Asian Journal of Research in Agriculture and Forestry

Volume 10, Issue 1, Page 79-90, 2024; Article no.AJRAF.113459
ISSN: 2581-7418

Exploring Agroecological Approaches for Sustainable Agriculture and Rural Development: A Comprehensive Review

Sujan Bhandari [a], Bishnu Yadav [a*], Pawan Kumar Yadav [a], Vivek Lahutiya [a] and Sudip Koirala [b]

[a] G. P. Koirala College of Agriculture and Research Centre, Purbanchal University, Gothgaun, Morang, Nepal, India.
[b] College of Natural Resource Management, Agriculture and Forestry University, Pakhribas, Dhankuta, Nepal, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJRAF/2024/v10i1271

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/113459

Review Article

Received: 15/12/2023
Accepted: 19/02/2024
Published: 22/02/2024

ABSTRACT

Agroecology, as an interdisciplinary field, integrates ecological principles into agricultural systems to promote sustainability. This paper examines the pivotal role of agroecological approaches in fostering sustainable agriculture and rural development. Initially concentrated on enhancing crop productivity and resilience, agroecology has evolved to encompass broader dimensions, including environmental stewardship, social equity, and economic viability. By emphasizing the sustainable use of resources and adopting diverse strategies, agroecology addresses contemporary challenges in agricultural production. This review synthesizes existing literature on the fundamental concepts and principles of agroecology, highlighting its profound implications for sustainable agriculture and

**Corresponding author: E-mail: bishnuyadav2073@gmail.com;*

rural development. By exploring agroecological approaches at various scales, from plot-level interventions to systemic changes within the food system, this paper underscores the critical linkage between agroecology and the pursuit of sustainable agricultural practices and rural prosperity.

Keywords: Agroecology; sustainable agriculture; agroecological principles; ecological political economy; agro-population ecology; integrated assessment of agricultural systems.

1. INTRODUCTION

Agroecology, as defined by Dalgaard et al.[1], is the interdisciplinary study of interactions within agricultural systems, encompassing plants, animals, humans, and the environment (Fig. 1). This field aims to understand and optimize these interactions to achieve sustainable agricultural practices. The term "agroecology" was introduced by Bensin in the late 1920s (Bensin, 1928, 1930) and later popularized by Gliessman (2007) and Warner (2007). However, over its 80-year history, there has been confusion regarding its definition and scope [2]. Despite this, agroecology has emerged as a multidisciplinary field crucial for sustainable agriculture and rural development.

Over the past three decades, agroecology has experienced significant evolution, largely driven by visionary farmers and academics. Initially rooted in agronomy and ecology, agroecology has gradually expanded its scope to encompass broader dimensions of environmental, social, economic, ethical, and developmental challenges facing agriculture today [2]. This expansion reflects the growing recognition of the need for holistic and sustainable approaches to agricultural production.

The core principle of agroecology is to design and manage agricultural systems in harmony with natural ecosystems, aiming to meet human needs while preserving ecological balance. This requires a deep understanding of local conditions and the implementation of context-specific agricultural strategies [3]. Agroecological approaches not only enhance ecological resilience and agricultural productivity but also promote social equity and rural livelihoods [4]. These approaches are essential for addressing the complex and interconnected challenges of sustainable agriculture and rural development.

Fig. 1. Sustainable and innovative agricultural systems in-focus: agroecology (modified from devereux, 2021)

Agroecology represents a paradigm shift in agricultural thinking, emphasizing the integration of scientific knowledge, local wisdom, and participatory action [5]. It advocates for transformative changes in agricultural practices, education, research, and policy to promote ecological, economic, and social sustainability across the entire food system. By challenging conventional agricultural paradigms and promoting alternative social structures and policy actions, agroecology seeks to create a more equitable, resilient, and sustainable food system.

2. AGROECOLOGICAL PRINCIPLES TO SARD

The principles of agroecology for Sustainable Agriculture and Rural Development (SARD), as elucidated by Alexander Wezel et al. [6] and Rajbhadari [7], encompass a holistic and integrated approach to agricultural practices (Fig. 2). One fundamental principle involves ensuring farmers' access to essential resources and capital while concurrently empowering and mobilizing communities to actively engage in sustainable agricultural practices. By prioritizing access to resources, this principle aims to enhance the capacity of farmers and communities to adopt and sustain environmentally conscious farming methods. Another vital aspect of agroecological principles is the conscientious use of renewable resources. This entails the utilization of bio-organic fertilizers, green manure, farmyard manure (FYM) [8], and biopesticides/ botanical pesticides [9, 10]. The emphasis on renewable resources aligns with the overarching goal of sustainable resource management, promoting practices that contribute to long-term environmental and agricultural viability. Resource conservation is a key tenet of agroecology, urging the implementation of practices that safeguard vital elements such as soil, water, energy, and genetic resources. This principle underscores the importance of responsible resource stewardship to mitigate environmental degradation and promote the resilience of agricultural systems. Agroecology also emphasizes the conservation and judicious use of biodiversity, spanning landscapes, biota, and cultural diversity. Prioritizing health, the principles advocate for the well-being of humans, animals, soil, plants, the environment, and cultural aspects, fostering a balanced and sustainable coexistence between agriculture and ecosystems. To minimize environmental and health risks, agroecological principles advocate for the reduction of toxic substances, advocating the elimination of materials like chemical pesticides, herbicides, and chemical fertilizers [11]. While several insecticides have demonstrated efficacy in controlling pests, they also have negative consequences on the environment and ecological processes [12]. Given their irreplaceable utility, further research is necessary to refine their dosage and evaluate their long-term effects on soil quality and biodiversity [13]. This approach can provide additional insights and assist in developing pesticides that are more effective yet less persistent in nature, thereby minimizing their impact on biodiversity.

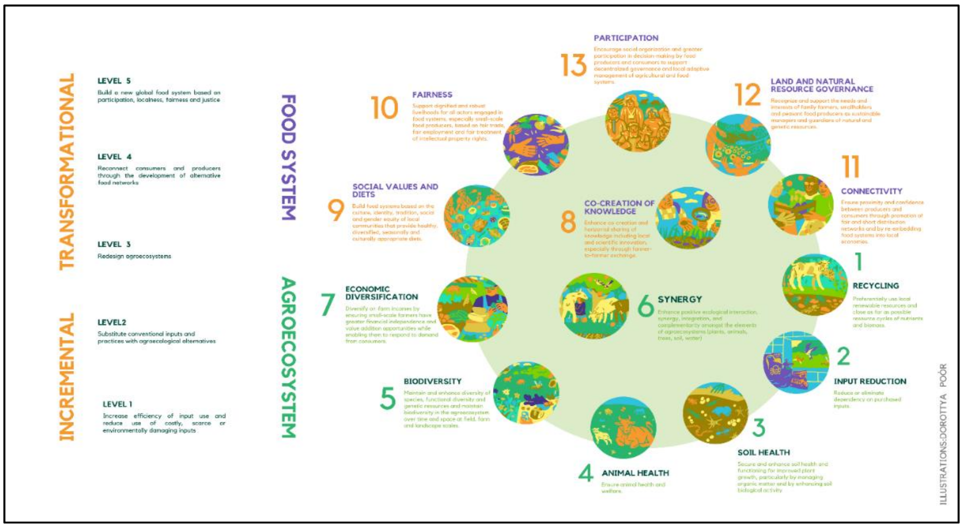

Fig. 2. Principles of agroecology and the levels of transition towards sustainable agriculture and rural development (Modified from Agroecology Europe, 2022)

Managing ecological relationships involves fostering productive interactions among plants, animals, soils, and the biosphere, enhancing ecological balance within agricultural systems. A holistic perspective is encouraged through the management of whole systems, considering landscapes, households, farms, communities, and ecological or bio-regions. Finally, the principles strive to optimize long-term benefits, focusing on intergenerational benefits, livelihoods, quality of life, and the overall sustainability of agricultural practices. In conclusion, the principles of agroecology represent a paradigm shift towards a comprehensive and sustainable approach to agriculture. Their implementation is designed to foster resilient, equitable, and environmentally conscious agricultural systems, thereby contributing to sustainable rural development.

3. AGROECOLOGICAL APPROACHES ON SARD

The various agroecological approaches related to Sustainable Agriculture and Rural Development, as highlighted by Rajbhadari [7] and Mason et al.[14], encompass a range of strategies aimed at promoting ecological sustainability, social equity, and economic viability in agricultural systems. Here are the identified agroecological approaches:

3.1 Ecosystems Agroecology

The foundation of comprehending the sustainability of agroecosystems lies in natural ecosystems and traditional, also known as local or indigenous, agroecosystems [15]. Natural ecosystems function as templates, providing insights into the ecological fundamentals crucial for the enduring viability of a specific region [15]. Over time, traditional agroecosystems have undergone transformations, serving as illustrative examples of how cultures and their surrounding environments adapt through processes that harmonize people's needs with ecological, technological, and socioeconomic factors [15]. The amalgamation of this understanding with insights into societal change has elevated the science of agroecology into a powerful instrument for reforming food systems. Natural ecosystems, crafted through prolonged adaptation to local ecological conditions and the utilization of indigenous resources, yield valuable lessons for sustainable agricultural practices. The distinction of traditional and indigenous agroecosystems from conventional systems lies in their evolution in periods or regions where inputs beyond human labor and local resources were either unavailable or undesirable [15]. Given that agriculture represents the primary nexus between humans and the environment, the imperative to strike a balance between crop output and environmental integrity, encapsulated in the concept of sustainable crop production, stands out as a critical challenge for agriculture and forthcoming generations of farmers [16]. This challenge underscores the necessity of integrating ecological principles, local knowledge, and sustainable practices in agriculture to ensure the well-being of both the environment and the communities it sustains [17].

The ecological services provided by soil biota play a crucial role in determining soil quality, plant health, and soil resilience [18,19]. Particularly, soil microorganisms forming mutually beneficial connections with plant roots have garnered increased attention in agricultural research due to their potential to enhance plant growth and reduce inputs in sustainable cropping systems [18]. However, human management of agroecosystems, impacting natural ecosystem structures and processes, poses challenges in their analysis compared to natural ecosystems [15]. While agriculture and ecosystem services are essential for human survival and quality of life, current agricultural practices aimed at boosting global food supply have unintentionally resulted in negative consequences for the environment and ecosystem services [18]. The foundational concept of the ecosystem, characterized as a functional system of interconnected relationships between living organisms and their environment, is a cornerstone of agroecology [15]. When humans manipulate an environment to establish agricultural output, they create an agroecosystem, and understanding these systems requires an ecological perspective. Computational agroecology emerges as a tool to convert various types of land into new food-producing ecosystems aligned with local conditions and long-term ecological health and food security [3]. In contrast to a well-developed natural ecosystem that is stable, self-sustaining, and adaptable to change, agroecosystems undergo manipulation for human purposes and require sustainable management practices. Agroecology provides a comprehensive ecological framework for understanding the structure, function, linkages, and dynamics of agroecosystems at various levels, from individual plants or animals to farms, regions, and the global food chain [15,20]. In-depth examinations of the ecological effects of cultivation, grazing, irrigation, and fertilization on the soil ecosystem are essential. Solutions are recommended to maintain a healthy, productive soil and crop ecosystem, considering negative effects of pesticides and proposing alternatives such as biological control, crop rotation and diversity, sanitation, and innovative chemical attractants and technology, deterrents [21,22] and plant resistance [23,24]. The symbiotic relationship between arbuscular mycorrhizal (AM) fungi and plant roots is highlighted for its role in enhancing plant nutrient uptake and providing non-nutritional benefits such as soil stabilization, erosion prevention, and alleviation of plant stress caused by various factors [18].

3.2 Ecological Political Economy

Ecological political economy, a multidisciplinary field primarily led by human geographers, offers a comprehensive perspective on various environmental challenges through a socio-ecological lens [25]. This field, rooted in a political-economic critique of industrial agriculture, draws extensively from the social sciences, presenting a critical view of the prevailing capitalist economy that freely exploits resources and waste-sinks [14]. Central to ecological political economy is the concept of commodification theory, where theories generally assume a capitalist system that commodifies resources without adequate consideration for environmental consequences [26]. It has evolved as a practical response to the environmental and social repercussions arising from industrial agriculture, reflecting a commitment to address and mitigate these impacts [14]. The idea of "political agroecology," as emphasized by Gonzalez de Molina in 2013, underscores the need to establish institutions, policies, and social momentum to facilitate the agroecological transition [14]. This approach acknowledges the role of politics and governance in shaping agricultural practices and environmental outcomes. Optimists within the ecological political economy envision a new era of capitalist prosperity as an opportunity for progressive political forces to build more stable, inclusive, and just political economies compared to those that followed the crises of the 1970s [25]. The belief is that by leveraging this period of economic growth, there is potential to address environmental and social challenges more effectively. For agroecological science to contribute meaningfully to a transition toward environmental, economic, and social sustainability, it must move beyond simplification [14]. This suggests a need for a nuanced understanding of the complex interactions within agroecosystems and the broader socio-economic context, recognizing the intricate relationships between ecological processes and political-economic structures.

Agriculture faces a triad of interconnected challenges: meeting the escalating demand for food security in a continually growing global population, adapting to the impacts of climate change, and mitigating climate change without compromising production [27,28]. To effectively catalyze a transition to environmental, economic, and social sustainability, agroecological science needs to progress beyond merely investigating farming concepts and methods that balance productivity and environmental considerations [14]. The term "ecological political economy" (EPE) is chosen over the alternative "environmental political economy" due to its superior descriptive precision [25]. EPE underscores capitalism as a system characterized by widespread commoditization of labor and production, fossil fuel-based industrialization, and technical innovation oriented toward continuous monetary profit expansion [26]. Linking the state to the demands of capital, EPE delves into a range of political economy issues by highlighting the unequal distribution of power among people and animals, considering economic, political, and ecological dynamics as outcomes of this power imbalance [25]. Crucially, ecological political economy necessitates a transition theory that elucidates the pathway from the present state to more desirable futures [26]. Establishing its significance in the broader realm of political ecology, work grounded in EPE contributes uniquely to understanding and addressing environmental challenges within the context of political-economic structures. Capitalism, with its inherent contradictions and reliance on finite resources, energy, and waste sinks on a finite planet, is a central focus of ecological political economy [26]. Activists and social movements increasingly link environmental crises with capitalism, signaling a growing awareness of the intertwined nature of ecological and economic issues [26]. In contrast, various political economy literatures, committed to the contextualized study of modern political-economic change, emphasize the connection between nature, class relations, and capital accumulation [25]. This underscores the importance of understanding how ecological considerations intersect with broader socio-economic dynamics.

EPE offers an integrated perspective that considers the socio-economic, political, and ecological dimensions of agriculture and rural development [29]. By acknowledging the interconnectedness of these factors, EPE facilitates a more holistic understanding of the challenges and opportunities for sustainability in agricultural systems. The concept of "political agroecology" emphasizes the importance of establishing supportive institutions, policies, and social momentum to facilitate the transition towards agroecological practices [30]. By integrating political and governance considerations into agricultural strategies, EPE can help ensure that sustainability goals are effectively pursued and supported at the policy level. EPE recognizes the environmental and social repercussions of industrial agriculture and offers a critical perspective on the prevailing capitalist economy's exploitation of resources and waste-sinks [31]. By addressing these issues through a political-economic critique, EPE aims to mitigate negative impacts and promote more sustainable agricultural practices. Further, EPE emphasizes the need for a transition theory that elucidates the pathway from the current state to more desirable futures [32]. By providing a framework for understanding and navigating the complexities of transitioning towards sustainability, EPE can guide the development and implementation of strategies for sustainable agriculture and rural development. EPE contributes to the broader field of political ecology by uniquely addressing environmental challenges within the context of political-economic structures [33]. By highlighting the unequal distribution of power and considering economic, political, and ecological dynamics as outcomes of this power imbalance, EPE offers insights into the underlying drivers of unsustainability in agricultural systems and suggests pathways for addressing these issues. Moreover, EPE focuses on capitalism as a central focus, considering its contradictions and reliance on finite resources within a finite planet [34]. By exploring the intersection of ecological and economic issues, EPE contributes to a growing awareness of the need to reevaluate current economic paradigms to achieve sustainability in agriculture and rural development.

3.3 Agro-Population Economy

Agronomic agroecology, significantly influenced by agronomy, has emerged as a practical field responding to the environmental and social consequences of industrial agriculture [14]. In light of three interconnected challenges—meeting the demands of a growing global population for increased productivity and revenue to ensure food security, adapting to the impacts of climate change, and mitigating climate change without compromising production [27] —agroecological science faces the critical task of transcending traditional research on farming concepts and methods. The aim is to strike a balance between productivity and environmental considerations, facilitating a seamless transition toward environmental, economic, and social sustainability [14]. Katel et al. [35] shed light on the significant role played by crop import and consumption patterns in a country's food system. They emphasize the importance of understanding these patterns as a key component in addressing the challenges posed by a changing climate. Notably, various management-level adaptation options for agricultural systems have been proposed to tackle anticipated climate change impacts. Among these options are strategies such as soil organic matter management and the application of technologies for water collection and soil moisture retention. Adjustments in planting dates, particularly for spring crops, are also considered under climate change scenarios [36]. Implementing proper rotations, introducing agro-ecological service crops (ASC) as buffer zones or break crops, adopting reduced tillage practices, and managing fertilization can provide valuable services to agro-ecosystems [37]. These practices contribute to weed, pest, and disease management, reduce NO3 leaching, and enhance crop tolerance to drought in low-input and organic farming systems [36]. Further, Yadav et al. [38] found that the incorporation of several cultural practices such as intercropping, cover cropping, biomass harvesting and utilization, rotational grazing, and controlled burning into farming, silviculture, and rangeland management significantly contributes to the control of numerous invasive weed species that impact the biodiversity. Efficient energy use by the agricultural sector is identified as a criterion for sustainable agriculture, providing financial savings, preserving fossil resources, and reducing air pollution [36]. This underscores the importance of aligning agricultural practices with sustainability goals and optimizing resource utilization for long-term environmental and economic benefits.

Agro-population economy recognizes the challenges of meeting the demands of a growing global population while ensuring food security [39]. By integrating agronomic agroecology principles, which emphasize sustainable farming practices, Agro-population economy aims to increase productivity while minimizing environmental impacts. Likewise, agro-population economy acknowledges the need to adapt agricultural systems to the impacts of climate change [40]. This approach emphasizes the importance of implementing adaptive management strategies, such as adjusting planting dates and adopting soil and water management technologies, to maintain agricultural productivity in the face of changing climatic conditions. Further, agro-population economy recognizes the role of agriculture in mitigating climate change by reducing greenhouse gas emissions and enhancing carbon sequestration [41]. This approach promotes the adoption of sustainable agricultural practices, such as agroforestry and conservation agriculture, which contribute to climate change mitigation while maintaining or improving productivity. Similarly, agro-population economy emphasizes the importance of building resilient food systems that can withstand environmental and socio-economic shocks [39]. By diversifying crop rotations, promoting agroecological service crops, and reducing reliance on external inputs, Agro-population economy enhances the resilience of agricultural systems and contributes to food security in rural areas. It contributes to rural development by supporting smallholder farmers and promoting inclusive agricultural growth [42]. By focusing on sustainable intensification strategies, such as agroecological practices and participatory extension services, Agro-population economy fosters economic opportunities and improves livelihoods in rural communities. It integrates environmental sustainability principles into agricultural development strategies [43]. By promoting practices that conserve soil and water resources, reduce chemical inputs, and enhance biodiversity, Agro-population economy ensures the long-term viability of agricultural production systems while preserving ecosystem services.

3.4 Agro-Population Ecology

Agro-population ecology is a scientific discipline situated at the intersection of agriculture and ecology, drawing on principles from natural science. It explores the dynamics of agricultural populations, considering various ecological perspectives to understand the relationships between organisms, their environment, and the sustainability of farming systems [14]. Agro-population ecology provides insights into the dynamics of agricultural populations within ecosystems, considering ecological principles such as biodiversity, nutrient cycling, and ecosystem services [44]. By understanding these dynamics, farmers can implement practices that enhance ecosystem health and resilience, leading to sustainable agricultural production. Further, agro-population ecology emphasizes the importance of biodiversity in agricultural systems for enhancing resilience to pests, diseases, and environmental stresses [45]. By promoting diverse crop rotations, intercropping, and habitat management, Agro-population ecology supports the conservation of biodiversity while improving crop productivity and reducing reliance on external inputs. It recognizes the central role of soil health in sustainable agriculture [46]. By adopting practices such as cover cropping, conservation tillage, and organic amendments, Agro-population ecology improves soil fertility, structure, and water retention capacity, leading to increased agricultural productivity and resilience to climate variability. It also promotes efficient resource use in agricultural production systems [47]. By optimizing water, energy, and nutrient use through precision agriculture techniques, Agro-population ecology reduces environmental impacts and enhances the economic viability of farming operations. It recognizes the importance of agroecosystem services such as pollination, pest control, and nutrient cycling in agricultural production [48]. By fostering habitat diversity and enhancing ecosystem connectivity, Agro-population ecology supports the provision of these services, leading to increased agricultural productivity and resilience. It promotes community-based approaches to agricultural development, empowering local farmers and stakeholders to participate in decision-making processes [49]. By fostering social capital and knowledge exchange, Agro-population ecology strengthens rural communities and contributes to sustainable rural development.

4. INTEGRATED ASSESSMENT OF MULTIFUNCTIONAL AGRICULTURAL SYSTEMS

The integrated assessment of agricultural systems demands a comprehensive consideration of various roles, involving the quantification and integration of economic, social, and environmental variables associated with these systems' performance [50]. Achieving objectives aligned with sustainable development relies on the adoption of innovative agro technologies, the (re-)design of agricultural systems, and the implementation of policies related to agriculture, environment, and rural development across different hierarchical levels [51]. To effectively calculate multiple indicators, a multi-criteria analysis and the integration of knowledge from diverse fields, including economics, agronomy, ecology, and social sciences, are essential. This integration encompasses knowledge derived from scientific research as well as local wisdom [50]. Various studies, such as those conducted by Yadav et al. [52,53], provide significant information, models, or insights that allow us to quantify crop production without exerting stress on the environment. A process-based understanding of agro-ecological relationships is crucial for evaluating the performance of agricultural systems and their contributions to sustainable development. However, this assessment needs to strike a balance, offering a certain level of detail while being tailored for seamless integration with other factors and systems [51]. Integrated assessment, a relatively recent addition to agronomic studies, has gained prominence, with research recommending the adoption of integrated assessment and modeling (IAM) as a means to enhance the management of intricate environmental systems [54]. Policies in agriculture, environment, and rural development are urged to align with these goals in a cost-effective and efficient manner, emphasizing the need for a holistic and integrated approach [54].

The assessment of agricultural systems must encompass their contributions to long-term development, requiring an integrated evaluation of their performance across economic, social, and environmental dimensions at various scales, ranging from the field to the regional level [50]. Model-based methods play a key role in translating agronomic knowledge into integrated research. Two commonly encountered methods in literature involve dynamic crop or cropping system models with varying levels of complexity and the generation and utilization of input-output coefficients for agricultural activities [51]. Integrated Assessment Modeling (IAM) is characterized as an interdisciplinary and participatory process that combines, interprets, and communicates knowledge from diverse scientific disciplines, fostering a better understanding of complex phenomena [54]. Agricultural systems worldwide are in a state of constant flux due to factors such as expanding trade blocs, globalization, liberalization, the adoption of novel agro-technologies, evolving societal needs, and the impacts of climate change [54].

5. CONCLUSION

Agro-ecology emerges as a comprehensive multidisciplinary field, delving into a range of ecological processes with a primary focus on the intricate interplay between the environment and agricultural systems. Rooted in the principles of sustainable agriculture, it champions the use of renewable resources, advocates for the preservation of nature and the environment, and encourages the adoption of organic farming practices. The influence of social, ecosystemic, and political ecology stands prominently, shaping and influencing the nuanced processes within the realm of agro-ecology.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Dalgaard, T., Hutchings, N. J., & Porter, J. R. Agroecology, scaling and interdisciplinarity. Agriculture, Ecosystems and Environment. 2003;100(1–3):39–51. Available:https://doi.org/10.1016/S0167-8809(03)00152-X
2. Wezel A, Bellon S, Doré T, Francis C, Vallod D, David C. Agroecology as a science, a movement and a practice. Sustainable Agriculture. 2009;2:27–43. Availavle:https://doi.org/10.1007/978-94-007-0394-0_3
3. Raghavan B, Nardi B, Lovell ST, Norton J, Tomlinson B, Patterson DJ. (2016). Computational agroecology: Sustainable food ecosystem design. Conference on Human Factors in Computing Systems – Proceedings. 2016;07:423–435. Availavle:https://doi.org/10.1145/2851581.2892577
4. Tomich TP, Brodt S, Ferris H, Galt R, Horwath WR, Kebreab E, Leveau JHJ,

Liptzin D, Lubell M, Merel P, Michelmore, R, Rosenstock T, Scow K, Six J, Williams N, Yang L. Agroecology: A review from a global-change perspective. Annual Review of Environment and Resources. 2011;36: 193–222.
Availavle:https://doi.org/10.1146/annurev-environ-012110-121302

5. Gliessman S. Defining Agroecology. Agroecology and Sustainable Food Systems. 2018;42(6): 599–600.
Available:https://doi.org/10.1080/21683565.2018.1432329

6. Wezel Alexander, Herren BG, Kerr RB, Barrios E, Gonçalves ALR, Sinclair F. (2020). Agroecological principles and elements and their implications for transitioning to sustainable food systems. A review. Agronomy for Sustainable Development. 2020;40(6).
Availavle:https://doi.org/10.1007/s13593-020-00646-z

7. Rajbhadari BP. Fundamentals of Sustainable Agriculture and Rural Development. In HICAST Publication; 2015. (Issue February).

8. Adhikari R, Katel S, Chhetri PK, Simkhada P, Chaudhari P, Yadav SPS. Effect of different sources of organic fertilizers on crop growth and yield of cabbage. Journal of Agriculture and Applied Biology. 2023;4(1):83-94.
Availavle:http://dx.doi.org/10.11594/jaab.04.01.09

9. Yadav SPS, Sharma R, Ghimire N, Yadav B. History, presence and perspective of botanical insecticides against insect pests. Advances in Agricultural Entomology. 2022a;49-69.

10. Yadav SPS, Bhattarai S, Ghimire NP, Yadav B. A review on ecology, biology, and management of a detrimental pest, Tuta absoluta (*Lepidoptera: gelechiidae)*. Journal of Agriculture and Applied Biology. 2022b;3(2):77-96.
Available:http://dx.doi.org/10.11594/jaab.03.02.02

11. Karki N, Soti A, Katel S. Bhandari R, Thapa N, Yadav SPS. (2023). Field Efficacy of Different Insecticides Against Fall Armyworm (*Spodoptera frugiperda* JE Smith) in Spring Maize (*Zea mays* L.). Agro Environmental Sustainability. 2023;1(2):93-104.
Available:https://doi.org/10.59983/s2023010202

12. Yadav SPS, Pokhrel S, Poudel A, Devkota S, Katel S, Bhattarai N, Gautam P. Evaluation of different insecticides against Liriomyza sativae (Diptera: Agromyzidae) on cucumber plants. Journal of Agriculture and Food Research. 2024a;15:100987.
Available:https://doi.org/10.1016/j.jafr.2024.100987

13. Katel S, Lamshal BS, Singh Yadav SP, Timsina S, Mandal HR, Kattel S, Adhikari N. Efficacy of different insecticides against the yellow stem borer (Scirpophaga incertulus Walker)(Lepidoptera: Crambidae) in spring rice cultivation. Cogent Food & Agriculture. 2023a; 9(1):2218254.
Available:https://doi.org/10.1080/23311932.2023.2218254

14. Mason RE, White A, Bucini G, Anderzén J, Méndez VE, Merrill SC. (2021). The evolving landscape of agroecological research. Agroecology and Sustainable Food Systems. 2021;45(4):551–591.
Available:https://doi.org/10.1080/21683565.2020.1845275

15. Gliessman SR. Agroecology and Agroecosystems. 2016;43:19–29.
Available:https://doi.org/10.2134/agronmonogr43.c2

16. Yadav SPS, Adhikari R, Bhatta D, Poudel A, Subedi S, Shrestha S, Shrestha J. Initiatives for biodiversity conservation and utilization in crop protection: A strategy for sustainable crop production. Biodiversity and Conservation. 2023a;3*2*(14);4573-4595.
Available:https://doi.org/10.1007/s10531-023-02718-4

17. Yadav SPS, Lahutiya V, Ghimire NP, Yadav B, Paudel P. (2023b). Exploring innovation for sustainable agriculture: A systematic case study of permaculture in Nepal. Heliyon. 2023b; 9(5).
Available:https://doi.org/10.1016/j.heliyon.2023.e15899

18. Gianinazzi S, Gollotte A, Binet MN, van Tuinen D, Redecker D, Wipf D. Agroecology: The key role of arbuscular mycorrhizas in ecosystem services. Mycorrhiza. 2010;20(8): 519–530.
Available:https://doi.org/10.1007/s00572-010-0333-3

19. Yadav SPS, Bhandari S, Bhatta D, Poudel A, Bhattarai S, Yadav P, Oli B. Biochar application: A sustainable approach to improve soil health. Journal of Agriculture and Food Research. 2023c;100498. Available:https://doi.org/10.1016/j.jafr.2023.100498
20. Gliessman S. Agroecology: Growing the roots of resistance. Agroecology and Sustainable Food Systems.2013;37(1):19–31. Available:https://doi.org/10.1080/10440046.2012.736927
21. Yadav SPS, Lahutiya V, Paudel P. A review on the biology, ecology, and management tactics of helicoverpa armigera (*Lepidoptera: noctuidae*). Turkish Journal of Agriculture-Food Science and Technology. 2022c;10(12):2467-2476. Available:https://doi.org/10.24925/turjaf.v10i12.2467-2476.5211
22. Yadav SPS, Sharma R, Ghimire NP, Yadav B. Sterile Insect Technology (SIT) in New World Screwworm. Advances in Agricultural Entomology. AkiNik Publications 2022dl;15-34.
23. Yadav SPS, Bhattarai S, Bhandari S, Ghimire NP, Majhi SK, Mehata DK, Gautam B. Evaluation of host plant resistance against the rice leaf folder (*Cnaphalocrosis medinalis*) and yellow stem borer (*Scirpophaga incertulus*) through genotypic screening of rice. Agrica.2023d;12(1):48-56. Available:https://doi.org/10.5958/2394-448X.2023.00006.8
24. Sharma R, Keval R, Yadav SPS, Yadav B. Screening of pigeonpea [*Cajanus cajan* (L.) mill sp.] against blue butterfly, L. boeticus (L.)(Lepidoptera: Lycaenidae) in long duration pigeonpea genotypes. The Pharma Innovation Journal. 2022;SP-11(9):1511-1514.
25. Craig MPA, Hay C. Ecological Political Socio-Ecological Crisis; 2017.
26. Quastel N. Ecological political economy: towards a strategic-relational approach. Review of Political Economy. 2016;28(3), 336–353. Available:https://doi.org/10.1080/09538259.2016.1145382
27. Raseduzzaman M. Intercropping for enhanced yield stability and food security.2016;3–68. Available:http://stud.epsilon.slu.se/9396/1/raseduzzaman_m_160817.pdf
28. Katel S, Yadav SPSY, Turyasingura B, Mehta A. Salicornia as a salt-tolerant crop: potential for addressing climate change challenges and sustainable agriculture development. Turkish Journal of Food and Agriculture Sciences. 2023b;5(2):55-67. Available:https://doi.org/10.53663/turjfas.1280239
29. Orihuela JC. Assembling participatory Tambopata: Environmentality entrepreneurs and the political economy of nature. Forest policy and Economics. 2017;80:52-62.
30. Anderson CR, Bruil J, Chappell MJ, Kiss C, Pimbert MP. Agroecology now!: Transformations towards more just and sustainable food systems. Springer Nature. 2021;199.
31. Tilzey M. Political ecology, food regimes, and food sovereignty: Crisis, resistance, and resilience. Springer; 2017.
32. Gare A. After neoliberalism: From Eco-Marxism to ecological civilization, Part 2. Capitalism Nature Socialism. 2021;32 (3):43-60.
33. Blaikie P. The political economy of soil erosion in developing countries. Routledge; 2016.
34. López Santillán ÁA. Justice, Nature and the Geography of Difference. Península. 2007;2:161-164.
35. Katel S, Yadav SPS, Khadka A, Karki N, Neupane S. Cereal import and consumption patterns in nepal–analysis of rice, wheat, maize, and millet: a review. RJOAS: Russian Journal of Agricultural and Socio-Economic Sciences. 2023c; 7(139). Available:https://doi.org/10.18551/rjoas.2023-07.03
36. Diacono M, Persiani A, Fiore A, Montemurro F, Canali S. Agro-ecology for potential adaptation of horticultural systems to climate change: Agronomic and energetic performance evaluation. Agronomy. 2017;7(2). Available:https://doi.org/10.3390/agronomy7020035
37. Yadav G, Rai S, Adhikari N, Yadav SPS, Bhattarai S. Efficacy of different doses of NPK on growth and yield of rice bean (Vigna umbellata) in Khadbari, Sankhuwasabha, Nepal. Archives of Agriculture and Environmental Science. 2022e;7(4):488-494.

Available:https://doi.org/10.26832/24566632.2022.070401

38. Yadav SPS, Mehata DK, Pokhrel S, Ghimire NP, Gyawali P, Katel S, Timsina U. Invasive alien plant species (Banmara): Investigating its invasive potential, ecological consequences on biodiversity, and management strategies. Journal of Agriculture and Food Research. 2024b; 101031.
Available:https://doi.org/10.1016/j.jafr.2024.101031
39. Garnett T, Appleby MC, Balmford A, Bateman IJ, Benton TG, Bloomer P, Godfray HCJ. Sustainable intensification in agriculture: Premises and Policies. Science. 2013;341(6141):33-34.
40. Porter JR, Xie L, Challinor AJ, Cochrane K, Howden SM, Iqbal MM, Lobell DB. Food security and food production systems. In Climate Change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press. 2014;485-533.
41. Smith P, Martino Z, Cai D. Agriculture in Climate change: mitigation; 2007.
42. Dixon J, Gulliver A, Gibbon D. Improving farmers' livelihoods in a changing world. FAO/World Bank, Rome and Washington DC; 2001.
43. Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S. Agricultural sustainability and intensive production practices. Nature. 2002;418(6898):671-677.
44. Perfecto I, Vandermeer J, Wright A. Nature's matrix: linking agriculture, biodiversity conservation and food sovereignty. Routledge; 2019.
45. Bommarco R, Kleijn D, Potts SG. Ecological intensification: harnessing ecosystem services for food security. Trends in Ecology & Evolution. 2013;28(4):230-238.
46. Lal R. Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. Science. 2004;304(5677):1623-1627.
47. Foley JA, Ramankutty N, Brauman KA, Cassidy ES, Gerber JS, Johnston M, Zaks DP. Solutions for a cultivated planet. Nature. 2011;478(7369): 337-342.
48. Kremen C, Williams NM, Thorp RW. Crop pollination from native bees at risk from agricultural intensification. Proceedings of the National Academy of Sciences. 2002;99(26): 16812-16816.
49. Pretty JN, Williams S, Toulmin C. Sustainable intensification: Increasing productivity in African food and agricultural systems. Routledge; 2012.
50. Sylvestre D, Lopez-Ridaura S, Barbier JM, Wery J. Prospective and participatory integrated assessment of agricultural systems from farm to regional scales: Comparison of three modeling approaches. Journal of Environmental Management. 2013;129:493–502.
Available:https://doi.org/10.1016/j.jenvman.2013.08.001
51. Van Ittersum MK, Wery J. Integrated assessment of agricultural systems at multiple scales. Scale and Complexity in Plant Systems Research. 2007; 303–317.
Available:https://doi.org/10.1007/1-4020-5906-x_23
52. Yadav SPS, Mehata DK, Bhattarai S, Bhandari S, Ghimire NP, Majhi SK, Bhujel S. Genetic variability of panicle architecture traits in different rice accessions under the Eastern Terai conditions of Nepal. Cogent Food & Agriculture. 2023e;9(1):2238420.
Available:https://doi.org/10.1080/23311932.2023.2238420
53. Yadav SPS, Adhikari R, Paudel P, Shah B., Pokhrel, S., Puri, S., ... & Bhujel, S. Effect of different chemical priming agents on physiological and morphological characteristics of rice (*Oryza sativa* L.). Heliyon. 2023f;9(11).
Available:https://doi.org/10.1016/j.heliyon.2023.e22389
54. Van Ittersum M, Ewert F, Olsson JA, Andersen E, Bezlepkina I, Brouwer F, Donatelli M, Flichman G, Heckelei T, Olsson L, Lansink AO, Rizzoli A, Van Der Wal T, Wery J. Integrated assessment of agricultural and environmental policies – Towards a computerized framework for the

EU (SEAMLESS-IF). Proceedings of the IEMSs 3rd Biennial Meeting, Summit on Environmental Modelling and Software; 2006.

55. Agroecology Europe. Principles of agroecology. A European association for agroecology, European Union, Fondation de France, Fondation Bjorg Bonneterre et Citoyens; 2022.

56. Devereux EJ. Sustainable & innovative agricultural systems in-focus: agroecology. Eco Food Dev; 2021.
Available:https://www.ecofooddev.com/sustainable-innovative-agricultural-systems-in-focus-agroecology/

57. Wojtkowski P. Agroecology; 2012. Available:https://doi.org/10.1007/978-3-319-93209-5

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/113459