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Agroecological Approach to Agricultural Sustainability, Food Sovereignty And Endogenous Circular Economy

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Abstract

The resource over-exploitative, waste-burdening, linear developmental model has transgressed the planetary safe operating limits of the earth systems engendering climatic emergencies and also exacerbated socioeconomic imbalances. The only way of mitigating these planetary and social crises is to formulate and strictly enact ecofriendly, resource recycling, circular economic, equitable, decentralized and peoples´ participatory developmental policies and practices. The objective of this review is to contribute to the discourse on transformative agriculture-centred, circular economic policies and practices that foster nature-based solutions and prudent extraction, use, re-use, and recycling of resources while minimizing waste and environmental externalities. The review highlights Nepal's geophysical, agroecological and socioeconomic realities, their manifestations and policy implications. It also explores how past development policies have been mismatched with these realities, eroding the indigenous resource bases and knowledge systems, and thereby, disrupting the agriculture-based, self-reliant, and food sovereign livelihoods systems. The article argues that agroecology, as a science, practice and movement envisions a nature-based, circular economic and socially just transformative pathway towards sustainable agri-food systems embracing food sufficiency, safety and sovereignty. This pathway contributes to healthy people, healthy animals and healthy ecosystems, hence strengthening the vision of One Health. Building on the agroecological perspectives, this article presents the resynthesized eight operational elements referred to as "8-S-elements" for agroecological transformation. These elements pertain to the prudent management of space (S1), species (S2), seeds (S3), soils (S4), seasonality (S5) and stress factors (S6) through the synergistic integration of agroecosystems and livelihood systems components (S7) with socioeconomic rationality (S8). In the Nepalese context, as an agriculture-based economy, agri-food and livelihoods are viewed as complementary facets. This study recommends the transformative policy options based on the principles of ecological stewardship and socioeconomic objectivity.

Keywords: "8-S"-elements, agroecology, ecosystem services, nature-based solutions, Nepal, Policy

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1. Introduction

The predominant model of economic development and industrial agriculture led to myriads of ecological and climatic externalities while magnifying socioeconomic disparity and social insecurity. Industrial agriculture is one of the culprits for the loss of biodiversity (Brühl & Zaller, 2019; Dirzo et al., 2022), land degradation (Baude et al., 2019; Hossain et al., 2020; Prăvălie et al., 2021), reduction in soil carbon stock (X. Chen et al., 2020; Lal, 2018), greenhouse gas emission (Garnier et al., 2019; Laborde et al., 2021), environmental pollution (Glibert, 2020; Özkara et al., 2016; Tudi et al., 2021), evolution of resistance of pests against pesticides (Bras et al., 2022; Gould et al., 2018; Hawkins et al., 2019; Karlsson Green et al., 2020), loss of ecosystems resiliency, and increasing costs and risks in production systems (Crews et al., 2018). The greenhouse gas emission driving the climate change will further perturb the agriculture and food systems (Ma et al., 2021; Malhi et al., 2021; Mora et al., 2018). At the same time, the overemphasis on capital-centered development, economic efficiency and growth neglecting the environmental and social costs has also exerted adverse impacts on the human social system (Crews et al., 2018)

Six of the nine processes that regulate the stability and resilience of the Earth system have transgressed beyond the safe operating limit (Jaramillo & Destouni, 2015; Persson et al., 2022; Wang-Erlandsson et al., 2022). The anthropogenic factors that have exceeded the safe operating limit include environmental pollutants and other "novel entities" including plastics (Persson et al., 2022), loss of biodiversity (Cowie et al., 2022), climate change (McLaughlin, 2011), land system change (Winkler et al., 2021) and biogeochemical flows of nitrogen (N) and phosphorus (P) (Jaramillo & Destouni, 2015). More recently green water functions (terrestrial precipitation, evaporation and soil moisture) have also been shown to be transgressed (Wang-Erlandsson et al., 2022). Agriculture is attributed to be a driver of overshooting the planetary safe operating limits (Campbell et al., 2017). Alarmed with the finding that exceeding 1.5°C global warming could trigger multiple climate tipping points in the earth system (McKay et al., 2022), scientific communities have declared ecological and climatic emergencies and have urged for advocacy and collective activism for mitigating the negative trends by promoting eco-friendly practices (Gardner et al., 2021).

Since the start of developmental planning, Nepal's economic development strategies evolved from a neo-classical to a neoliberal framework. The ideologies and perspectives did not reflect the ground reality of Nepal's geophysical specificities, agroecological diversities and agrarian complexities (Sugden, 2009) in designing agricultural research, development and education systems. The challenges to economic development persisted and endogenous self-reliance on basic needs worsened over time despite various political changes in the country (Guthman, 1997; Khadka, 1998; N. R. Khanal et al., 2020; Metz, 1995). Those policies and practices emphasized a simplified intensification and commercialization approach to farming with heavy reliance on external synthetic inputs, and adoption of a few externally-bred cultivars at the expense of local landraces and under-utilized crops (N. R. Khanal et al., 2020; Uprety & Shivakoti, 2019) while making the food system increasingly reliant on the import of food, agricultural products, fertilizers and pesticides (Adhikari, Shrestha, et al., 2021). This severely undermined the indigenous knowledge and finely-tuned nutrient recycling, circular-economic practices (Willett, 1993), food and nutritional security (Rasul et al., 2018), and at the same time, eroded the seed sovereignty and dignity of agriculture-based livelihood systems (Adhikari, Shrestha, et al., 2021; Ghale, 2010). Climate change has aggravated various risks to Nepal's agroecosystems including the naturalization of invasive plant species (B. B. Shrestha & Shrestha, 2021; U. B. Shrestha & Shrestha, 2019) and a decrease in carbon storage (Ge et al., 2022; S. Rijal et al., 2021). The interplay of mismatching policies straining the people's livelihood strategies, Nepal is also undergoing varied manifestations of global socioecological issues (Givens et al., 2019).

Nepal has progressively declined from a food surplus to an importer country over time. Import dependency is also colossal for various agricultural products and synthetic inputs (Adhikari, Shrestha, et al., 2021). However, Nepal has ample potential to transform the agriculture and agri-food system to a sustainable agroecological model to replace imports and develop surplus, sovereign, localized, diversity-based healthy food systems. The objective of this review is to contribute to the discourse for transformative agriculture-centred, circular economic policies and practices fostering nature-based solutions and prudent extraction, use, re-use, and recycling of resources while minimizing waste and environmental externalities. This review proposes ecology-guided management of space (S1), species (S2), seeds (S3), soils (S4), seasonality (S5) and stress factors (S6) through the synergistic integration of agroecosystems and livelihood systems components (S7) with socioeconomic rationality (S8). It also highlights the salient geophysical and socio-economic realities of Nepal and their implications for generic and agricultural development strategies.

2. Research Methodology

The research approach involved a narrative review with the incorporation of the authors' experiences from Nepal, Canada, and the USA. Literature was searched with various words and phrases such as agroecology, agricultural systems, agricultural sustainability, food security, permaculture, conservation agriculture, climate-smart agriculture, biodynamic agriculture, sustainable intensification, regenerative agriculture, food sovereignty, landscape engineering, bioengineering, biodiversity, planetary boundary/safe operating limit, climate change, landlocked fragile geography, tourism, seed sovereignty, agroecosystems services, UN sustainable development goals, nature-based solutions with and without the words "agriculture" and "Nepal". Relevant examples of agroecological initiatives from other developing or low-income countries are extracted as case studies.

3. Results and Discussion

3.1 Nepal's geophysical and socioeconomic realities and their policy implications

Salient geophysical and socioeconomic realities of Nepal include landlocked, geo-tectonically active fragile geography, an abundance of ecological diversity, a heterogeneous cultural landscape embedded with agroecosystems, a treasure trove of natural beauty, and copious water resources. These specificities call for varied policy imperatives (Table 1). The landlocked situation presents high transaction costs and volatility in international trade (Grechyna, 2021; Vindegg, 2022), hence implicating a diversified endogenous circular economy and food-sufficiency approach to development (Corral et al., 2022; Papangelou & Mathijs, 2021; Schröder et al., 2020). The COVID-19 pandemic situation proved the fragility of the industrial corporate food systems (Montenegro de Wit, 2021), and the resilience and vitality of the localized, short-chain, diversified and sovereign approach to food systems (Adhikari, Timsina, et al., 2021; Menconi et al., 2022; Nemes et al., 2021; Turnšek et al., 2022; Zollet et al., 2021). Landlocked boundary and fragile geography dictate emphasis on contextual integration of cleaner locally available renewal energy options such as animal draft power, biogas, solar and wind energy, and micro-hydroelectrical power systems (Khatri & Paija, 2021; Koirala & Acharya, 2022; Malla, 2022; Neupane et al., 2022; Raihan & Tuspekova, 2022; K. Rijal et al., 1991; Suman, 2021) for residential use and agricultural and rural/agro-industrial mechanization to replace import of fossil fuel while reducing wastes and hazards.

The geo-tectonically active, fragile mountainous landscape and rainfall extremes under changing climates engenderer slope instability, excessive runoff, soil erosion, landslides, and destructive scouring, flooding, and sedimentation in the valleys and plain areas damaging roads and constraining transportation (N. Chen et al., 2023; Dahal, 2022; Li et al., 2022; Tiwari, 2000). This implicates eco-engineering policies and practices for infrastructure development and land use system (Gobinath et al., 2022; Y. Zhang et al., 2020) with minimal disturbance to land and natural drainage systems such as ropeways (Magar, 2016), micro-hydropower (Hussain et al., 2019), and eco-cultural conservation-based development (Baral et al., 2007; ICOMOS, 2021; Schröder et al., 2020; Stronza et al., 2022) and localized, sovereign food systems (Béné, 2020; Canfield et al., 2021) to minimize risky transports and food in security.

The treasure trove of natural beauty and cultural diversity holds bountiful leisure and recreation potentials for eco-tourism, cultural tourism and agro-tourism (Dhakal, 2022). This calls for policies ensuring Nepal as a haven for tourism while promoting indigenous cuisines and preserving cultural integrity and natural trove. With visionary management strategies, the colossal water resources suffice for residential and agricultural usage, and for hydro-electricity generation for fueling industries, ropeways and agricultural mechanization (Nepal et al., 2021; Upadhyay & Gaudel, 2018).

The abundance of ecological diversity offers diverse natural food, medicines, bio-pesticides, fodder and pasture, animal bedding materials, handicraft materials, pasture and timber resources for ecologically adaptive livelihood systems (Fonzen & Oberholzer, 1985; Rajbhandari, 2017; RHOADES & THOMPSON, 1975). It requires strong policy measures incentivizing community-based conservation and sustainable utilization of the resources. Diversity of agroecosystems and cultures implicates policy support for diversity-based integrated agriculture embedded in indigenous food culture, preserving and promoting indigenous knowledge (Perfecto et al., 2019; Willett, 1993).

Table 1: Salient geophysical and socioeconomic realities of Nepal and their policy implications

Realities	Manifestations	Policy implications	References
Landlocked boundary	High transaction costs and volatility in international trade	Promote diversified endogenous circular economy and food sufficiency approach to development; contextual integration of cleaner locally available and renewable energy options to replace import of fossil fuel, while reducing wastes and hazards	(Corral et al., 2022; Grechyna, 2021; Khatri & Paija, 2021; Malla, 2022; Neupane et al., 2022; Papangelou & Mathijs, 2021; Raihan & Tuspekova, 2022; K. Rijal et al., 1991; Schröder et al., 2020; Suman, 2021; Vindegg, 2022)

Realities	Manifestations	Policy implications	References
Geo-tectonically active, fragile mountainous landscape and rainfall extremes	Slope instability, excessive runoff, soil erosion, landslides, and destructive scouring, flooding, and sedimentation in the valleys and plain areas damaging roads and constraining transportation	Champion eco-engineering in infrastructure development with minimal disturbance to land and natural drainage systems; eco-cultural conservation-based development; and localized, sovereign food systems to minimize risky transports	(Baral et al., 2007; Béné, 2020; Canfield et al., 2021; N. Chen et al., 2023; Dahal, 2022; Gobinath et al., 2022; Hussain et al., 2019; ICOMOS, 2021; Li et al., 2022; Magar, 2016; Schröder et al., 2020; Stronza et al., 2022; Tiwari, 2000; Y. Zhang et al., 2020)
The abundance of ecological diversity	Availability of diverse natural food, medicines, bio-pesticides, fodder and pasture, animal bedding materials, handicraft materials, pasture and timber resources for ecologically adaptive livelihood systems	Devise policy measures incentivising community-based conservation and sustainable utilization of the resources	(Fonzen & Oberholzer, 1985; Perfecto et al., 2019; Rajbhandari, 2017; Rhoades & Thompson, 1975; Willett, 1993)
Cultural and agroecosystems diversity	Differential combination of crop and animal species and land races, seasonality, land use patterns, non-farm activities, feast and festivals, food ingredients and preparations	Diversity-based integrated agriculture embedded in indigenous food culture, preserving and promoting indigenous knowledge	(Fonzen & Oberholzer, 1985; Perfecto et al., 2019; Rajbhandari, 2017; Rhoades & Thompson, 1975)

Realities	Manifestations	Policy implications	References
The treasure trove of natural beauty	Bountiful leisure and recreation potential for eco-tourism, cultural tourism and agro-tourism	Strong policy measures for making Nepal a haven for tourism while promoting indigenous cuisines and preserving cultural integrity and a natural trove	(Dhakal, 2022; Nepal et al., 2021; Upadhyay & Gaudel, 2018)

3.2 Agrocological pathway to the agri-food system

Various contesting terminologies and perspectives have emerged in the agricultural sustainability discourse. Some of them to name are permaculture (Hirschfeld & Van Acker, 2021), conservation agriculture (Palm et al., 2014), climate-smart agriculture (Lipper et al., 2014), biodynamic agriculture (Soltani et al., 2016), sustainable intensification (Rockström et al., 2017), regenerative agriculture (Gordon et al., 2022) and agroecology (Wezel et al., 2020). Agroecology takes a more holistic discourse covering both ecological and socioeconomic perspectives embracing the science, practice and movement for agricultural transformation. The agro-ecological model comprises two phases of incremental and transformational strategies. The incremental phase involves three simultaneous schemes: (i) enhance resource use efficiency based on comparative advantage, appropriate regenerative technology and renewal energy-based mechanization; (ii) substitute harmful inputs and practices with ecofriendly alternatives; and (iii) redesign diversified agricultural production systems to enhance nutrient recycling and synergize the agroecosystem processes through functional diversification of production systems components. The transformational phase involves the integration of food and livelihood systems components from the local to regional and national levels. The model emphasizes the co-creation of innovation and practices through the blend of indigenous wisdom and scientific knowledge (Anderson et al., 2021; Wezel et al., 2020). This requires a radical shift in paradigm in the education, research, extension and development system. Selected examples of agroecological initiatives and outcomes in developing countries are given in the box below:

Case study I: Switching to low external input systems in Ethiopia - After the severe droughts in the 1980s, Ethiopia started adopting intensive external input-oriented agriculture, including chemical fertilizers. Besides increased food production, this approach increased dependency on costly chemical fertilizers, the price of which was continuously increasing putting many farmers in debt. Experts found a close interrelationship between the use of external inputs, degraded farmland, poverty, and food insecurity. In 1996, a low external input approach was promoted in the area focusing on organic composting, soil erosion control, rainwater harvesting, cover cropping, reintroduction of indigenous grass species, agroforestry, etc. Farmers reported several agro-ecological benefits, including improved soil fertility and moisture retention, higher local water tables due to conservation, increased temporal as well as spatial crop diversity, and production stability.

Case study II: Promotion of bio-intensive farming in Kenya - Kenya's agricultural policies traditionally emphasized producing cash crops for export, thereby neglecting smallholder farmers that make up most producers. A three-year drought in the early 1980s created severe food insecurity and hunger in far-western Kenya. Following the drought, cereal imports increased by 245 percent in a few years, which affected smallholder farmers. In the following years, some private agencies helped farmers to practice the "Grow Biointensive" method. The project aimed to help smallholders grow the most food needs on the least land using locally available inputs and resources such as compost, open-pollinated seeds, botanical pesticides, and natural pest-predators. The average yields for crops under bio-intensive agriculture were 2-4 times higher than in conventional farming, soil fertility has improved, and water supplies and retention have stabilized. After the program, farmers and their families not only produced enough food for themselves, but they also generated an average income of $30 per month from selling excess produce in the local market. Most households in the area can now afford school fees by selling extra produce.

Case study III: Community seed bank/seed fair approach in Zimbabwe and Uganda - Traditionally, the Zimbabwe government and private agencies have promoted the use of hybrid seeds and chemical fertilizers to increase maize production. Such hybrid seeds and chemical fertilizers made farmers solely dependent on private suppliers. The use of hybrid seeds has also promoted monocropping. Regardless of its price, the timely availability of seed and fertilizer became the major issue. Consequently, low yield and hunger are commonplace during the 1990s and early 2000s. After 2006, with support from various organizations, farmers started practicing conservation farming (CF) based on minimal tillage and locally available open-pollinated maize seeds conserved at community seed banks. Organic manure was used to boost soil fertility and mulch was used to conserve soil moisture. Community seed banks were established in every 4-5 villages. Chemical fertilizers were fully replaced by organic manure starting the second year of the project, which enhanced yields and was a lot cheaper and readily available to farmers. The participating farmers were also less vulnerable to drought and more likely to have a good harvest even if there was less rainfall because of the improvement in soil quality and the use of locally adapted crop varieties. See fair program with hands-on training was also successful in Uganda.

Case study IV: Promotion of locally adapted crops in Zambia and Malawi - Traditionally, both Zambia and Malawi's governments have promoted maize cultivation through massive subsidies and price support to farmers. As a result, maize replaced traditional crops like cassava, millet, and sorghum, which were e more drought-tolerant. In the early 1980s, a series of droughts seriously affected maize, because it is one of the high-water demanding crops. Further, the financial constraints forced governments to reduce maize subsidies and support systems. Following the drought years, both Zambia and Malawi's governments decided to promote cassava that can be harvested throughout the year, demands little labor, and doesn't require chemical inputs (fertilizers, pesticides). Research and breeding programs focused on the identification of the best local varieties of cassava and the distribution of clean planting material to avoid pest contamination. In the 1990s, they explicitly discouraged maize production in drier areas to provide space for more drought-resistant crops, cassava, and sweet potato. By 2009, there were over 397,000 cassava farmers each in Zambia and Malawi. In both countries, improved cassava varieties produced more output with the same labor and land and without purchased external inputs (pesticides and fertilizers).

Note: These case studies were compiled and published by the Oakland Institute and the Alliance for Food Sovereignty in Africa (AFSA) at different periods. A full set of case studies can be found at www.oaklandinstitute.org and www.afsafrica.org.

3.3 The 8-S Operational Elements For Agroecological Pathways

Building on the concept of agro-ecological pathways, Khanal (2023) has developed a framework of eight operational elements, which are referred to as the '8-S elements'. These elements aim to enhance the sustainable functioning of agroecosystems and livelihood systems. The framework integrates the management of space (S1), species (S2), seeds (S3), soils (S4), season (S5) and stressors (S6) through a systems approach, integrating synergistic components for balancing the ecological and economic trade-offs (S7) with socioeconomic objectivity (S8). The framework provides an operational guideline for policies and practices. Readers are encouraged to refer to Khanal (2023) for a global review and examples. For readers' convenience, a brief excerpt of the review, additional contextual findings, and opinions are presented below:

3.3.1 Spatial bioengineering

Agricultural systems evolve through efforts to accommodate socio-economic needs while considering the prevailing natural environment and agrarian policies. Spatial bioengineering is consciously designed systems that achieve desired socioeconomic outcomes while sustaining the carrying capacity of the natural environments. Various terminologies are found in the literature to describe the design of watershed management and land use systems, such as ecoengineering (Gobinath et al., 2022), climate-smart landscapes (Scherr et al., 2012), agroecological engineering (Dollinger et al., 2015) and soil and water bioengineering (Rey et al., 2019). Khanal (2023) uses the term spatial bioengineering to refer to the adaptive modification of physical and vegetal landscape tailored to the constraints presented by climatic, geographic, and soil conditions. It can be scaled up from field to community and/or watershed level or scaled down from the watershed to field scale depending on the pre-existing development and landscape complexity. Land sharing and land sparing perspectives can be contextually adapted to balance the ecosystem's functions for food production, biodiversity conservation and environmental protection (Phalan et al., 2011). Prudently planned spatial bioengineering can serve multiple productive, protective and micro-climatic modulating functions. These functions range from the stabilization of agricultural and peripheral landscapes and regulation of water resources (Scherr et al., 2012; Y. Zhang et al., 2020), the provision of operational and conservation features (such as homesteads, barns, farm ponds, and structures for grain and feed storage, composting, water-harvesting and drainage) (Liu et al., 2013; H. Zhang et al., 2022), the diversification of physical landscape terracing and diking (Baryła & Pierzgalski, 2008; D. Chen et al., 2017; Giráldez et al., 1988), and the integration of production system components with varied annual and perennial crops, economic plantations, natural vegetation and livestock vegetation (Paul et al., 2017; Quandt et al., 2019). The assorted landscape and vegetal features condition the local micro-climate, providing a comfortable setting for humans and animals, and a favorable environment for crop production (Schmidt et al., 2017). The micro-environmental setting enhances resiliency in the production and social system (Freeman et al., 2021) through mosaics of habitats for beneficial biodiversity (D'Acunto et al., 2016; Gallé et al., 2020; A. E. Martin et al., 2020; E. A. Martin et al., 2019), nutrient recycling and carbon sequestration (D'Acunto et al., 2014; Schoeneberger, 2009), and thereby synergizing the agroecosystem components. Thus, the emergent multi-functional landscape system lays the foundation for transformative livelihoods and food systems that prioritize sustainability and resilience.. Nepal's traditional agriculture and land use systems exhibit strategic spatial bioengineering characteristics that support a range of community needs and services..

Community or watershed level spatial bioengineering might include zoning for settlement, arable land, support infrastructures, location for irrigation channels, water harvesting reservoir, ponds etc. for water supply and recharge, and small-hydroelectricity system, schools/vocational training centres (demos of best practices, cultivating science), biodiversity sanctuaries, land stabilizing vegetation, market place, local processing/manufacturing, recycling, waste disposal, biogas/biofuel generation plants, stable roadways, community-based tourism support structures.

3.3.2 Species diversification

Spatial bioengineering can create niches that are diversified with various crop species and peripheral vegetation in spatial and temporal patterns. This enhances the landscape's carrying capacity, while also providing shelter for productive and supportive ecosystem services such as pollinators and natural enemies of pests, through the land-sharing approach (Phalan et al., 2011). The crop diversification strategies with the mosaics of cropping systems and peripheral vegetation engender a multi-functional environment optimizing yield and ecosystem services such as soil formation, nutrient retention, organic matter storage, pest suppression, and abundance of natural enemies and pollinators (Crews et al., 2018; Gallé et al., 2020; Isbell et al., 2017; A. E. Martin et al., 2020; Vasseur C., Joannon A., Burel F., Goffi C., Meynard J.M., 2008; Vasseur et al., 2013), thereby reducing the need of conventional inputs.

3.3.3 Seed sovereignty

Agricultural systems evolved with the farmer's selection of desirable plants and seeds for subsequent cropping creating an abundance of agrobiodiversity. The crop landraces have gone through the guided evolution on-farm towards increasing fitness and adaptability to management regimes in the given agro-climatic environment. The crop landraces associate with a wealth of farmers' knowledge about their biology, agronomy, adaptation and uses. The landraces thus evolved have remained as freely accessible common pool resources with indefinite evolutionary potentials. However, modern plant breeding and genetic modification not only truncate the evolutionary continuum but also come with different governance policies and more recently with private ownership, which threatens agrobiodiversity and seed sovereignty (Mueller & Flachs, 2022). The industrial agricultural development policies favouring modern commercial cultivars and externally governed seed systems cause genetic erosion, lowering the future potential for feeding the variability into the breeding programs (Cowling, 2013; Khoury et al., 2022). It is paramount to fosterer the guided evolution of agrobiodiversity in on-farm niches for diversified and health food systems (Marone et al., 2021; Mir et al., 2020). Tremendous variability among landraces and wild relatives preserves the genetic potential for crop improvement in the future (Halewood et al., 2018; Khoury et al., 2019). On-farm agrobiodiversity conservation measures offer dynamic management of population evolution, adaptation, and diversity (Enjalbert et al., 2011; Thomas et al., 2012). On-farm seed selection, seed saving, and community-level seed exchange networks existed in the traditional agricultural systems (Altieri, 1993; Delêtre et al., 2011) and policy measures should incentivize such practices while protecting seed sovereignty. Participatory decentralized evolutionary plant breeding approaches have evolved to be a potential tool for improving crop landraces and developing cultivars with desired traits and local adaption, while conserving agrobiodiversity and seed sovereignty (Ceccarelli & Grando, 2019, 2022; Colley et al., 2022; Joshi et al., 2020).

3.3.4 Seasonal synchrony and satiation

Choice of crops or cultivars with climate-adaptive phenology, shifting seeding time and tailoring cropping sequences in response to changing weather patterns, and harnessing efficient irrigation at critical stages are some of the seasonal adaptations of farming. Global climate change is bringing about more frequent erratic and extreme weather patterns. In arid unirrigated environments, crop performance depends on soil moisture during seeding for proper crop establishment. This imposes more stresses and perturbations on the agricultural production systems (Beillouin et al., 2020; Sun et al., 2019). Adjusting seeding time and seeding rate in response to changing weather patterns can become a low-cost eco-friendly approach to minimize production risks. In production systems prone to terminal drought and temperature stresses, early seeding may allow crops to escape the stresses resulting in higher yields. Timely seeding and sequencing of crops along with conservation agricultural practices in the rice-wheat cropping system in South Asia helped mitigate terminal moisture and temperature stresses on wheat, which led to an increase in wheat yield and overall systems productivity (Devkota et al., 2019; Somasundaram et al., 2020). Spatial bioengineering and supplemental irrigation enhance local microclimate enabling smooth systems functioning and resiliency measures (Soltani et al., 2016). Readers are referred to Khanal (2023) for the global examples of seasonality adaptation of cropping systems.

3.3.5 Soil health management

Soil health management embraces the integration of diverse practices that conserve soil, maximize nitrogen fixation, enhance nutrient recycling and enrich the soil properties for sustaining crop productivity while optimizing the agro-ecological and economic trade-offs. It may include various tillage systems such as conservation tillage, strategic or occasional tillage, bio-tillage, cover cropping, residue management, green manuring, organic amendments, biochar, biofertilizers and supplemental nutrient applications in the right forms, at right time, at the right rates and with right methods. Under favourable environmental conditions, annual legume crops can fix up to 260 kg atmospheric nitrogen per ha (equivalent to 565 kg Urea fertilizer) (Herridge et al., 2022), and preceding legumes crops can meet full nitrogen requirement for the immediate succeeding crop and up to 50% nitrogen requirement for the second succeeding crop (N. Khanal, 2022; N. Khanal et al., 2021). In his review article, Khanal (2023) has extracted global examples of diverse soil management practices and their tradeoffs. The policy measures should incentivize sustainable soil management practices that generate ecosystem services to the benefit of society and the environment.

3.3.6 Stressors management

The spatial bioengineering, species diversification, seed sovereignty, seasonal synchrony and soil health management impart high resiliency and nature-based solution to the production systems against various abiotic and biotic stresses such as drought, heatwaves, floods, crop weeds, diseases, and insect pests. The supplementary stressors management strategies involve contextual integration of the above-noted elements and adopt nature-based solutions to alleviate abiotic and biotic stresses and perturbations. Integrated pest and disease management (IPDM) helps to keep the pest population below the economic threshold level while minimizing the potential loss from insects/pests. Crop and livestock insurance and disaster preparedness would help either to transfer or minimize the risk associated with biotic and abiotic factors.

3.3.7 Systems integration

Eight of the UN Sustainable Goals (SDGs) relate to agriculture and food systems. Agriculture development policy must embrace all those SGDs as an integrated package for the effective realization of the impact indicators (Barrett et al., 2022). A systems approach to integrating synergistic components helps optimize the ecological and economic trade-offs from field to landscape scale. To this end, it is important to revitalize, incentivize and advance the integrated systems such as agro-forestry, crop-livestock integration, integrated multi-trophic aquaculture, and biogas/biofuel-integrated farm mechanization and agro-processing plants (Kitaoka, 2019), agro-tourism (Huber et al., 2020), and local food and marketing networks. The multi-sectoral and interdisciplinary approaches enable income diversification and drive a circular economy. It may include value addition through the establishment of household/ community-based small agri-food processing industries powered with renewable energy such as bio-gas and small hydro-units; launch of community-based agro-tourism and agri-fairs (homestay, local/organic food fairs etc.); regulated fair marketing through community-based cooperatives, local haat-bazaar, and provisioning of micro-financing and insurance systems; development of support infrastructures (storage, irrigation, marketing stalls, collection centres, energy and power systems etc.), and re-connecting producers and consumers through short-chain local food networks, supported with publicly funded infrastructures and institutional networks to scale-up food networks through the governance structure. The country's agricultural research, education, and extension system should integrate both sustainable agriculture and food systems innovations. The innovations should encompass crop production, land use, distribution and their environmental footprints, dietary improvements and waste management for circular economy and OneHealth. It requires stakeholders' engagement for the charting of transition pathways and development of appropriate incentives, regulations and social licence measures.

3.3.8 Socioeconomic objectivity

Strong policy measures are required to abolish policy-bias, power-asymmetry and enact subsidy measures to promote the practices that produce public goods and services and boost the dignity of farmers and agri-entrepreneurs. The policy should visualize outmigration and labor shortage; promote renewal energy-based mechanization and land consolidation measures (such as waiver of land title transfer fees for land consolidation to make single-parcel operations units), to enhance time efficiency amidst labor shortage; need bottom-up scaling of policy from community groups to Wards through municipalities to national level. Small, fragmented landholding limits mechanization, implicating region-specific selective mechanization based on animal, biofuel and hydro-electric power. It is a shame to exchange human resources with fossil fuels by exporting the youth labour force abroad and importing the fossil fuel for inapt mechanization. The transformative policy must provide an incentive for public goods and services; subsidize investment in community-based resource conservation and development; restructure education, extension and developmental systems; provide vocational training and investment supports to youths and landless tenants to the reclamation and use of arable barren land. Accordingly, the policy measures should subsidize only those practices that produce public goods such as biodiversity conservation including indigenous minor food crops, integration of agro-ecosystems components, environmental protection, maintenance of aesthetic landscape, and building social capitals.

4. Conclusions and Policy Recommendations

Nepal's geophysical and socioeconomic realities call for an endogenous, self-reliant, regenerative, and holistic model of development. Past and current agricultural development policies and practices have emphasized the synthetic chemical-dependent, modern cultivar-based, simplified agricultural practices leading to resource degradation, environmental pollution, and eroded indigenous agro-biodiversity and knowledge systems. This trend has further disrupted the agriculture-based, self-reliant livelihood systems, and weakened food sovereignty. It must be reversed, and it is both possible and urgent. It requires a paradigm shift to balance the tradeoffs between economic growth and socio-ecological health. The policy orientation must transform from sectoral silos to multi-disciplinary, multi-sectoral and integrative bottom-up approaches. It should focus on developing nature-based solutions and devise strong measures to diversify and circularize local economies. Drawing on the aforementioned discussions, the policy recommendations are summarized below:

- Emphasize the co-creation of innovation and farming practices through the blend of indigenous wisdom and scientific knowledge.
- Incentivize the gradual substitution of external synthetic inputs (fertilizers, pesticides) with locally available and ecofriendly alternatives.
- Focus research and extension efforts on redesigning diversified agricultural production systems to enhance nutrient recycling and synergize the agroecosystem processes through functional diversification of components such as integration of crops, livestock, annuals, perennials, pollinators, aquaculture, and peripheral biodiversity components.
- Subsidize biodiversity-based agriculture and food systems, and promote indigenous or underutilized food crops, resource conservation and cooperative initiatives.
- Incentivize components integration rather than a specialized or single practice that does not synergize outputs or does not produce ecosystem services.
- Provide support to diversify local economies through value addition (household/community-based small agri-food processing industries powered with bio-gas and small hydro-units), community-based agro-tourism (homestay, local/organic food fairs etc.), fair marketing (community-based cooperative marketing, micro-financing, local haat-bazaar etc.), and local food networks (re-connect producers and consumers through short-chain markets) underpinned with publicly funded infrastructures (storage, irrigation, marketing, collection centers) and institutional services.

Authors Contribution Statement

Nityananda Khanal: Conceiving ideas; formulation of overarching research goals and aims; Development or design of methodology; Application of statistical, mathematical, computational, or other formal; Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection; Report initial draft/review/ final draft polishing;

Sushil Thapa: Application of statistical, mathematical, computational, or other formal; Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection; Provision of study materials, reagents, materials, instrumentation, computing resources; Report initial draft/review/final draft polishing;

Conflict of Intrest

The authors declare no conflict of interest. Views expressed in the article are solely of the authors, which do not represent the views of their respective organizations.

References

Adhikari, J., Shrestha, M., & Paudel, D. (2021). Nepal's growing dependency on food imports: A threat to national sovereignty and ways forward. *Nepal Public Policy Review*, *1*, 68–86. https://doi.org/10.3126/nppr.v1i1.43429

Adhikari, J., Timsina, J., Khadka, S. R., Ghale, Y., & Ojha, H. (2021). COVID-19 impacts on agriculture and food systems in Nepal: Implications for SDGs. *Agricultural Systems*, *186*, 102990. https://doi.org/10.1016/j.agsy.2020.102990

Altieri, M. A. (1993). Ethnoscience and biodiversity: key elements in the design of sustainable pest management systems for small farmers in developing countries. *Agriculture, Ecosystems and Environment*, *46*(1–4), 257–272. https://doi.org/10.1016/0167-8809(93)90029-O

Baral, N., Stern, M. J., & Heinen, J. T. (2007). Integrated conservation and development project life cycles in the Annapurna Conservation Area, Nepal: Is development overpowering conservation? *Biodiversity and Conservation*, *16*(10), 2903–2917. https://doi.org/10.1007/s10531-006-9143-5

Barrett, C. B., Benton, T., Fanzo, J., Herrero, M., Nelson, R. J., Bageant, E., Buckler, E., Cooper, K., Culotta, I., Fan, S., Gandhi, R., James, S., Kahn, M., Lawson-Lartego, L., Liu, J., Marshall, Q., Mason-D'Croz, D., Mathys, A., Mathys, C., … Wood, S. (2022). *Socio-Technical Innovation Bundles for Agri-Food Systems Transformation* (C. B. Barrett, T. Benton, J. Fanzo, M. Herrero, R. J. Nelson, E. Bageant, E. Buckler, K. Cooper, I. Culotta, S. Fan, R. Gandhi, S. James, M. Kahn, L. Lawson-Lartego, J. Liu, Q. Marshall, D. Mason-D'Croz, A. Mathys, C. Mathys, … S. Wood (eds.); pp. 1–20). Springer International Publishing. https://doi.org/10.1007/978-3-030-88802-2_1

Baryla, A., & Pierzgalski, E. (2008). Ridged terraces – functions, construction and use. *Journal of Environmental Engineering and Landscape Management*, *16*(2), 1–6. https://doi.org/10.3846/1648-6897.2008.16.104-109

Baude, M., Meyer, B. C., & Schindewolf, M. (2019). Land use change in an agricultural landscape causing degradation of soil based ecosystem services. *Science of the Total Environment*, *659*, 1526–1536. https://doi.org/10.1016/j.scitotenv.2018.12.455

Beillouin, D., Schauberger, B., Bastos, A., Ciais, P., & Makowski, D. (2020). Impact of extreme weather conditions on European crop production in 2018: Random forest - Yield anomalies. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *375*(1810), 20190510. https://doi.org/10.1098/rstb.2019.0510

Béné, C. (2020). Resilience of local food systems and links to food security – A review of some important concepts in the context of COVID-19 and other shocks. *Food Security*, *12*(4), 805–822. https://doi.org/10.1007/s12571-020-01076-1

Bras, A., Roy, A., Heckel, D. G., Anderson, P., & Karlsson Green, K. (2022). Pesticide resistance in arthropods: Ecology matters too. *Ecology Letters*, *25*(8), 1746–1759. https://doi.org/10.1111/ele.14030

Brühl, C. A., & Zaller, J. G. (2019). Biodiversity Decline as a Consequence of an Inappropriate Environmental Risk Assessment of Pesticides. *Frontiers in Environmental Science*, *7*, 177. https://doi.org/10.3389/fenvs.2019.00177

Campbell, B. M., Beare, D. J., Bennett, E. M., Hall-Spencer, J. M., Ingram, J. S. I., Jaramillo, F., Ortiz, R., Ramankutty, N., Sayer, J. A., & Shindell, D. (2017). Agriculture production as a major driver of the earth system exceeding planetary boundaries. *Ecology and Society*, *22*(4). https://doi.org/10.5751/ES-09595-220408

Canfield, M., Anderson, M. D., & McMichael, P. (2021). UN Food Systems Summit 2021: Dismantling Democracy and Resetting Corporate Control of Food Systems. *Frontiers in Sustainable Food Systems*, *5*, 661552. https://doi.org/10.3389/fsufs.2021.661552

Ceccarelli, S., & Grando, S. (2019). From participatory to evolutionary plant breeding. In *Farmers and Plant Breeding: Current Approaches and Perspectives* (pp. 231–243). Routledge. https://doi.org/10.4324/9780429507335-15

Ceccarelli, S., & Grando, S. (2022). Return to Agrobiodiversity: Participatory Plant Breeding. *Diversity*, *14*(2), 126. https://doi.org/10.3390/d14020126

Chen, D., Wei, W., & Chen, L. (2017). Effects of terracing practices on water erosion control in China: A meta-analysis. *Earth-Science Reviews*, *173*, 109–121. https://doi.org/10.1016/j.earscirev.2017.08.007

Chen, N., Liu, M., Allen, S., Deng, M., Khanal, N. R., Peng, T., Tian, S., Huggel, C., Wu, K., Rahman, M., & Somos-Valenzuela, M. (2023). Small outbursts into big disasters: Earthquakes exacerbate climate-driven cascade processes of the glacial lakes failure in the Himalayas. *Geomorphology*, *422*, 108539. https://doi.org/10.1016/j.geomorph.2022.108539

Chen, X., Chen, H. Y. H., Chen, C., Ma, Z., Searle, E. B., Yu, Z., & Huang, Z. (2020). Effects of plant diversity on soil carbon in diverse ecosystems: a global meta-analysis. *Biological Reviews*, *95*(1), 167–183. https://doi.org/10.1111/brv.12554

Colley, M. R., Tracy, W. F., Lammerts van Bueren, E. T., Diffley, M., & Almekinders, C. J. M. (2022). How the Seed of Participatory Plant Breeding Found Its Way in the World through Adaptive Management. *Sustainability (Switzerland)*, *14*(4), 2132. https://doi.org/10.3390/su14042132

Corral, F. J. G., Vázquez, R. M. M., García, J. M., & Valenciano, J. de P. (2022). The Circular Economy as an Axis of Agricultural and Rural Development: The Case of the Municipality of Almócita (Almería, Spain). *Agronomy*, *12*(7), 1553. https://doi.org/10.3390/agronomy12071553

Cowie, R. H., Bouchet, P., & Fontaine, B. (2022). The Sixth Mass Extinction: fact, fiction or speculation? *Biological Reviews*, *97*(2), 640–663. https://doi.org/10.1111/brv.12816

Cowling, W. A. (2013). Sustainable plant breeding. *Plant Breeding*, *132*(1), 1–9. https://doi.org/10.1111/pbr.12026

Crews, T. E., Carton, W., & Olsson, L. (2018). Is the future of agriculture perennial? Imperatives and opportunities to reinvent agriculture by shifting from annual monocultures to perennial polycultures. *Global Sustainability*, *1*, e11. https://doi.org/10.1017/sus.2018.11

D'Acunto, L., Semmartin, M., & Ghersa, C. M. (2014). Uncropped field margins to mitigate soil carbon losses in agricultural landscapes. *Agriculture, Ecosystems and Environment*, *183*, 60–68. https://doi.org/10.1016/j.agee.2013.10.022

D'Acunto, L., Semmartin, M., & Ghersa, C. M. (2016). Uncultivated margins are source of soil microbial diversity in an agricultural landscape. *Agriculture, Ecosystems and Environment*, *220*, 1–7. https://doi.org/10.1016/j.agee.2015.12.032

Dahal, R. K. (2022). Earthquake-Induced Landslides in the Nepal Himalaya. In *Coseismic Landslides: Phenomena, Long-Term Effects and Mitigation* (pp. 59–82). Springer. https://doi.org/10.1007/978-981-19-6597-5_3

Delêtre, M., McKey, D. B., & Hodkinson, T. R. (2011). Marriage exchanges, seed exchanges, and the dynamics of manioc diversity. *Proceedings of the National*

Academy of Sciences of the United States of America, *108*(45), 18249–18254. https://doi.org/10.1073/pnas.1106259108

Devkota, M., Devkota, K. P., Acharya, S., & McDonald, A. J. (2019). Increasing profitability, yields and yield stability through sustainable crop establishment practices in the rice-wheat systems of Nepal. *Agricultural Systems*, *173*, 414–423. https://doi.org/10.1016/j.agsy.2019.03.022

Dhakal, C. P. (2022). A Glimpse of the Tourism Sector in Nepal. *Hong Kong Journal of Social Sciences*, 60. https://doi.org/10.55463/hkjss.issn.1021-3619.60.28

Dirzo, R., Ceballos, G., & Ehrlich, P. R. (2022). Circling the drain: the extinction crisis and the future of humanity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *377*(1857), 20210378. https://doi.org/10.1098/rstb.2021.0378

Dollinger, J., Dagès, C., Bailly, J. S., Lagacherie, P., & Voltz, M. (2015). Managing ditches for agroecological engineering of landscape. A review. *Agronomy for Sustainable Development*, *35*(3), 999–1020. https://doi.org/10.1007/s13593-015-0301-6

Enjalbert, J., Dawson, J. C., Paillard, S., Rhoné, B., Rousselle, Y., Thomas, M., & Goldringer, I. (2011). Dynamic management of crop diversity: From an experimental approach to on-farm conservation. *Comptes Rendus - Biologies*, *334*(5–6), 458–468. https://doi.org/10.1016/j.crvi.2011.03.005

Fonzen, P. F., & Oberholzer, E. (1985). Use of multipurpose trees in hill farming systems in Western Nepal. *Agroforestry Systems*, *2*(3), 187–197. https://doi.org/10.1007/BF00147033

Freeman, J., Anderies, J. M., Beckman, N. G., Robinson, E., Baggio, J. A., Bird, D., Nicholson, C., Finley, J. B., Capriles, J. M., Gil, A. F., Byers, D., Gayo, E., & Latorre, C. (2021). Landscape Engineering Impacts the Long-Term Stability of Agricultural Populations. *Human Ecology*, *49*(4), 369–382. https://doi.org/10.1007/s10745-021-00242-z

Gallé, R., Geppert, C., Földesi, R., Tscharntke, T., & Batáry, P. (2020). Arthropod functional traits shaped by landscape-scale field size, local agri-environment schemes and edge effects. *Basic and Applied Ecology*, *48*, 102–111. https://doi.org/10.1016/j.baae.2020.09.006

Gardner, C. J., Thierry, A., Rowlandson, W., & Steinberger, J. K. (2021). From Publications to Public Actions: The Role of Universities in Facilitating Academic Advocacy and Activism in the Climate and Ecological Emergency. *Frontiers in Sustainability*, *2*, 679019. https://doi.org/10.3389/frsus.2021.679019

Garnier, J., Le Noë, J., Marescaux, A., Sanz-Cobena, A., Lassaletta, L., Silvestre, M., Thieu, V., & Billen, G. (2019). Long-term changes in greenhouse gas emissions from French agriculture and livestock (1852–2014): From traditional agriculture to conventional intensive systems. *Science of the Total Environment*, *660*, 1486–1501. https://doi.org/10.1016/j.scitotenv.2019.01.048

Ge, G., Zhang, J., Chen, X., Liu, X., Hao, Y., Yang, X., & Kwon, S. M. (2022). Effects of land use and land cover change on ecosystem services in an arid desert-oasis ecotone along the Yellow River of China. *Ecological Engineering*, *176*, 100963. https://doi.org/10.1016/j.ecoleng.2021.106512

Ghale, Y. (2010). Corporate globalisation: Hunger and livelihood insecurity in Nepal. *Livelihood Insecurity and Social Conflict in Nepal*, 09–48.

Giráldez, J. V., Ayuso, J. L., Garcia, A., López, J. G., & Roldán, J. (1988). Water harvesting strategies in the semiarid climate of southeastern Spain. *Agricultural Water Management*, *14*(1–4), 253–263. https://doi.org/10.1016/0378-3774(88)90079-0

Givens, J. E., Huang, X., & Jorgenson, A. K. (2019). Ecologically unequal exchange: A theory of global environmental injustice. *Sociology Compass*, *13*(5), e12693. https://doi.org/10.1111/soc4.12693

Glibert, P. M. (2020). From hogs to HABs: impacts of industrial farming in the US on nitrogen and phosphorus and greenhouse gas pollution. *Biogeochemistry*, *150*(2), 139–180. https://doi.org/10.1007/s10533-020-00691-6

Gobinath, R., Ganapathy, G. P., Gayathiri, E., Salunkhe, A. A., & Pourghasemi, H. R. (2022). Ecoengineering practices for soil degradation protection of vulnerable hill slopes. In *Computers in Earth and Environmental Sciences* (pp. 255–270). Elsevier. https://doi.org/10.1016/b978-0-323-89861-4.00002-6

Gordon, E., Davila, F., & Riedy, C. (2021, November 2). Transforming landscapes and mindscapes through regenerative agriculture. *Agriculture and Human Values*, *39*(2), 809–826. https://doi.org/10.1007/s10460-021-10276-0

Gould, F., Brown, Z. S., & Kuzma, J. (2018). Wicked evolution: Can we address the sociobiological dilemma of pesticide resistance? *Science*, *360*(6390), 728–732. https://doi.org/10.1126/science.aar3780

Grechyna, D. (2021). Trade openness and political distortions. *Economics and Politics*, *33*(3), 644–663. https://doi.org/10.1111/ecpo.12179

Guthman, J. (1997). Representing crisis: The theory of Himalayan environmental degradation and the project of development in post-rana Nepal. *Development and Change*, *28*(1), 45–69. https://doi.org/10.1111/1467-7660.00034

Halewood, M., Chiurugwi, T., Sackville Hamilton, R., Kurtz, B., Marden, E., Welch, E., Michiels, F., Mozafari, J., Sabran, M., Patron, N., Kersey, P., Bastow, R., Dorius, S., Dias, S., McCouch, S., & Powell, W. (2018). Plant genetic resources for food and agriculture: opportunities and challenges emerging from the science and information technology revolution. *New Phytologist*, *217*(4), 1407–1419. https://doi.org/10.1111/nph.14993

Hawkins, N. J., Bass, C., Dixon, A., & Neve, P. (2019). The evolutionary origins of pesticide resistance. *Biological Reviews*, *94*(1), 135–155. https://doi.org/10.1111/brv.12440

Herridge, D. F., Giller, K. E., Jensen, E. S., & Peoples, M. B. (2022). Quantifying country-to-global scale nitrogen fixation for grain legumes II. Coefficients, templates and estimates for soybean, groundnut and pulses. *Plant and Soil*, *474*(1–2), 1–15. https://doi.org/10.1007/s11104-021-05166-7

Hirschfeld, S., & Van Acker, R. (2021). Review: ecosystem services in permaculture systems. *Agroecology and Sustainable Food Systems*, *45*(6), 794–816. https://doi.org/10.1080/21683565.2021.1881862

Hossain, A., Krupnik, T. J., Timsina, J., Mahboob, M. G., Chaki, A. K., Farooq, M., Bhatt, R., Fahad, S., & Hasanuzzaman, M. (2020). Agricultural Land Degradation: Processes and Problems Undermining Future Food Security. In *Environment, Climate, Plant and Vegetation Growth* (pp. 17–61). Springer. https://doi.org/10.1007/978-3-030-49732-3_2

Huber, L., Schirpke, U., Marsoner, T., Tasser, E., & Leitinger, G. (2020). Does socioeconomic diversification enhance multifunctionality of mountain landscapes? *Ecosystem Services*, *44*, 101122. https://doi.org/10.1016/j.ecoser.2020.101122

Hussain, A., Sarangi, G. K., Pandit, A., Ishaq, S., Mamnun, N., Ahmad, B., & Jamil, M. K. (2019). Hydropower development in the Hindu Kush Himalayan region: Issues, policies and opportunities. *Renewable and Sustainable Energy Reviews*, *107*, 446–461. https://doi.org/10.1016/j.rser.2019.03.010

ICOMOS. (2021). Heritage and the Sustainable Development Goals. *International Journal of Heritage Studies*. https://openarchive.icomos.org/id/eprint/2453/1/ICOMOS_SDGs_Policy_Guidance_2021.pdf

Isbell, F., Adler, P. R., Eisenhauer, N., Fornara, D., Kimmel, K., Kremen, C., Letourneau, D. K., Liebman, M., Polley, H. W., Quijas, S., & Scherer-Lorenzen, M. (2017). Benefits of increasing plant diversity in sustainable agroecosystems. *Journal of Ecology*, *105*(4), 871–879. https://doi.org/10.1111/1365-2745.12789

Jaramillo, F., & Destouni, G. (2015). Comment on "planetary boundaries: Guiding human development on a changing planet." *Science*, *348*(6240), 1217–c.

https://doi.org/10.1126/science.aaa9629

Joshi, B. K., Ayer, D. K., Gauchan, D., & Jarvis, D. (2020). Concept and rationale of evolutionary plant breeding and its status in Nepal. *Journal of Agriculture and Forestry University*, 1–11. https://doi.org/10.3126/jafu.v4i1.47023

Karlsson Green, K., Stenberg, J. A., & Lankinen, Å. (2020). Making sense of Integrated Pest Management (IPM) in the light of evolution. *Evolutionary Applications*, *13*(8), 1791–1805. https://doi.org/10.1111/eva.13067

Khadka, N. (1998). Challenges to developing the economy of Nepal. *Contemporary South Asia*, *7*(2), 147–165. https://doi.org/10.1080/09584939808719836

Khanal, N. (2022). Integration of perennial forage seed crops for cropping systems resiliency in the Peace River region of western Canada. *Canadian Journal of Plant Science*. https://doi.org/10.1139/cjps-2022-0125

Khanal, N. (2023). Sustainable Agriculture and Cultivation Practices. *Reference Module in Food Science*. https://doi.org/10.1016/b978-0-12-823960-5.00080-9

Khanal, N., Azooz, R., Rahman, N., Klein-Gebbinck, H., Otani, J. K., Yoder, C. L., & Gauthier, T. M. (2021). Value of integrating perennial forage seed crops in annual cropping sequences. *Agronomy Journal*, *113*(5), 4064–4084. https://doi.org/10.1002/agj2.20781

Khanal, N. R., Nepal, P., Zhang, Y., Nepal, G., Paudel, B., Liu, L., & Rai, R. (2020). Policy provisions for agricultural development in Nepal: A review. *Journal of Cleaner Production*, *261*, 121241. https://doi.org/10.1016/j.jclepro.2020.121241

Khatri, A., & Paija, N. (2021). A long-run nexus of renewable energy consumption and economic growth in Nepal. In *Energy-Growth Nexus in an Era of Globalization* (pp. 27–66). Elsevier. https://doi.org/10.1016/B978-0-12-824440-1.00017-5

Khoury, C. K., Brush, S., Costich, D. E., Curry, H. A., de Haan, S., Engels, J. M. M., Guarino, L., Hoban, S., Mercer, K. L., Miller, A. J., Nabhan, G. P., Perales, H. R., Richards, C., Riggins, C., & Thormann, I. (2022). Crop genetic erosion: understanding and responding to loss of crop diversity. *New Phytologist*, *233*(1), 84–118. https://doi.org/10.1111/nph.17733

Khoury, C. K., Greene, S. L., Krishnan, S., Miller, A. J., & Moreau, T. (2019). A road map for conservation, use, and public engagement around north america's crop wild relatives and wild utilized plants. *Crop Science*, *59*(6), 2302–2307. https://doi.org/10.2135/cropsci2019.05.0309

Kitaoka, S. (2019). Current State and Future Prospects of Environmental Barrier Coatings. *Materia Japan*, *58*(7), 387–390. https://doi.org/10.2320/materia.58.387

Koirala, D. P., & Acharya, B. (2022). Households' fuel choices in the context of a decade-long load-shedding problem in Nepal. *Energy Policy*, *162*, 112795. https://doi.org/10.1016/j.enpol.2022.112795

Laborde, D., Mamun, A., Martin, W., Piñeiro, V., & Vos, R. (2021). Agricultural subsidies and global greenhouse gas emissions. *Nature Communications*, *12*(1), 2601. https://doi.org/10.1038/s41467-021-22703-1

Lal, R. (2018). Digging deeper: A holistic perspective of factors affecting soil organic carbon sequestration in agroecosystems. *Global Change Biology*, *24*(8), 3285–3301. https://doi.org/10.1111/gcb.14054

Li, D., Lu, X., Walling, D. E., Zhang, T., Steiner, J. F., Wasson, R. J., Harrison, S., Nepal, S., Nie, Y., Immerzeel, W. W., Shugar, D. H., Koppes, M., Lane, S., Zeng, Z., Sun, X., Yegorov, A., & Bolch, T. (2022). High Mountain Asia hydropower systems threatened by climate-driven landscape instability. *Nature Geoscience*, *15*(7), 520–530. https://doi.org/10.1038/s41561-022-00953-y

Lipper, L., Thornton, P., Campbell, B. M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., . . . Torquebiau, E. F. (2014, November 26). Climate-smart agriculture for food security. *Nature Climate Change*, *4*(12), 1068–1072. https://doi.org/10.1038/nclimate2437

Liu, Y., Duan, M., & Yu, Z. (2013). Agricultural landscapes and biodiversity in China. *Agriculture, Ecosystems and Environment*, *166*, 46–54. https://doi.org/10.1016/j.agee.2011.05.009

Lockwood, C. (2021). Agroecology now! Transformations towards more just and sustainable food systems. In *Agroecology and Sustainable Food Systems* (Vol. 45, Issue 10). Springer Nature. https://doi.org/10.1080/21683565.2021.1952363

Ma, C. Sen, Zhang, W., Peng, Y., Zhao, F., Chang, X. Q., Xing, K., Zhu, L., Ma, G., Yang, H. P., & Rudolf, V. H. W. (2021). Climate warming promotes pesticide resistance through expanding overwintering range of a global pest. *Nature Communications*, *12*(1), 5351. https://doi.org/10.1038/s41467-021-25505-7

Magar, R. T. (2016). *Gravity Goods Ropeways: A Sustainable Solution for Rural Transportation in Hilly and Mountainous Regions of Nepal*. http://scholarsbank.uoregon.edu/xmlui/handle/1794/20424

Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability (Switzerland)*, *13*(3), 1–21. https://doi.org/10.3390/su13031318

Malla, S. (2022). An outlook of end-use energy demand based on a clean energy and technology transformation of the household sector in Nepal. *Energy*, *238*, 121810. https://doi.org/10.1016/j.energy.2021.121810

Marone, D., Russo, M. A., Mores, A., Ficco, D. B. M., Laidò, G., Mastrangelo, A. M., & Borrelli, G. M. (2021). Importance of landraces in cereal breeding for stress tolerance. *Plants*, *10*(7), 1267. https://doi.org/10.3390/plants10071267

Martin, A. E., Collins, S. J., Crowe, S., Girard, J., Naujokaitis-Lewis, I., Smith, A. C., Lindsay, K., Mitchell, S., & Fahrig, L. (2020). Effects of farmland heterogeneity on biodiversity are similar to—or even larger than—the effects of farming practices. *Agriculture, Ecosystems and Environment*, *288*, 106698. https://doi.org/10.1016/j.agee.2019.106698

Martin, E. A., Dainese, M., Clough, Y., Báldi, A., Bommarco, R., Gagic, V., Garratt, M. P. D., Holzschuh, A., Kleijn, D., Kovács-Hostyánszki, A., Marini, L., Potts, S. G., Smith, H. G., Al Hassan, D., Albrecht, M., Andersson, G. K. S., Asís, J. D., Aviron, S., Balzan, M. V., … Steffan-Dewenter, I. (2019). The interplay of landscape composition and configuration: new pathways to manage functional biodiversity and agroecosystem services across Europe. *Ecology Letters*, *22*(7), 1083–1094. https://doi.org/10.1111/ele.13265

McKay, D. I. A., Staal, A., Abrams, J. F., Winkelmann, R., Sakschewski, B., Loriani, S., Fetzer, I., Cornell, S. E., Rockström, J., & Lenton, T. M. (2022). Exceeding 1.5°C global warming could trigger multiple climate tipping points. *Science*, *377*(6611), eabn7950. https://doi.org/10.1126/science.abn7950

McLaughlin, P. (2011). Climate Change, Adaptation, and Vulnerability. In *Organization & Environment* (Vol. 24, Issue 3). IPCC Geneva, Switzerland: https://doi.org/10.1177/1086026611419862

Menconi, M. E., Giordano, S., & Grohmann, D. (2022). Revisiting global food production and consumption patterns by developing resilient food systems for local communities. *Land Use Policy*, *119*, 106210. https://doi.org/10.1016/j.landusepol.2022.106210

Metz, J. J. (1995). Development in Nepal: Investment in the status quo. *GeoJournal*, *35*(2), 175–184. https://doi.org/10.1007/BF00814063

Mir, R. A., Sharma, A., & Mahajan, R. (2020). Crop Landraces: Present Threats and Opportunities for Conservation. *Rediscovery of Genetic and Genomic Resources for Future Food Security*, 335–349. https://doi.org/10.1007/978-981-15-0156-2_13

Montenegro de Wit, M. (2021). What grows from a pandemic? Toward an abolitionist agroecology. *Journal of Peasant Studies*, *48*(1), 99–136. https://doi.org/10.1080/03066150.2020.1854741

Mora, C., Spirandelli, D., Franklin, E. C., Lynham, J., Kantar, M. B., Miles, W., Smith, C. Z., Freel, K., Moy, J., Louis, L. V., Barba, E. W., Bettinger, K., Frazier, A. G., Colburn IX, J. F., Hanasaki, N., Hawkins, E., Hirabayashi, Y., Knorr, W., Little, C. M., … Hunter, C. L. (2018). Broad threat to humanity from cumulative climate hazards intensified by greenhouse gas emissions. *Nature Climate Change*, *8*(12), 1062–1071. https://doi.org/10.1038/s41558-018-0315-6

Mueller, N. G., & Flachs, A. (2022). Domestication, crop breeding, and genetic modification are fundamentally different processes: implications for seed sovereignty and agrobiodiversity. *Agriculture and Human Values*, *39*(1), 455–472. https://doi.org/10.1007/s10460-021-10265-3

Nemes, G., Chiffoleau, Y., Zollet, S., Collison, M., Benedek, Z., Colantuono, F., Dulsrud, A., Fiore, M., Holtkamp, C., Kim, T. Y., Korzun, M., Mesa-Manzano, R., Reckinger, R., Ruiz-Martínez, I., Smith, K., Tamura, N., Viteri, M. L., & Orbán, É. (2021). The impact of COVID-19 on alternative and local food systems and the potential for the sustainability transition: Insights from 13 countries. *Sustainable Production and Consumption*, *28*, 591–599. https://doi.org/10.1016/j.spc.2021.06.022

Nepal, S., Neupane, N., Belbase, D., Pandey, V. P., & Mukherji, A. (2021). Achieving water security in Nepal through unravelling the water-energy-agriculture nexus. *International Journal of Water Resources Development*, *37*(1), 67–93. https://doi.org/10.1080/07900627.2019.1694867

Neupane, D., Kafle, S., Karki, K. R., Kim, D. H., & Pradhan, P. (2022). Solar and wind energy potential assessment at provincial level in Nepal: Geospatial and economic analysis. *Renewable Energy*, *181*, 278–291. https://doi.org/10.1016/j.renene.2021.09.027

Özkara, A., Akyıl, D., & Konuk, M. (2016). Pesticides, environmental pollution, and health. In *Environmental health risk-hazardous factors to living species*. IntechOpen.

Palm, C., Blanco-Canqui, H., DeClerck, F., Gatere, L., & Grace, P. (2014). Conservation agriculture and ecosystem services: An overview. *Agriculture, Ecosystems and Environment*, *187*, 87–105. https://doi.org/10.1016/j.agee.2013.10.010

Papangelou, A., & Mathijs, E. (2021). Assessing agro-food system circularity using nutrient flows and budgets. *Journal of Environmental Management*, *288*, 112383. https://doi.org/10.1016/j.jenvman.2021.112383

Paul, C., Weber, M., & Knoke, T. (2017). Agroforestry versus farm mosaic systems – Comparing land-use efficiency, economic returns and risks under climate change effects. *Science of the Total Environment*, *587–588*, 22–35. https://doi.org/10.1016/j.scitotenv.2017.02.037

Perfecto, I., Vandermeer, J., & Wright, A. (2019). Nature's Matrix: Linking Agriculture, Biodiversity Conservation and Food Sovereignty. In *Nature's Matrix: Linking Agriculture, Biodiversity Conservation and Food Sovereignty*. Routledge. https://doi.org/10.4324/9780429028557

Persson, L., Carney Almroth, B. M., Collins, C. D., Cornell, S., De Wit, C. A., Diamond, M. L., Fantke, P., Hassellöv, M., Macleod, M., Ryberg, M. W., Søgaard Jørgensen, P., Villarrubia-Gómez, P., Wang, Z., & Hauschild, M. Z. (2022). Response to Comment on "outside the Safe Operating Space of the Planetary Boundary for Novel Entities." *Environmental Science and Technology*, *56*(3), 1510–1521. https://doi.org/10.1021/acs.est.2c02265

Phalan, B., Onial, M., Balmford, A., & Green, R. E. (2011). Reconciling food production and biodiversity conservation: Land sharing and land sparing compared. *Science*, *333*(6047), 1289–1291. https://doi.org/10.1126/science.1208742

Pravalie, R., Patriche, C., Borrelli, P., Panagos, P., Rosca, B., Dumitrascu, M., Nita, I. A., Savulescu, I., Birsan, M. V., & Bandoc, G. (2021). Arable lands under the pressure of multiple land degradation processes. A global perspective. *Environmental Research*, *194*, 110697. https://doi.org/10.1016/j.envres.2020.110697

Quandt, A., Neufeldt, H., & McCabe, J. T. (2019). Building livelihood resilience: what role does agroforestry play? *Climate and Development*, *11*(6), 485–500. https://doi.org/10.1080/17565529.2018.1447903

Raihan, A., & Tuspekova, A. (2022). The nexus between economic growth, energy use, urbanization, tourism, and carbon dioxide emissions: New insights from Singapore. *Sustainability Analytics and Modeling*, *2*, 100009. https://doi.org/10.1016/j.samod.2022.100009

Rajbhandari, B. P. (2017). Bio-Intensive Farming System and Sustainable Livelihoods. In *Himalayan College of Agricultural Sciences and Technology (HICAST)* (pp. 98–99). Himalayan College of Agricultural Sciences and Technology (HICAST) PO Box .... https://www.researchgate.net/profile/Binayak-Rajbhandari/publication/320416381_Biointensive_farming_system_and_sustainable_livelihoods/links/5a0ff681aca27287ce274ca6/Biointensive-farming-system-and-sustainable-livelihoods.pdf

Rasul, G., Hussain, A., Mahapatra, B., & Dangol, N. (2018). Food and nutrition security in the Hindu Kush Himalayan region. *Journal of the Science of Food and*

Agriculture, *98*(2), 429–438. https://doi.org/10.1002/jsfa.8530

Rey, F., Bifulco, C., Bischetti, G. B., Bourrier, F., De Cesare, G., Florineth, F., Graf, F., Marden, M., Mickovski, S. B., Phillips, C., Peklo, K., Poesen, J., Polster, D., Preti, F., Rauch, H. P., Raymond, P., Sangalli, P., Tardio, G., & Stokes, A. (2019). Soil and water bioengineering: Practice and research needs for reconciling natural hazard control and ecological restoration. *Science of the Total Environment*, *648*, 1210–1218. https://doi.org/10.1016/j.scitotenv.2018.08.217

Rhoades, R. E., & Thompson, S. I. (1975). Adaptive Strategies in Alpine Environments: Beyond Ecological Particularism 1 . *American Ethnologist*, *2*(3), 535–551. https://doi.org/10.1525/ae.1975.2.3.02a00110

Rijal, K., Bansal, N. K., & Grover, P. D. (1991). Energy in subsistence agriculture: A case study of nepal. *International Journal of Energy Research*, *15*(2), 109–122. https://doi.org/10.1002/er.4440150205

Rijal, S., Rimal, B., Acharya, R. P., & Stork, N. E. (2021). Land use/land cover change and ecosystem services in the Bagmati River Basin, Nepal. *Environmental Monitoring and Assessment*, *193*(10), 1–17. https://doi.org/10.1007/s10661-021-09441-z

Rockström, J., Williams, J., Daily, G., Noble, A., Matthews, N., Gordon, L., Wetterstrand, H., DeClerck, F., Shah, M., Steduto, P., de Fraiture, C., Hatibu, N., Unver, O., Bird, J., Sibanda, L., & Smith, J. (2016, July 12). Sustainable intensification of agriculture for human prosperity and global sustainability. *Ambio*, *46*(1), 4–17. https://doi.org/10.1007/s13280-016-0793-6

Scherr, S. J., Shames, S., & Friedman, R. (2012). From climate-smart agriculture to climate-smart landscapes. *Agriculture & Food Security*, *1*, 1–15.

Schmidt, M., Jochheim, H., Kersebaum, K. C., Lischeid, G., & Nendel, C. (2017). Gradients of microclimate, carbon and nitrogen in transition zones of fragmented landscapes – a review. *Agricultural and Forest Meteorology*, *232*, 659–671. https://doi.org/10.1016/j.agrformet.2016.10.022

Schoeneberger, M. M. (2009). Agroforestry: Working trees for sequestering carbon on agricultural lands. *Agroforestry Systems*, *75*(1), 27–37. https://doi.org/10.1007/s10457-008-9123-8

Schröder, P., Lemille, A., & Desmond, P. (2020). Making the circular economy work for human development. *Resources, Conservation and Recycling*, *156*, 104686. https://doi.org/10.1016/j.resconrec.2020.104686

Shrestha, B. B., & Shrestha, K. K. (2021). Invasions of Alien Plant Species in Nepal. *Invasive Alien Species*, *2*, 168–183. https://doi.org/10.1002/9781119607045.

ch20

Shrestha, U. B., & Shrestha, B. B. (2019). Climate change amplifies plant invasion hotspots in Nepal. *Diversity and Distributions*, *25*(10), 1599–1612. https://doi.org/10.1111/ddi.12963

Soltani, A., Hajjarpour, A., & Vadez, V. (2016). Analysis of chickpea yield gap and water-limited potential yield in Iran. *Field Crops Research*, *185*, 21-30. https://doi.org/10.1016/j.fcr.2015.10.015

Somasundaram, J., Sinha, N. K., Dalal, R. C., Lal, R., Mohanty, M., Naorem, A. K., Hati, K. M., Chaudhary, R. S., Biswas, A. K., Patra, A. K., & Chaudhari, S. K. (2020). No-Till Farming and Conservation Agriculture in South Asia–Issues, Challenges, Prospects and Benefits. *Critical Reviews in Plant Sciences*, *39*(3), 236–279. https://doi.org/10.1080/07352689.2020.1782069

Stronza, A. L., Hunt, C. A., & Fitzgerald, L. A. (2022). Ecotourism for conservation? *Routledge Handbook of Ecotourism*, *44*, 372–397. https://doi.org/10.4324/9781003001768-28

Sugden, F. (2009). Neo-liberalism, markets and class structures on the Nepali lowlands: The political economy of agrarian change. *Geoforum*, *40*(4), 634–644. https://doi.org/10.1016/j.geoforum.2009.03.010

Suman, A. (2021). Role of renewable energy technologies in climate change adaptation and mitigation: A brief review from Nepal. *Renewable and Sustainable Energy Reviews*, *151*, 111524. https://doi.org/10.1016/j.rser.2021.111524

Sun, Q., Miao, C., Hanel, M., Borthwick, A. G. L., Duan, Q., Ji, D., & Li, H. (2019). Global heat stress on health, wildfires, and agricultural crops under different levels of climate warming. *Environment International*, *128*, 125–136. https://doi.org/10.1016/j.envint.2019.04.025

Thomas, M., Demeulenaere, E., Dawson, J. C., Khan, A. R., Galic, N., Jouanne-Pin, S., Remoue, C., Bonneuil, C., & Goldringer, I. (2012). On-farm dynamic management of genetic diversity: The impact of seed diffusions and seed saving practices on a population-variety of bread wheat. *Evolutionary Applications*, *5*(8), 779–795. https://doi.org/10.1111/j.1752-4571.2012.00257.x

Tiwari, P. C. (2000). Land-use changes in Himalaya and their impact on the plains ecosystem: Need for sustainable land use. *Land Use Policy*, *17*(2), 101–111. https://doi.org/10.1016/S0264-8377(00)00002-8

Tudi, M., Ruan, H. D., Wang, L., Lyu, J., Sadler, R., Connell, D., Chu, C., & Phung, D. T. (2021). Agriculture development, pesticide application and its impact on the environment. *International Journal of Environmental Research and Public Health*, *18*(3), 1–24. https://doi.org/10.3390/ijerph18031112

Turnšek, M., Gangenes Skar, S. L., Piirman, M., Thorarinsdottir, R. I., Bavec, M., & Junge, R. (2022). Home Gardening and Food Security Concerns during the COVID-19 Pandemic. *Horticulturae*, *8*(9), 778. https://doi.org/10.3390/horticulturae8090778

Upadhyay, S. N., & Gaudel, P. (2018). Water Resources Development in Nepal: Myths and Realities. *Hydro Nepal: Journal of Water, Energy and Environment*, *23*, 22–29. https://doi.org/10.3126/hn.v23i0.20822

Uprety, R., & Shivakoti, S. (2019). Extension policies and reforms in Nepal: an analysis of challenges, constraints, and policy options. In *Agricultural Extension Reforms in South Asia: Status, Challenges, and Policy Options* (pp. 61–77). Elsevier. https://doi.org/10.1016/B978-0-12-818752-4.00004-7

Vasseur C., Joannon A., Burel F., Goffi C., Meynard J.M., B. J. (2008). The mosaic of crop management sequences: a hidden part of agricultural landscapes heterogeneity. *The 15th Annual IALE(UK) Conference: Landscape Ecology and Conservation*, 33–41.

Vasseur, C., Joannon, A., Aviron, S., Burel, F., Meynard, J. M., & Baudry, J. (2013). The cropping systems mosaic: How does the hidden heterogeneity of agricultural landscapes drive arthropod populations? *Agriculture, Ecosystems and Environment*, *166*, 3–14. https://doi.org/10.1016/j.agee.2012.08.013

Vindegg, M. (2022). Borderline politics: Reading Nepal-India relations as 'energohistory.' *History and Anthropology*, 1–20.

Wang-Erlandsson, L., Tobian, A., van der Ent, R. J., Fetzer, I., te Wierik, S., Porkka, M., Staal, A., Jaramillo, F., Dahlmann, H., Singh, C., Greve, P., Gerten, D., Keys, P. W., Gleeson, T., Cornell, S. E., Steffen, W., Bai, X., & Rockström, J. (2022). A planetary boundary for green water. *Nature Reviews Earth and Environment*, *3*(6), 380–392. https://doi.org/10.1038/s43017-022-00287-8

Wezel, A., Herren, B. G., Kerr, R. B., Barrios, E., Gonçalves, A. L. R., & Sinclair, F. (2020). Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review. *Agronomy for Sustainable Development*, *40*(6), 1–13. https://doi.org/10.1007/s13593-020-00646-z

Willett, A. B. J. (1993). Indigenous Knowledge and Its Implication for Agricultural Development and Agricultural Education: a Case Study of the Vedic Tradition in Nepal. In *Education*. Iowa State University.

Winkler, K., Fuchs, R., Rounsevell, M., & Herold, M. (2021). Global land use changes are four times greater than previously estimated. *Nature Communications*, *12*(1), 2501. https://doi.org/10.1038/s41467-021-22702-2

Zhang, H., Li, P., Zhang, Z., Li, W., Chen, J., Song, X., Shibasaki, R., & Yan, J.

(2022). Epidemic versus economic performances of the COVID-19 lockdown: A big data driven analysis. *Cities*, *120*. https://doi.org/10.1016/j.cities.2021.103502

Zhang, Y., Fan, J., & Wang, S. (2020). Assessment of ecological carrying capacity and ecological security in China's typical eco-engineering areas. *Sustainability (Switzerland)*, *12*(9), 3923. https://doi.org/10.3390/su12093923

Zollet, S., Colombo, L., De Meo, P., Marino, D., McGreevy, S. R., McKeon, N., & Tarra, S. (2021). Towards territorially embedded, equitable and resilient food systems? Insights from grassroots responses to covid-19 in italy and the city region of rome. *Sustainability (Switzerland)*, *13*(5), 1–25. https://doi.org/10.3390/su13052425

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