REVIEW ARTICLE

One Health and Ecosystem Services in Sustainable Agriculture: Challenges, Opportunities, and Policy Imperatives – A Critical Review

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ABSTRACT

One health approach, a strategy of sustainably balancing and optimizing human, animal, and ecosystem health, provides a serious platform for tackling sustainability issues in agriculture. This One Health model attempts to reduce zoonotic diseases, antimicrobial resistance (AMR), and environmental degradation by increasing food security through ecosystem services, which are the benefits of natural processes (provisioning, regulating, supporting, and cultural services).To analyse synergies between One Health and ecosystem services in agrifood systems, this commentary will rely on post-2015 literature, particularly peer-reviewed studies, and reports published by international organisations, e.g., FAO, WHO, and IPBES. Observational data from sub-Saharan Africa show that the prevalence of AMR is high, with multidrug-resistant bacteria found in 62.9-87.4 % of farming sources in Ethiopia, demonstrating the importance of combined efforts. However, a methodological limitation, including the lack of longitudinal information, hampered rigorous evaluation. Policy recommendations include multisectoral programs of action to enhance resilience, and prevention efforts may have a higher benefit to cost ratio. Agroecological surveillance and innovation may complement the Sustainable Development Goals (SDGs) 2, 3, and 15, with inconsistent evidence on their potential to scale in low- and middle-income countries (LMICs), but more research is needed in longitudinal studies.

Keywords: One health, Ecosystem services, Sustainable agriculture, SDGs, Ecosystem health

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INTRODUCTION

Sustainable agriculture under the threat of climate change and biodiversity loss demands trans-disciplinary responses. One Health (formally introduced by Quadripartite organizations (FAO, WHO, UNEP and WOAH, 2022) is a concept that seeks to integrate human, animal, and ecosystem health into a mutually reinforcing relationship (Zhang *et al*., 2024). This is also applied to ecosystem services, as stipulated in the Millennium Ecosystem Assessment (MA), where about 60 percent of assessed services (15 of 24) are degraded or provided unsustainably, such as freshwater and fisheries (Ahmed *et al.,* 2022). These interdependencies between environmental and health sustainability in agrifood systems describe developments since 2015, including the SDGs and the One Health Joint Plan of Action (2022-2026) (FAO, WHO, UNEP, WOAH, 2022). About one-third of agrifood activities release anthropogenic greenhouse gas emissions, which cause further impacts on the climate (Ogunseitan, 2022). Additionally, six in ten emerging infectious diseases are zoonotic and animal-borne, which may have contributed up to 75 % (Hahn *et al*., 2020). Hence, there is an urgent need to keep our ecosystem sustainable and also healthier. The adoption of intensive agriculture increases soil erosion rates, sometimes surpassing the natural limit of less than 2 Mg ha^{-1} yr^{1}, reaching 22.5 Mg ha^{-1} yr^{1} in certain agricultural landscapes (Steinhoff-Knopp *et al*., 2021).

Combining One Health and ecosystem services enhances resilience, as was the case with pollination by animals, which adds 235-577 billion dollars of value to the world's crop production each year (IPBES, 2016). However, some implementation gaps remain, as 90.9 percent of One Health programs involve a policy and fewer ecological metrics (Milazzo *et al*., 2025). This critical commentary addresses these dynamics by using an evidence-to-policy lens that examines such factors in relation to sustainable evidence, constraints, policy suggestions, and future directions.

The One Health Framework in Agricultural Contexts

In livestock systems with a high burden of zoonoses, One Health assists in cooperation to address risks at the interface itself. Due to the modification of agricultural habitats, zoonotic diseases are estimated to account for 60-75 % of the infectious hazard in Low- and Middle-Income Countries (LMICs) (Hahn *et al*., 2020). The framework can promote antimicrobial governance in settings with high rates of Antimicrobial Resistance (AMR), including 47.6 percent of Escherichia coli isolates resistant to at least three antibiotic classes in poultry in Kenya. Integrated surveillance can be illustrated by the Kenyan Zoonotic Disease Unit, which was established in 2011 but faces certain limitations in achieving particular outcome reductions (Lewnard *et al*., 2024). Systematic reviews show that quantitative assessments cover only 4.83% of One Health operations, with reactive measures strongly favoured after a crisis. In smallholder settings, diversification could help reduce risk, but intensive systems lead to higher AMR, and therefore, 72 % of E. coli from ill chickens are resistant (Out *et al*., 2024). There are gender differences that influence effects, including women being less likely to seek healthcare assistance, which could further underrepresent the problem in terms of agrochemical use, which hampers ecosystem health as well (Dangore *et al.,* 2024). Sometimes, the risk of uncertainty in longitudinal research can overestimate the benefits in heterogeneous agroecologies.

Ecosystem Services as Pillars of Agricultural Sustainability

Agroecosystems dependent on ecosystem services that provide provisioning (food, fiber), regulating (pollination, pest control), supporting (nutrient cycling, soil formation), and even cultural benefits (aesthetic values) (Dinesh, 2022). In 60 percent of evaluated services, soil and water quality degradation is reported to result from unsustainable practices. There is a favoured erosion of crop lands beyond natural levels (<2 Mg ha^{-1} yr^{1}) that will reduce productivity and release nutrients (Steinhoff-Knopp *et al*., 2021).

In fact, pollination by animals (especially insects) boosts crop yields worth 235-577 billion dollars annually worldwide, with 35% of crops made up at the national level (IPBES, 2016). Regulating services such as biological pest control or carbon sequestration are critical; an example is perennial grassland, which offers nutrient cycling and erosion control, thereby limiting degradation (Jothieswaran and Vidhyavathi, 2025). These services also increase through agroecological measures, such as intercropping (Kokkini *et al*. 2025). Cover cropping provides important ecosystem services, such as adaptability across various situations, which significantly improve soil quality and biodiversity (Yousefi *et al*., 2024).

Ecosystem value is emphasized in economic terms, although considerable disparities exist in the methods used to value ecosystem services in LMICs, which have inevitably under-evaluated cultural services and over-valued regulating services. Sustainable agricultural practices and biodiversity conservation practices like Agroforestry, Regenerative Farming, Zero Budget Natural Farming (ZBNF), Permaculture, Conservation Agriculture, Integrated Farming System (IFS), Biodynamic Farming, Silvopasture, Low External Input Sustainable Agriculture (LEISA), Organic Farming, and Natural Farming, and ultimately results in improved quality and health of soil (Diyaolu *et al*., 2024). Conservation farming provides many ecosystem services, which could raise productivity and reduce environmental impacts (Gangadaran *et al.,* 2026).

Synergies and Integration: A Pathway Forward

Enhancing and interlinking One Health with ecosystem services in agriculture necessary to increase the sustainability of the systems (Mwangi, 2022). Synergies can be harnessed through holistic management, linking soil health to reduced zoonotic risks and boosting productivity. It is possible to consider soil microbiomes as a point of convergence, as sustainable practices to scale down AMR spread and enhance nutrient cycling (Hou, 2023). According to estimates, 3 billion USD can be spent on investment in prevention through One Health, with the potential to save up to USD 37 billion each year through zoonotic disease prevention.

The sense of integration increases resilience in agroecological systems, where biodiversity enhances pollination and pest control, resulting in food security. These dimensions, through the Food Systems (Balaji *et al.,* 2025), One Health, and Resilience (FOR) approach, will be able to solve multidimensional problems by considering food system perspectives (Kandpal., 2024). Operationalization is achieved through shared actions, although only one in ten programs with an eventual policy emphasis has ecological integration (Nitzan *et al*., 2023).

Future research should focus on microbiome engineering and subsequent AI-driven surveillance to anticipate risks and perhaps optimize delivery. Irrespective of such uncertainties, transdisciplinary measurement is necessary to quantify synergies and facilitate interdisciplinary integration between health and the environment to achieve net-zero agriculture (Pepin *et al*., 2024).

Empirical Evidence from Case Studies

The advantages of integration are shown in the following case studies. In Tanzania, the HALI Project (2006 to present) uses One Health to control zoonoses in pastoral systems, which includes the surveillance, livelihoods, and effects on the ecosystem, although quantified reductions in pathogens are not described in primary reports; the project builds capacity and approaches interdisciplinary (Mazet *et al*., 2009). More case studies and real-world examples that integrate One Health and Ecosystem Services are mentioned in Table 1.

In Nigeria, One Health strategy investigating the connection between farming and health found that it faces several barriers, including financial constraints and zoonotic risks such as African swine fever (Out *et al*., 2024). Research on AMR carried out in Ethiopia in 2023 indicates that the level of multidrug resistance in agricultural bacteria is low, and this is where gaps in surveillance arise. Legal measures exist to minimize pesticide residues, but non-adherence to safety protocols necessitates the use of protective gear in farming practices to improve the connection with the One Health perspective. These instances show that they can entail risks during the integration process, but they lack data on economic and ecological outcomes (Out *et al*., 2024). The broader literature on African efforts in community engagement reveals deficiencies in impact scalability. Inconsistencies in intervention efficacy highlight methodological bias that popularizes the need for and development of powerful assessment tools (Yopa *et al*., 2023).

Persistent Challenges, Research Gaps, and Future Directions

The integration of One Health and ecosystem services in sustainable agriculture is hindered by complex challenges that limit successful implementation, and it also faces knowledge gaps requiring new research. The presence of poor governance systems and political approaches is among the major obstacles to concerted efforts in the integration of human, animal, and environmental sectors (Yopa *et al*., 2023) (Fig. 1).

This is further accelerated by the lack of adequate human, financial, and logistical capacities and is more apparent in low-and middle-income countries (LMICs) where resources are constraining the implementation of multisectoral approaches. In sub-Saharan Africa, where zoonotic infections

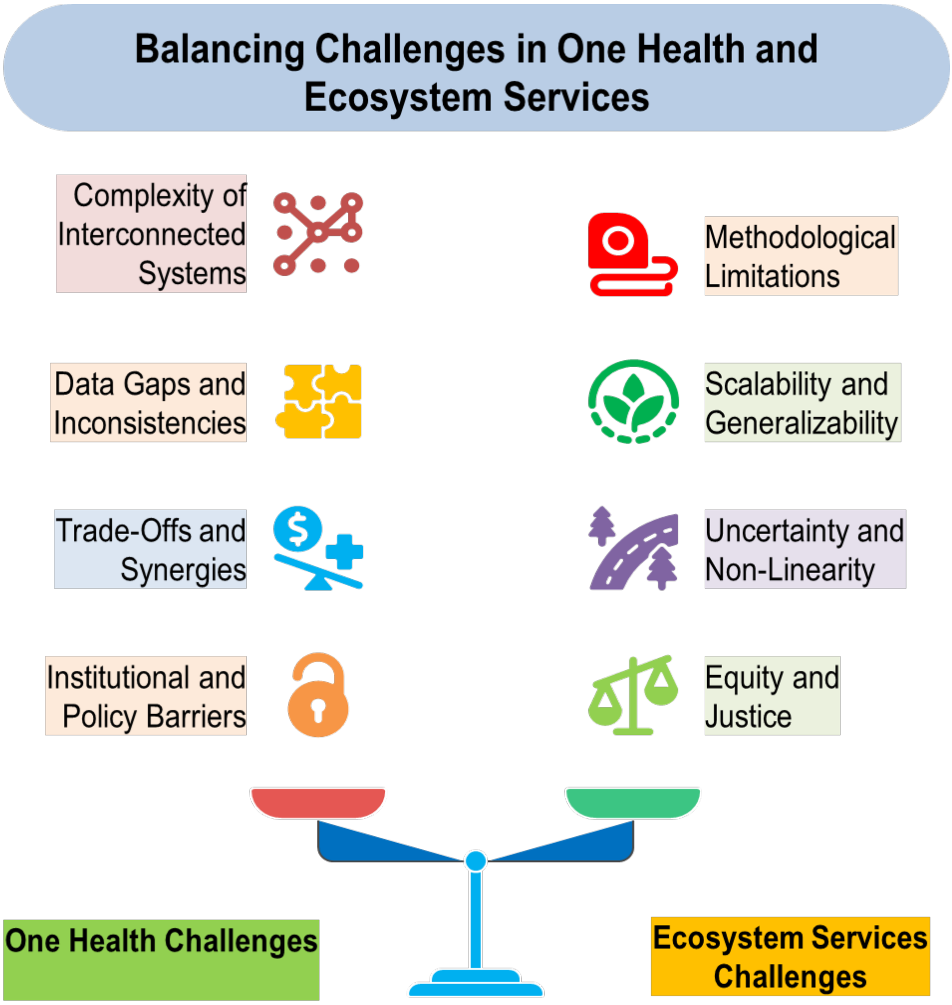
Table 1. Initiatives Integrating One Health & Ecosystem Services in Sustainable Agriculture

Initiative Name	Lead Organization(s)	Region	Approach	Primary Approach	Key Mechanisms	One Health Integration	Ecosystem Services	References
One Health Joint Plan of Action (OHJPA)	FAO, WOAH, WHO, UNEP (Quadripartite)	Global	Core Focus	Policy & Governance	Defines a plan of action for collaboration of various sectors to handle zoonotic diseases, AMR, and food safety, with six actions including surveillance and ecosystem health.	Human, animal, plant, and ecosystem health are deliberately and explicitly integrated as one coordinated policy and capacity building program.	Biodiversity, Disease Regulation, Food Security	FAO, UNEP, WHO, and WOAH. 2022
Agri-Ecosystem Stewardship Initiative (AESI)	Investment Agriculture Foundation (IAF) of BC	Canada (British Columbia)	Indirect	Economic Incentives (PES)	Makes available substantial funds for farmers to carry out activities such as the installation of riparian buffers and the development of pollinator habitats, thereby enhancing natural values of ecosystem and reducing environmental degradation.	Pathogen loads and chemical runoff are minimized allowing bacteria or viruses affecting animals or humans to be eliminated hence human and animal health are supported via better environmental conditions.	Water Purification, Pollination, Carbon Sequestration, Biodiversity	(McEachern et al., 2022)
Sustainable Agriculture Strategy (SAS)	Agriculture and Agri-Food Canada	Canada	Systems-Based	National Policy Framework	Sets the necessary targets for climate-smart agriculture, offers financial support for soil health and biodiversity programs, and encourages the use of nature-friendly methods to lower pollution.	On one hand, it improves the health of agri-ecosystem and on the other, One Health is indirectly supported by alleviating the environmental stress and encouraging resilience.	Soil Formation & Retention, Climate Regulation, Water Regulation	(Gemmill-Herren et al., 2024)
National Mission on Biodiversity and Human Well-Being (NMBHWB)	Govt. of India (Proposed)	India	Explicit	Research & Implementation	Is a comprehensive program to monitor biodiversity, revitalize ecosystems, and use biodiversity as a means of sustainable agriculture and health, with nutrition and climate resilience as the major focus areas.	By linking biodiversity to nutrition security, climate resilience, and zoonotic disease control, the program extends its scope through interdisciplinary research.	Genetic Diversity, Resilience, Biodiversity, Food Security	Bawa *et al.*, (2021)

The PREZODE Initiative	International Research Consortium	Global	Core Focus	Prevention & Research	Emphasizes the modification of agricultural practices and land-use policies to prevent zoonotic emergence, with the drivers of the environment being the core of the changes.	To be more specific, it is dealing with environmental causes that lead to the release of zoonotic viruses in nature by attending the issue thoroughly by scientific research with the help of policy regulations.	Disease Regulation, Biodiversity, Habitat Provision	Peyre *et al.*, (2021)
Soil Health Card Scheme	Ministry of Agriculture & Farmers' Welfare, India	India	Indirect	Precision Agronomy	Offers soil testing and nutrient management advice tailored to the needs of the client, thus encouraging the correct use of fertilizers and the practice of balanced soil remediation.	One way to achieve this goal is to limit the spread of antibiotic resistance genes in the environment by reducing the runoff of manure and chemical inputs thus the integrity of the ecosystem is maintained.	Soil Fertility, Water Quality	Reddy (2018)
Paramparagat Krishi Vikas Yojana (PKVY)	Ministry of Agriculture & Farmers' Welfare, India	India	Direct	Practice-Based Transition	Supports the development of organic farming through the use of cluster-based strategies and financial aid for the process of an independent organization's certification, thus increasing chemical-free agriculture.	One of the main methods to achieve this goal is through the reduction of pesticides in farmers, consumers, and wildlife thereby ensuring the health of soil microbiomes and other organisms overall health.	Soil Health, Biodiversity, Pollination, Water Purification	Reddy (2018)
Livestock Environmental Assessment and Performance (LEAP) Partnership	FAO	Global	Indirect	Metrics & Standards	The stage is set to create a set of standardized metrics to assess livestock supply chains' environmental impact, to use as a reference for adopting sustainable practices.	The program aims to achieve One Health through a range of data-driven improvements that can lead to a reduction in harmful environmental practices thus supporting the health of the planet and One Health principles.	Climate Regulation, Water Use Efficiency, Land Use	Boulay *et al.*, (2021)

HALI Project in Rural Tanzania: Ecosystem Health and Zoonotic Disease Management	UC Davis One Health Institute, Sokoine University of Agriculture	Tanzania (Ruaha Ecosystem)	Transdisciplinary	Research & Surveillance	Measures pathogens in the animals of the concern, which include plague carriers, through the sampling of blood and other bodily fluids and tissues. Testing water for impurities and training locals in isolated pastoral communities to resolve the issues of infectious diseases are part of the activities.	The integration of human, animal, and ecosystem health is done in order to check the zoonotic impacts and resource limitations.	Water Purification, Biodiversity, Habitat Provision, Disease Regulation	Zadoks *et al*., (2017)
Zoonotic Disease Unit (ZDU) in Kenya: AMR and Agricultural Surveillance	Kenyan Government (Ministry of Health and Agriculture/ Livestock)	Kenya	Cross-Sectoral	Surveillance & Coordination	Implements surveillance techniques for diseases that transfer from animals to humans and for AMR by working closely with the human, animal, and environmental health sectors and sharing information and resources among them.	One Health is made functional through the inter-ministerial collaboration which is responsible for disease response and AMR management.	Disease Regulation, Food Security, Biodiversity	Cheptoyek *et al*., (2024)
URBANE Peri-Urban Farming in Lagos, Nigeria: Agroecological Interventions	EU-Funded Consortium (e.g., Waziup e.V., partners in Nigeria)	Nigeria (Lagos State)	Explicit	Research & Agroecology	Includes inquiries as a farming method that has health benefits and examines the implementation of crop and livestock integration along with the dangers of zoonosis	One Healthis employed to investigate and promote agroecological transitions that focus on the production of the land that is good for both nature and humans' health risks are low.	Soil Health, Biodiversity, Pollination, Water Quality	Otu *et al*., (2024)
Rabies Control in Tanzania: Policy Translation from Local Research	Tanzanian Government, WHO, Partners (e.g., University of Glasgow)	Tanzania	Multi-Sectoral	Vaccination & Policy	Starts mass dog vaccination programs and surveillance activities, thus moving from research to national programs for the elimination of rabies by 2030.	The support of One Health for rabies control means the inclusion of human-animal health coordination and community engagement.	Disease Regulation, Biodiversity, Habitat Provision	Sambo *et al*., (2022)

Fig. 1 Challenges in integrating One health and Ecosystem Services in the Sustainable Agriculture



are prevalent and new emerging infectious risks are emerging, governance problems result in vulnerable agrifood systems. The inadequate quantitative assessment of One Health efforts further complicates the promotion, leading to reactive practice rather than proactive (Ogunseitan *et al*., 2022). It also has conflict in prioritization across sectors (Miao *et al*., 2022); agricultural sectors prioritize forms of food production (Kandpal, 2024), and environmental sectors prioritize the protection of biodiversity, which results in the establishment of various research agendas failing to take into consideration interdependencies within ecosystems (Ahmed *et al*., 2023).

The issue of regional disproportion, with the vast majority of One Health research centred on Europe and North America at the expense of efforts in Asia and Africa, where agricultural expansion is growing rapidly, may lead to habitat fragmentation and zoonotic risks (Ahmed *et al*., 2023). Studies indicated that top priorities should be given to One Health and an interdisciplinary approach, including zoonotic illnesses, AMR, food security, and the absence of inclusion of ecosystem services, such as soil security, composed of interrelations of the nutrient flow and health (Miao *et al*., 2022; Swan *et al*., 2024). Soil erosion in agricultural landscapes exceeds 2 Mg ha^{-1} yr^{-1} and demonstrates a high level of soil deterioration, with practically no longitudinal data on microbiome shifts and health outcomes (Boix-Fayos *et al*., 2023). Problems in plant health include insufficient surveillance of phytopathogens and their zoonotic risks, as well as incomplete knowledge of predictive and preventive approaches within the One Health concept (Morris *et al*., 2022). When it comes to balancing human-animal-ecosystem health, moral issues threaten the involvement of disease control rather than the ecological integrity, which ethically addresses the issue of socially responsible zoonotic management (Bovenkerk *et al*., 2018).

Uncertainty persists in quantifying trade-offs, such as between provisioning services (crop yields) and regulating services (pest control), with 60% of ecosystem services degraded due to intensive practices. Gaps in interdisciplinary metrics hinder assessments of biodiversity's role in maintaining complex ecological relationships essential for sustainable agriculture. Furthermore, social-ecological systems theory emphasizes reciprocal links between poverty and health challenges, but empirical studies lack depth in LMICs, where agricultural intensification amplifies zoonotic risks without adequate surveillance (Wilcox *et al*., 2019). There also remains uncertainty in quantifying trade-offs. The lack of interdisciplinary measures interferes with the evaluation of the contribution of biodiversity to the preservation of a complex ecological context needed in sustainable agricultural settings. In addition, social-ecological systems theory highlights the symbiotic relationships between poverty and health challenges, but at the empirical level, it is superficial in LMICs, as intensification of agriculture exacerbates threats posed by zoonotic pandemics that lack appropriate surveillance (Wilcox *et al*., 2019).

The One Health High-Level Expert Panel (OHHLEP) emphasizes the importance of systemic efforts. But it faces some obstacles, such as limited funding and gaps in implementation, and research priorities need to be changed to include consideration of ecosystem health at a holistic level (Mettenleiter *et al*., 2023). According to the Joint Plan of Action, oversights in the research agenda include demanding an annual review of priorities that demonstrate discrepancies between action in traditional and emerging interfaces between plants-animals-human (FAO, UNEP, WHO, and WOAH, 2022). Mixed-analyses on business farms in savanna systems suggest difficulties with welfare measurement in the context of commercial systems and the ability to obtain only qualitative analysis, not metrics that can be applied to a larger sample (Romero *et al*., 2025). In general, the mentioned challenges underscore the need for locally relevant, high-quality research to fill such gaps, while accounting for methodological biases that can overestimate intervention effects across a wide range of agroecologies.

Future possibilities for the use of microbiome-based approaches to reduce the use of chemicals are a move towards sustainable production and an easy way to achieve the One Health objectives. Regional disparities in research priorities also imply an emphasis on operations in Asia and Africa, where the agricultural expansion puts risks on the agenda (Ahmed *et al*., 2023). Lessons learnt from International Livestock Research Institute (ILRI) projects indicate the need to venture into animal-human-ecosystem intersections and to reflect on adaptive approaches. Urban agriculture solutions based on nature can provide co-benefits by enabling climate-proof food system transformations with respect to sustainability (Ebenso *et al*., 2022). Biodiversity should be given policy priority because ecosystem services are dependent on complex relationships (Pitt and Gunn, 2024).

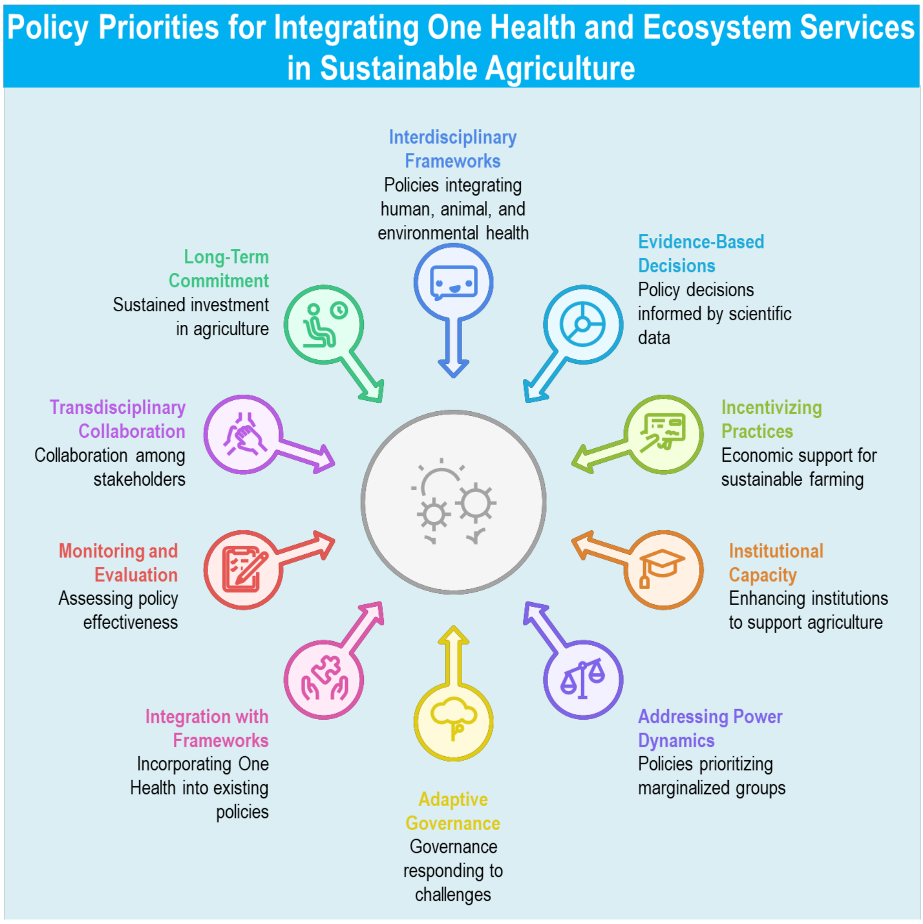
Policy Implications and Future Directions

Multisectoral frameworks are needed, as the policy implications of incorporating One Health and ecosystem services into sustaining agriculture require collaboration and the allocation of resources. The One Health Joint Plan of Action (2022-2026) suggests using multi-sectoral/interdisciplinary strategies to establish healthy agrifood systems, with the implementation of healthy livestock and fish sectors as a foundation of sustainability (FAO, UNEP, WHO, and WOAH, 2022). The political landscape may play a vital role, where poor governance would undermine the progress; policy needs to motivate some cross-sectoral collaboration like payment to services of the environment to prevent its deterioration (Yopa *et al*., 2023; Power *et al*., 2010) (Fig. 2).

Economic valuations point towards advantages, where One Health preventative investments produce returns tenfold their costs, and billion dollars is possible to save per year on agrifood systems scenarios (Zhang *et al*., 2024). However, the incoherent evidence on cost-efficiency in LMICs leads to the development of specific rules to address ethical considerations, ensuring the socially acceptable management of zoonotic diseases (Zhang *et al*., 2024; van Herten *et al*., 2019).

Forward-thinking refers to bringing together Eco Health and One Health to increase attention to the environment and to approach pandemics through systems routes (Zinsstag, 2013). Economic incentives, including zoonotic mitigation, can help reduce the disease burden without sacrificing ecosystem services. In current farming, policies must address GHG emissions through One Health

Fig. 2 Policy priorities for integrating One health and Ecosystem Services in the Sustainable Agriculture



lenses to promote agrifood-resilient systems (Zhang *et al*., 2024). Further studies are needed to assess the added value of cross-sectoral health activities, and the evidence that indicates efficiency increases. The advocacy for sustainable food procurement in health management can make a difference to policy, particularly in the event of ecological crises. Equitable policies must be encouraged, and interdisciplinary initiatives that fund and bridge implementation gaps to achieve sustainable futures (Harvie *et al*., 2009).

CONCLUSION

One Health, as part of a complete and holistic approach that balances human, animal, and ecosystem health, is consistent with the sustainability development goals because it reduces zoonotic risks, which account for 60-75 percent of new diseases like the SARS-CoV-2 virus, and supports resilient agrifood systems. Ecosystem services in intensive agriculture have been degraded by about 60 percent, but pollination alone is estimated to be worth $235-577 billion every year. Systematic assessments provide evidence of the necessity of capacity strengthening, since One Health systems enable improved detection, prevention, and response to sudden outbreaks. Destroying natural forests and increasing agricultural land use led to an increase in zoonotic disease incidence. Hence, policies that address interdependencies are critical, particularly for preventing a public health pandemic. The maintenance of biodiversity is important because it supports complex relationships that sustain ecosystem services and alleviate threats. Interventions should be designed to maximize results across sectors, as the value of One Health lies in reducing diseases in both technical and economic terms. The agricultural ecosystems sustain the necessities, yet trade-offs require movement through complexities to human welfare. The social-ecological systems theory enables greater adoption by encouraging people to become familiar with complexity. An overview of 10 years of development shows that there is still a long way to go, and the key to interdisciplinary success lies in the destruction of those barriers. The role of modern agriculture in food security has to include One Health to reduce poverty and enhance safety. Interconnections are realized through food systems linkages that offer ways to prevent pandemics. This potential can only be realised through rigorous research and cutting-edge policy development, resulting in positive changes in sustainable agriculture.

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1. Govindaraj Kamalam Dinesh: Conceptualization; Writing – Original Draft

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Conflict of interest

The authors declare that they have no conflict of interest. The research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The manuscript has not been submitted for publication in any other journal.

Ethics approval

Not applicable.

Data availability statement

All the necessary data and information to replicate the study are included in the article/supplementary material. If additional data are required, they can be made available upon request. Further inquiries can be directed to the corresponding author/s.

Ethical statement for animal and human data usage

Not applicable for this study

AI tool usage declaration

During the preparation of this work, the author(s) used Grammarly and QuillBot to correct grammatical errors and improve readability, content flow, and language. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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