numbers can limit manure availability, contributing to lower crop productivity. This can weaken household income and resilience, potentially encouraging permanent out-migration. The breakdown of these connections illustrates how ecological degradation can affect agricultural production and household livelihoods through interconnected social and ecological processes.

3.3.2 Institutional and Socio-Ecological Constraints in Smallholder Farming

The Uttarakhand case highlights several institutional and social challenges affecting smallholder farming, including unequal participation in decision-making, the vulnerability of local seed systems and changes in traditional knowledge.

- **Gendered Division of Labour and Decision-Making Barriers:** Women account for an average of 62% of the agricultural workforce engaged in farming operations across the hill agro-ecologies, compared with 36% for men. The source does not specify the composition of the remaining share (Bisht, 2021). Despite their substantial contribution to farming, women face barriers to land ownership, access to credit, participation in cooperatives and involvement in public decision-making. This highlights the gap between women's contribution to agricultural work and their participation in decision-making (Bisht, 2021).
- **Importance and Challenges of Informal Seed Systems:** Informal seed systems meet approximately 95% of the seed requirements of traditional hill farming communities. These systems, mainly managed by women, depend on farmers producing, storing and reusing seeds. However, Bisht (2021) notes that the availability of farmer varieties is not always

reported and identifies the loss of landrace diversity in farming landscapes as a concern. These findings highlight the importance of supporting local seed management and the continued use of traditional crop varieties.

- **Changes in Traditional Knowledge and System Resilience:** Traditional farming systems should not be assumed to remain resilient under changing social and economic conditions. Bisht (2021) reports a negative association between local ecological knowledge and the education and wealth levels of farming households. The study identifies losses in knowledge relating to traditional food recipes, the identification and use of wild plants, and livestock healthcare. It also notes the growing influence of commercial fast-food marketing, although access to these foods remains relatively limited in local rural markets.

Together, these findings show that farming practices and environmental conditions are closely connected to household livelihoods, local institutions and traditional knowledge. They highlight the need to assess agricultural development approaches in relation to these wider social and ecological conditions.

3.4 Regenerative Development: A Possible Alternative

Regenerative Development has emerged as a framework that seeks to address the limitations of conventional sustainability approaches. Rather than focusing primarily on reducing environmental damage or maintaining existing conditions, Regenerative Development aims to restore relationships between people and nature, strengthen social capital and improve ecosystem health.

3.4.1 Concept and Approach

It is important to distinguish between Regenerative Agriculture and Regenerative Development.

- **Regenerative Agriculture:** Refers primarily to field-level agricultural practices that use soil conservation as an entry point to improve soil functions, build soil organic carbon and reduce reliance on synthetic agrochemicals (Schreefel et al., 2020, 2022).
- **Regenerative Development:** Represents a broader, place-based and systemic approach that seeks to strengthen relationships between people, communities and ecosystems. It considers ecological integrity, institutional capacity, cultural knowledge and livelihood viability as interconnected elements of development. Regenerative Agriculture can contribute to these wider goals through improvements in soil health and ecological functions at the field level.

Food sovereignty and political agroecology also address several dimensions associated with regenerative approaches, including farmers' access to land, seeds and water; local autonomy over agricultural production; locally connected production and consumption systems; and farmer-to-farmer knowledge exchange (Altieri, 2009, as cited in Bisht, 2021). These overlaps show that such social and institutional concerns are not unique to Regenerative Development but are also established within food sovereignty and agroecology.

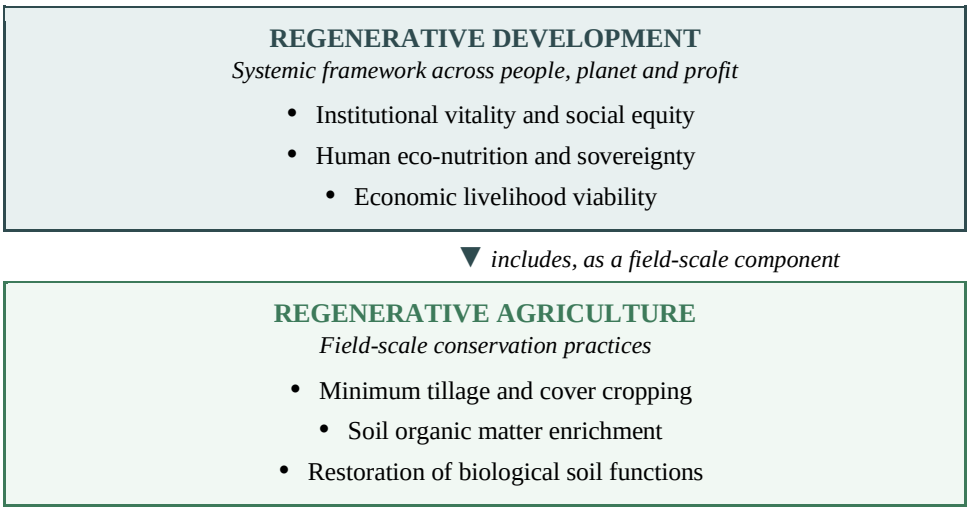


Figure 3. Relationship between Regenerative Development and Regenerative Agriculture.

3.4.2 Application and Evidence in Agriculture

The literature identifies several approaches that could support smallholder farming, including local marketing, school-meal procurement, value-chain development and off-farm employment. Bisht (2021) discusses these approaches as possible ways to support traditional crops, household livelihoods and local food systems. However, the study does not experimentally test these interventions or measure their ecological and economic outcomes. They should therefore be understood as proposed pathways rather than demonstrated results. Studies of woody agroecosystems in Mediterranean drylands and regenerative soil management in temperate settings highlight the importance of adapting agricultural practices to local soil and environmental conditions rather than applying standardised packages (Luján Soto et al., 2021; Zwetsloot et al., 2020). Research on field redesign also shows how spatial diversification can support multiple ecosystem services, although improvements in individual soil functions do not necessarily translate into better overall farm performance (Ditzler et al., 2021; see also the Dutch farm analysis in Section 3.2.2 and Figure 1). At the market and community levels, alternative agrifood networks and Community-Supported Agriculture (CSA) can strengthen

producer–consumer relationships. The Uttarakhand case also identifies local marketing and value addition as potential strategies for supporting smallholder livelihoods (Allen et al., 2003; Hvitsand, 2016; Bisht, 2021).

The following approaches illustrate how these pathways could be developed in smallholder contexts:

Community-Supported Agriculture (CSA): Establishing village-level farmer cooperatives to coordinate production across fragmented landholdings and develop direct supply relationships with urban consumers interested in traditional and sustainably produced foods. Where feasible, certification could help farmers access specific organic markets.

1. **Decentralised Mid-Day Meal (MDM) Procurement:** Reforming school-meal procurement by increasing the use of locally produced traditional crops, including native millets such as madua (*Eleusine coracana*) and barnyard millet, red rice and pulses such as bhat (*Glycine max*) and gahat (*Macrotyloma uniflorum*). Local procurement could provide additional markets for smallholders while diversifying the nutritional content of school meals.
2. **Value-Chain Development and Premium Processing:** Developing local processing, packaging and branding facilities for traditional foods and wild plant resources to improve value addition and enable smallholders to access higher-value regional and urban markets.
3. **Off-Farm Youth Employment and Agro-Ecotourism:** Diversifying rural livelihood opportunities through farm-based ecotourism, community forest and common property resource (CPR) management, and women-led activities such as handicrafts, tailoring and food processing. Bisht (2021) reports earnings of approximately INR 1,000–4,000 per month per member from some of these activities. Such opportunities could supplement household income and potentially reduce rural youth out-migration.

Table 2. Evaluated Regenerative Interventions, Outcomes, and Systemic Trade-Offs

Intervention Practice/Scheme	System Level (Field/Farm/Community)	Potential Ecological and Livelihood Benefits	Implementation Requirements and Potential Challenges
Herb-Rich Grassland & Solid Manure	Field to Farm	Improved soil organic matter balance and selected soil functions; individual function ratings are reported in Section 3.2.2 and Figure 1 (Schreefel et al., 2022).	Lower primary productivity and farm profitability, increased labour requirements, and greater reliance on purchased concentrate feed (Schreefel et al., 2022).
Community-Supported Agriculture (CSA)	Community / Regional	Promotes organic polycultures; eliminates synthetic agrochemicals; enhances agrobiodiversity conservation (Bisht, 2021).	High initial transaction costs in pooling fragmented land; seasonal supply mismatch; requires consumer education on traditional crops (Bisht, 2021).
Localized Mid-Day Meal (MDM) Sourcing	Community / Institutional	Incentivizes multi-crop millet/legume cultivation; reduces transportation emissions; preserves native landraces (Bisht, 2021).	Requires institutional policy reform away from centralized grain procurement; potential administrative resistance; seasonal availability limits (Bisht, 2021).
Value-Chain & Functional Food Processing	Community / Market	Encourages preservation of traditional crops and wild food species; reduces post-harvest biomass waste (Bisht, 2021).	Needs capital investment in processing technology; stringent hygiene/labelling requirements; market access barriers for unorganized smallholders (Bisht, 2021).
Women Self-Help Groups (SHGs) & Ecotourism	Community / Household	Restores common property resources; incentivizes non-timber forest product conservation (Bisht, 2021).	Requires local skill development; seasonal tourist fluctuations; potential socio-cultural disruption from untamed tourism (Bisht, 2021).

3.4.3 Critical Assumptions and Limitations

The evidence reviewed identifies several limitations and potential challenges in applying Regenerative Development approaches:

- **Non-Linear Relationships Between Field and Farm Outcomes:** Improvements in soil functions at field level do not necessarily translate into better outcomes across the whole farm or landscape. The Dutch dairy-farm model shows that improving selected soil functions can also increase dependence on resources from outside the farm. In the improved management scenario, reduced grass production was accompanied by increased purchases of concentrate feed to meet

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livestock nutritional requirements (Schreefel et al., 2022). This illustrates why agricultural sustainability needs to be assessed beyond individual fields, taking account of farm-level production and resource use.

- **Limitations of Soil Model Calibration and Soil pH Conditions:** The calibration and validation of decision-support tools such as Soil Navigator remain limited for peat soils. Across the five soil-function models, only five of the 94–251 sites used for calibration and validation were located on peat soils (Schreefel et al., 2022). This limits the available evidence for assessing how well the models apply to peat soils. Soil pH also affects the suitability of some interventions. The Dutch case farm had a soil pH (pH-KCl) of 5.5, compared with the reported average of 4.7 for Dutch peat soils (Rutgers et al., 2007; Schreefel et al., 2022). White clover establishment and biological nitrogen fixation are also influenced by soil pH, making it difficult to generalise the case-farm findings to all peat soils (de Wit et al., 2004; van Eekeren, 2007).
- **Potential Socio-Economic Challenges for Smallholders:** Transitioning to more ecological farming practices may require additional labour, financial resources and institutional support. In the Dutch dairy-farm model, labour requirements increased by 5%, from 2,989 to 3,147 hours per year, while primary productivity declined from high to medium (Schreefel et al., 2022). However, these findings come from a commercial dairy farm and do not establish the transition costs faced by smallholders in Uttarakhand. Bisht (2021) identifies socioeconomic and market-related challenges in traditional hill farming but does not measure the costs or yield losses associated with adopting regenerative practices. Based on these findings, this review identifies potential implementation challenges for smallholders, including limited financial resources, fragmented landholdings, seasonal market supply and insufficient institutional support. Financial assistance, stronger market connections and payments for ecosystem services may help address some of these challenges, although their effectiveness requires further investigation.

These limitations highlight the need to assess agricultural outcomes across ecological, economic and social dimensions rather than relying on field-level improvements or production measures alone.

4. DISCUSSION

Evaluating the potential of Regenerative Development to reconcile agricultural productivity and ecological conservation requires an integrated analysis across Ecological Economics, Social-Ecological Systems theory, and empirical field data.

4.1 Re-examining the Paradox through Ecological Economics and Social-Ecological Systems

Synthesising Ecological Economics and SES theory provides a useful framework for understanding why the productivity–conservation paradox persists:

- **Conventional agricultural economics:** Often focuses narrowly on marketable output, such as yield per hectare, while giving insufficient attention to biophysical limits, soil organic matter depletion, natural capital depreciation and externalised environmental costs (Poore & Nemecek, 2018).
- **Strict conservation approaches:** May prioritise ecological restoration without adequately accounting for smallholder livelihood security, household cash requirements, labour constraints or the economic consequences of losing access to ecosystem services (Bisht, 2021).

These perspectives highlight a broader limitation of conventional agricultural development: its emphasis on marketable outputs can overlook the social and ecological relationships that support agricultural production. The Uttarakhand case illustrates how local knowledge, agrobiodiversity and collective management of common resources contribute to the resilience of smallholder systems (Bisht, 2021). Their decline therefore represents not only a loss of traditional practices but also a weakening of the institutional and ecological relationships that support agricultural livelihoods. This suggests that productivity and conservation need to be examined in relation to the wider social, ecological and institutional conditions of farming systems.

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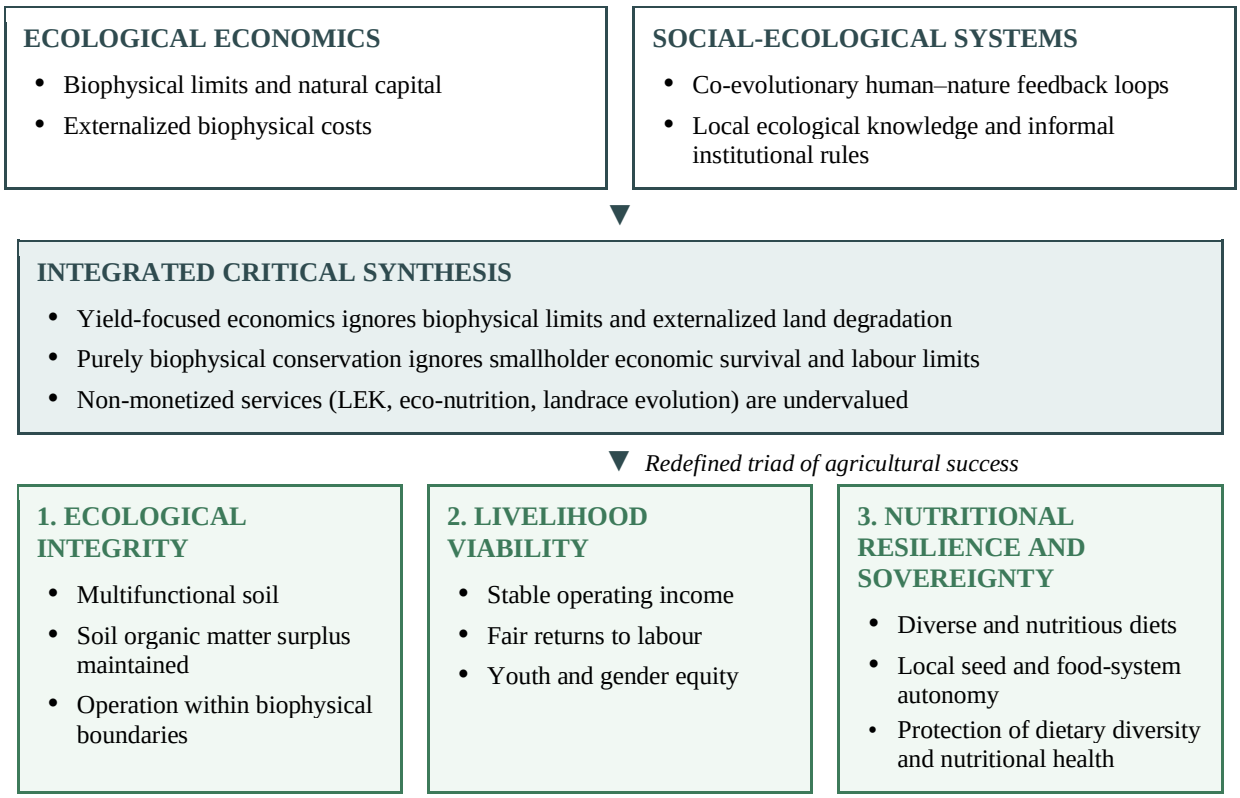


Figure 4. Integrated critical synthesis and the proposed triad of agricultural success.

4.2 Evaluating the Potential of Regenerative Development

Regenerative Development offers a theoretical framework for reconciling agricultural productivity with ecological conservation. However, empirical evidence shows that field-level regenerative practices do not automatically eliminate structural trade-offs.

As discussed in Section 3.2.2 and Figure 1, the Dutch dairy-farm model illustrates how improving selected soil functions can involve trade-offs in primary productivity and farm profitability, alongside greater dependence on purchased inputs (Schreefel et al., 2022). This commercial-farm benchmark shows that regenerative practices do not automatically remove biophysical constraints; they can redistribute costs and environmental pressures beyond the farm boundary. Its implications for smallholder systems therefore require careful qualification, given differences in farm size, capital, labour availability and market access.

These findings suggest that regenerative transitions in smallholder systems require institutional and economic support beyond changes in farm management. However, implementing such support can be difficult. Fragmented landholdings can increase the costs of organising produce for public procurement, while seasonal production and institutional barriers may limit reliable market access. Community-based seed conservation also requires continued farmer participation to maintain local seed diversity and knowledge. Payments for ecosystem services require credible methods for assessing ecological improvements, while the transferability of soil-function assessments across different environmental conditions requires further testing. Local processing facilities also require investment, technical skills and compliance with hygiene and labelling standards, which may be difficult for smallholders with limited resources. These constraints are further compounded by the institutional barriers faced by women in smallholder farming communities, despite their substantial contribution to agricultural labour (Bisht, 2021). Addressing these institutional and economic barriers is therefore important for making regenerative transitions more accessible and viable for smallholder households.

4.3 Reframing Agricultural Development

Understanding the productivity–conservation tension requires moving beyond physical yield as the sole measure of agricultural success. This review proposes three integrated assessment dimensions: ecological integrity, livelihood viability, and nutritional resilience and sovereignty. These dimensions bring together concerns identified in the reviewed literature and represent an analytical synthesis rather than an entirely new framework

1. **Ecological Integrity:** Assessing multiple soil functions, including primary productivity, climate regulation, nutrient cycling, water purification and biodiversity; maintaining positive soil organic matter (SOM) balances; and ensuring that agricultural production operates within biophysical limits (Schreefel et al., 2022).
2. **Livelihood Viability:** Assessing fair economic returns to smallholder labour, stable household farm incomes, opportunities for dignified rural youth employment, and gender equity in decision-making and land governance (Bisht, 2021).

3. **Nutritional Resilience and Sovereignty:** Supporting diverse and nutritious diets through agrobiodiversity, conserving native crop landraces and wild food resources, addressing dietary simplification and diet-related non-communicable diseases, and strengthening community control over seeds, land and local food systems (Bisht, 2021).

5. CONCLUSION

5.1 Key Findings and Contributions

This problematising review examines the productivity–conservation tension through the perspectives of Ecological Economics, Social-Ecological Systems and Regenerative Development. The main findings are summarised below:

1. **The Productivity–Conservation Tension Involves Context-Dependent Trade-Offs:** The reviewed evidence shows that improving selected soil functions can involve reductions in primary productivity and farm profitability. However, the extent of these trade-offs depends on farm management, resource availability and wider economic and institutional conditions.
2. **Regenerative Agriculture and Regenerative Development Have Different Scopes:** Regenerative Agriculture focuses mainly on field-level farming practices and improvements in soil health and ecological functions. Regenerative Development takes a broader approach, considering the relationships between ecological health, livelihoods, institutions and communities. However, several of these concerns are also addressed by established approaches such as agroecology and food sovereignty.
3. **Smallholder Viability Requires Institutional and Market Support:** Changes in farm management alone may not be sufficient to support smallholder transitions. Reliable market access, supportive institutions, collective resource management and appropriate economic incentives are also important for connecting ecological improvements with household livelihoods.
4. **Reframing Agricultural Success:** Agricultural performance should be assessed beyond physical yield per hectare. This review proposes three connected assessment dimensions: ecological integrity, smallholder livelihood viability, and nutritional resilience and sovereignty. These dimensions represent an analytical synthesis of the reviewed literature rather than a framework empirically tested by the two case studies.

5.2 Limitations and Future Research

Beyond the methodological limitations discussed in Section 2.7, including reliance on Scopus, exclusion of non-English publications, initial screening based on abstracts and incomplete access to full texts, this review has an additional empirical limitation. Its detailed empirical analysis draws mainly on two studies conducted in different geographical, ecological and farming contexts. Bisht (2021) examines smallholder farming systems and their social and ecological conditions in Uttarakhand, India, while Schreefel et al. (2022) use farm-level modelling to examine productivity, environmental and economic trade-offs in a commercial dairy system on Dutch peat soils. The studies also differ in their research approaches and the types of evidence they provide. Although they offer complementary insights, their findings are not directly comparable, and neither represents the full diversity of smallholder or commercial agricultural systems. The reviewed literature also identifies limitations in agricultural modelling, including difficulties in representing spatial variation, complex cropping systems and interactions among different parts of farming systems (Ditzler et al., 2021; Silva & Giller, 2021). In addition, assessments of agricultural transitions need to give greater attention to farmers' well-being and social and cultural outcomes alongside environmental and economic indicators (Brown et al., 2021).

To address these gaps, future research should focus on three areas:

- Long-Term Field Validation Across Different Soil and Climate Conditions: Evaluate soil multifunctionality models over several years and across different soil types, climates and soil pH conditions in smallholder farming systems.
- Including Farmers' Well-being in Agricultural Assessments: Expand farm-level assessments to consider farmers' mental health, gender equality, community relationships and other social and cultural outcomes alongside environmental and economic indicators.
- Assessing Policies Across Different Sectors: Examine how policies linking agriculture with public health, nutrition programmes and local markets can support smallholder livelihoods and ecological conditions.

Data availability

The dataset supporting this review, comprising raw Scopus records, records retained after screening, and the final list of 37 selected publications (of which 33 were included in the detailed full-text review), is publicly available in Zenodo: Asokakumar Korangode, T. (2026). *Dataset: Regenerative Development in Smallholder Agriculture* [Dataset]. Zenodo. https://doi.org/10.5281/zenodo.24362962.

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