

# Ecosystem Services, Poverty Alleviation and Land Productivity: A Critical Survey of a Complex “Ménage à Trois”

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**Abstract:** Ecosystem services, like water provision or pollination, may increase both agricultural productivity (that is, the capability of the sector to increase the output in volume and value) and alleviate poverty (for instance, through food provision). In addition, increased agricultural productivity can help alleviate poverty by increasing the profitability of the sector, the income of the farmers, and the rates of return on (natural and other) capital investments. However, those beneficial effects come at the cost of (possible) deterioration of existing ESs, that, *prima facie*, represented the main driver for the generation of benefits. This paper, therefore, identifies and discusses the implications (and possible remedies) of a critical issue that, to our knowledge, is under-studied in an integrated context and methodological approach.

**Keywords:** ecosystem services; poverty alleviation; agricultural productivity; trade-offs; ecosystem services depletion due to increased agricultural productivity and alleviated poverty; integrated assessment



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## 1. Introduction

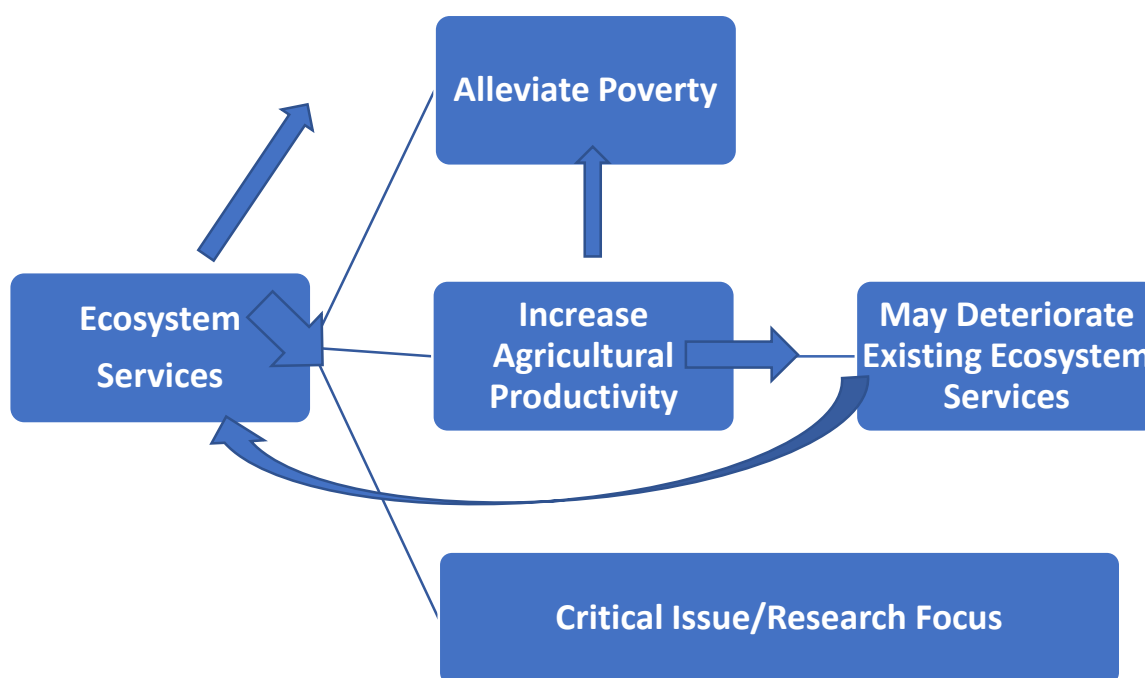
Ecosystem services (ESs) are “the benefits that ecosystems provide to humans” (MEA, 2005). Among their many benefits, ESs maintain agricultural productivity and help alleviate poverty. Many important ESs, in fact, support agricultural productivity. Ecosystem processes can provide supporting services, such as pollination, pest control, genetic diversity for future agricultural use, soil conservation, and regulation of soil fertility, nutrient cycling, and water. In addition, agricultural systems can be managed to promote biodiversity and enhance carbon sequestration. Promoting healthy ecosystem functioning ensures the resilience of agriculture as it intensifies to cope with the stress of growing demand for food production and increased agricultural productivity [1–3].

This is a very important benefit because agriculture is a well-known driver contributing to income growth and poverty reduction in both developed and developing countries by creating jobs and providing food at reasonable prices [4]. Agriculture provides food, income, and jobs, and can therefore be an engine of growth in agriculture-dominated countries and an effective tool for poverty reduction. It can therefore support development by enabling a sustainable transfer of resources from agriculture to the rest of the economy, including through the provision of capital to other sectors. Moreover, agriculture is an important component of the livelihoods of many poor people, and it is often argued that agricultural productivity is fundamental to poverty reduction [5]. For example, Matsuyama [6] showed that improvements in agricultural productivity have probably been the single most important factor in the rate and extent of poverty reduction over the last 40 years.

Although agriculture can contribute to poverty alleviation through the increased productivity ESs provide, it can also be a source of drawbacks, including loss of biodiversity, pollution by agrochemicals, sedimentation of water bodies, poisoning of non-target organisms by pesticides, and emission of greenhouse gases and pollutants. The Millennium

Ecosystem Assessment, for instance, recognized that the production or harvest of crops, livestock, and fish stocks has increased tremendously over the past 50 years, while the ability of these ecosystems to regulate pests, control erosion, and maintain soil health has declined.

There is thus a fundamental intertemporal trade-off between the present (or short-term) benefits accruing to the agricultural sector in reducing poverty, and the future (or longer-term) costs to ESs. In fact, The ES virtual cycle, spurred with the objective of reducing poverty and increasing agricultural productivity (which in turn contributes to poverty reduction) may have a fundamental drawback: increased agricultural productivity can jeopardize ESs, especially support and regulatory services, and reduce their potential. This is illustrated in a conceptual model, synthesized in Figure 1.



**Figure 1.** The trade-offs in the “ménage à trois” among ESs, poverty alleviation, and agricultural productivity.

The conceptual model, the fundamental links and intertemporal trade-offs of which are conveyed in Figure 1, mostly derives from economic theory-based thinking and intuition. If economics is “the science of choice in a context of scarce resources” [7], then the understanding of the management of scarcity is at the very heart of economic science. In a context of choice within the boundaries of scarcity, every possible solution and scenario implies trade-offs between the advantage of choice (benefit) and the disadvantage of giving up (cost). In this perspective, economic agents always face (present and/or intertemporal) trade-offs when confronted with a choice in a context of scarce resources. Applying the very fundamental economic conceptual scheme to the problem at hand, it is very intuitive to highlight that, given that ESs are exhaustible, scarce resources, the present economic and social benefits they accrue (e.g., poverty alleviation), come at the (future) cost of resource depletion. At the same time, such fundamental trade-offs might be paradoxically exacerbated by the positive impacts on poverty alleviation and increasing land productivity, which together may eventually contribute to and speed up ES depletion and exhaustion. This generates fundamental, intertemporal trade-offs that have stimulated the present need for researching, understanding, and critically addressing the state of the current literature on the issue.

Ecosystem services like water provision or pollination may in fact increase both agricultural productivity (that is, the capability of the sector to increase the output in

volume and value) and alleviate poverty (for instance, through food provision). In addition, increased agricultural productivity can help alleviate poverty by increasing the profitability of the sector, the income of the farmers, and the rates of return on (natural and other) capital investments. However, those beneficial effects come at the cost of (possible) deterioration of existing ESs, that, *prima facie*, represented the main driver for the generation of benefits. This paper, therefore, identifies and discusses the implications (and possible remedies) of a critical issue that, to our knowledge, is under-studied in an integrated context, as represented in Figure 1.

The main research questions critically address the issues and questions, such as: is the “ménage à trois” among ESs, poverty alleviation, and agricultural productivity (important variables for sustainable development) a sustainable relationship? What are the trade-offs, challenges, and limitations? What possible remedies can facilitate the “ménage à trois”?

The research questions are methodologically explored through a survey of the seminal literature on the links among ESs, agricultural productivity, and poverty alleviation and on the link between agriculture and ES depletion. The “ménage à trois” is addressed through a critical discussion that highlights gaps and further research to undertake.

This paper is organized as follows. Section 2 presents a critical review of the literature on the link between ESs and poverty alleviation and the link between ESs and agricultural productivity. Section 3 points out critical issues of the ménage à trois. Section 4 discusses selected remedies and further research through concluding remarks.

## 2. A Narrative Review of the Literature

This section revises and synthesizes the bulk of the literature and findings on (1) the link between ESs and poverty alleviation; (2) the link between ESs and agricultural productivity increases; and (3) the negative impacts of agricultural productivity on ESs. The narrative review methodology is used. This method aims at summarizing works on a particular topic, without attempting to generalize from what is reviewed and with a view to provide a qualitative interpretation of prior knowledge, following an unstructured approach. This type of review method (as an alternative to descriptive and systematic reviews) usefully gathers a critical number of studies to provide a comprehensive background of knowledge that inspires research ideas by highlighting gaps in knowledge and research. In this way, narrative reviews can stimulate scholars to better define and refine research focus and hypotheses [8].

The narrative literature review method also follows the procedural steps listed by Templier and Paré [9]. Those are:

1. Formulating the research question(s) and objective(s): the survey aims at finding research and relevant literature on intertemporal trade-offs between the present benefits accruing to the agricultural sector in reducing poverty and the future costs to ESs. For this reason, it is important to scrutinize how scholars have approached the topic, what perspectives and methodologies were used, and results.
2. Searching the extant literature and screening for inclusion: the search was concentrated on relevant results that were representative of most other works in the topics at hand. For this reason, we have searched on Google Scholar and selected papers published in peer-reviewed international journals. The keywords used for the Google Scholar search were either a combination of two key concepts (i.e., “ecosystem services and poverty alleviation”; “ecosystem services and land productivity; land productivity and poverty alleviation”), the three variables affecting the ménage à trois, or a combination of a key concepts and a specific ecosystem service (i.e., pest control, water retention, carbon sequestration).
3. Screening for inclusion and assessing the quality of primary studies: Given the scarcity of information, we have tried to include all possible relevant information, with a view to defining a qualitative standard. In this perspective, we have excluded all papers that dealt with case studies and empirical illustrations and focused on papers that provided a theoretical framework and/or a survey of existing frameworks/approaches

and were published in English-language peer-reviewed journals after 2010. Further refinements had to do with reading the papers and the final selection of the studies in order to understand whether the selected studies were sufficient for validity and to tackle major biases.

4. Extracting, analyzing, and presenting information. The selected studies are organized and presented in their descriptive content in tables that synthesize three main indicators: the objective of the research, adopted methodology, and the main results for the literature on ESs and poverty alleviation (Table 1). For the link between ESs and agriculture productivity, the criteria inspiring the data synthesis and presentation were different. Table 2 contains a selection of specific ESs, the presentation of the most relevant studies, and a short description of the impact of ESs on agricultural productivity.

#### *2.1. Ecosystem Services and Poverty Alleviation*

Table 1 reports a selection of papers on the link between ESs and poverty alleviation. The papers were searched for on Google Scholar, using very generalist keywords like “poverty alleviation and ecosystem services” summarized in the Table.

#### *2.2. Ecosystem Services and Agricultural Productivity*

Table 2 reports the core results from a selection of papers that explore the link between ESs and agricultural productivity. The studies were scanned through a research criterion that first looked for the link between agricultural productivity and specific ESs (like pest control, water availability, and so on). Most studies date right after the seminal MEA assessment report that has spurred research on ESs and their impacts (including on agricultural activities).

**Table 1.** Selected Studies on Ecosystem Services and Poverty Alleviation.

Study	Objective	Method	Main Findings
[10]	Application of the ES framework for understanding the impacts of development interventions.	The paper identifies four problems, using examples from coastal ES areas in developing countries: (1) different beneficiaries from different ESs; winners and losers when ESs change. (2) dynamic mechanisms of access (3) context and needs of individuals determine how ESs contribute to well-being. (4) limits of aggregate analyses that may neglect crucial mechanisms for poverty reduction, such as cash-based livelihoods.	Payments for ecosystem services (PESs) implicitly recognize the unequal distribution of costs and benefits of conserving ESs through financial compensation from “winners” to “losers”. Developing ES interventions that contribute to poverty alleviation requires a nuanced analysis that focuses on who derives what benefits from ecosystems and how those benefits contribute to the well-being of the poorest. Existing tools, such as stakeholder analysis and equity weighting, can improve the relevance of ES research to poverty reduction.
[11]	Analysis of the conceptual framework that can better support research at the interface between ES and poverty reduction.	Review framework synthesis of existing research on poverty–environment linkages (links among ES provision, condition determinants and dynamics of poverty, and political economy factors).	Synthesis of key contributions/gaps/lessons from a total of nine conceptual frameworks (differentiated for several indicators, such as social differentiation, access constraints/total availability of ESs, categories of services, production pathways, and contribution to poverty reduction. Recognition of the limitations of ESs for poverty reduction given that ESs tend to be associated with poverty prevention rather than poverty reduction.
[12]	Using the concept of ES to study poverty–ecosystem interactions.	Household surveys for assessing multidimensional poverty in six villages (57 households) in the region. Semi-structured interviews with household heads to identify drivers of ecosystem change. Identify linkages between ESs and basic human needs to find interventions to improve the livelihoods of the rural poor.	Highlighting the ecosystem-based approach to improve the livelihoods of the rural poor.
[13]	Define a conceptual framework to understand the ES/poverty nexus.		The framework can be used as a thinking tool, as a basis for multidisciplinary, policy-relevant research, and as an application to support practitioners in the pursuit of the shared policy goals of environmental sustainability and poverty reduction.
[14]	Identify the current state of knowledge on the extent and nature of linkages between ESs and poverty reduction and guide the future research agenda.	Overview of the empirical evidence and state of knowledge of the mechanisms linking ESs and poverty reduction.	Research has largely focused on utilities and on only two dimensions of poverty: income and assets and food security and nutrition. Most work contributes to the accumulating evidence that ESs promote well-being and perhaps prevent people from becoming poorer, but it provides little evidence of their contribution to poverty reduction and eradication. Few papers provide a context that allows a thorough understanding of poverty reduction (positive/negative).

Table 1. Cont.

Study	Objective	Method	Main Findings
[15]	Analysis of trade-offs related to the allocation of ESs via social norms used to justify why ecosystem governance should prioritize poverty alleviation.	Critical review of the empirical literature on social trade-offs in ES governance to identify the dominant notions of justice that inform scholarly evaluations of current practice.	Empirical studies present certain notions of justice as desirable benchmarks for ES governance, but rarely attempt to explain the precise meaning of these notions or what makes them desirable. The ES account of justice would benefit from more conceptual clarity and a fuller exploration of the various aspects of justice.
[16]	Analyze trade-offs between environmental protection and poverty alleviation by introducing ecosystem service payment programs (PESs) to achieve both goals simultaneously.	Combining quantitative regression tools and narrative reviews to synthesize the results of 56 PES programs from 69 studies conducted on 3 different continents to identify the key factors that determine the performance of PES programs.	Monitoring program activities to ensure that ecosystem services are delivered and providing sufficient payments to ecosystem service providers improves program performance from PESs. Programs lose effectiveness as they age, raising concerns about the long-term viability of PES programs. The importance of ex ante assessments of potential PES sites and prior engagement with ES providers. This allows program developers to identify stakeholder interests in order to design cost-effective programs that address local needs and interests.
[17]	Analysis of governance, ecosystem health/services and poverty reduction/livelihoods, with a focus on renewable natural resource management in low/middle income countries.	Systematic mapping of the literature and a thematic synthesis to identify how governance mediates the relationships between ESs and poverty reduction.	Very little literature, little evidence of interdisciplinary inquiry. Local and inclusive governance increases the potential ESs and livelihoods. A variety of governance structures and systems makes it difficult to trace causality, although such diversity creates opportunities for improved governance, ecosystem health, and livelihoods. Appropriate and adequate incentives are needed for governance to mediate positive linkages between ESs and poverty reduction.

**Table 2.** Selected Studies on Ecosystem Services and Agricultural Productivity.

Ecosystem Service	Selected Study	Impact on Agricultural Productivity
Biological pest control	[18–22]	Studies quantify the ecological impact of the ES reducing the need for pesticides, since selected species already existing in nature can neutralize the impact of agricultural parasites, therefore avoiding/ minimizing the use of industrial, often toxic, anti-parasitic substances. Studies also quantify in monetary terms the economic value of the ES.
Pollination	[23–25]	The studies quantify the amount of plant species and agricultural crop productions that rely on pollination by wild animals and domesticated honeybees. Studies also quantify in monetary terms the economic value of the ES.
Water supply (in quality and quantity)	[26–31]	Studies describe the impacts of ESs on water supply (quality and quantity) for agricultural productivity and the different effects ESs have across different cultivars, agricultural crops, and geographical areas.
Landscape conservation	[20,23,32–38]	Studies analyze the impact of ESs on landscape conservation and the impact of landscape on the capability of ESs to correctly produce their beneficial activities in different agronomic landscapes.
Soil structure and fertility	[19,39]	Studies describe the ecological impacts of ESs (providing bacteria, macrofauna, and fungi) through aeration and other beneficial practices to soil structure and fertility.

### 3. A Complex “Ménage à Trois”: Analyzing Trade-Offs

This section highlights selected critical issues concerning agricultural “services”, poverty, ESs, and the trade-offs involved. Since the seminal work of Dale and Polasky [40] and Power [41], it has been pointed out that there are costs (on ES provision) associated with increasing agricultural productivity. These costs may offset the positive effects of ESs. Thus, there is an underlying trade-off, often in the form of externalities, that needs to be evaluated and accounted for. Trade-offs are often multidimensional. This requires a thorough assessment of the:

- (1) spatial implications of the trade-off (are the costs and benefits found in the same geographic area or not?);
- (2) temporal implications of the trade-off (how are the costs and benefits distributed over time? Do they accrue simultaneously or not?);
- (3) nature and the (economic and ecologic) quantitative and qualitative value of the trade-offs.
- (4) the possibility that the impacts are reversible (or not).

This analysis is critical in defining how to properly manage trade-offs, as management and policy choices often aim at designing strategies for the immediate provision of a good or service at the expense of the same or another ecosystem service to be provided in the future, or in another geographical location, spatially distant.

With respect to points (1) and (2) it is important to stress that ES flows for agriculture differ in quality and quantity. This may affect farmers’ incentives to protect ecosystem services. Farmers have a direct incentive to protect ESs like soil fertility and retention, pollination, and pest control because these services are directly benefitting the farm and the fields and because the farmers can quickly earn and value the direct benefits provided by ESs. However, on a larger scale, these benefits are likely to be extended not only to the farmer providing the resource, but also to other stakeholders, including other farmers. The example described by Zhang et al. [38] considers the case of a farmer restoring the habitat complexity on his farm. Such an investment may increase pollination and pest control services to his neighbors and to himself. In this perspective, neighbors benefit from these

services without having to bear the related cost, such as for instance giving up land on which they would otherwise implement farm activities and generate profits and income. Greater landscape complexity can be interpreted as a shared resource. A farmer might give up on and drop the incentive to invest in the optimal amount of habitat if he accepts the impact on his neighbors' land (for free).

Another complex dimension refers to the non-linear interdependency of ESs on one another. In agriculture, for instance, the problem is usually seen as a trade-off between services—i.e., the production of agricultural goods such as food, fiber, or bioenergy—and regulatory services such as water purification, soil conservation, or carbon sequestration [19]. A study by FAO [33] suggests that increasing agricultural intensification will affect many ESs that are beneficial to agricultural productivity. Projections suggest that by 2030, 80 percent of crop production growth in developing countries will be due to intensification. Loss of aboveground carbon through deforestation or other land clearing (caused by agricultural intensification) can reduce soil carbon stocks. Studies estimate the loss to be 30–50% over 50–100 years in temperate regions and 50–75% over 20–50 years in the tropics [42]. Therefore, the more intensive the production of agricultural products, the more the use of ESs and the more carbon sequestration or soil conservation may be negatively affected.

As the temporal or spatial scale increases, trade-offs become more uncertain, complex, and difficult to address, manage, and solve. Biophysical and socioeconomic differences also lead to trade-offs, as each hectare of a particular habitat produces a particular ES that does not have the same value everywhere. In natural ecosystems, for example, habitat quality, unit size, and spatial arrangement are likely to influence the services provided by ecosystems. In addition, the values of marketable and nonmarketable goods and services produced by an ES change according to different biophysical and socioeconomic drivers.

Without information on the drivers that affect the quantity and value of ESs, (point (3)), it is very difficult to design and develop policies, incentives, or payment systems that can increase the provision of these services and/or improve and make them more efficient. When ESs are inputs to agricultural production, they are mostly provided by nature “for free”, at zero monetary cost. In such a perspective, the supply of natural resources used as inputs to production is not so great that it exceeds the quantity that could be demanded at any price. Such resources may indeed be depleted and/or over-harvested or exploited. This does not happen because supply is much greater than demand, as in the water–diamond paradox. It is because the production input is supplied directly by nature, not by a profit-maximizing corporation. Again, it is simply that the economic exploitation of such a resource provides many (private) benefits without (private) costs [43]. Therefore, the “real” value of the impact of ESs in alleviating poverty and increasing agricultural productivity might not be correctly assessed and computed.

The fourth point addresses the issue that agricultural activities may generate direct negative impacts on the quality of natural habitats, biodiversity, and climate change. Those impacts can be irreversible. For instance, the use of nitrogen- and phosphorus-containing fertilizers has greatly increased the amount of new nitrogen and phosphorus in the biosphere and has had complex effects on natural ecosystems by reaching groundwater and surface waters, with potentially negative consequences for human health, the environment, and the future provision of ESs. Pesticide use negatively impacts biodiversity, and pesticide residues in surface and groundwater affect water supplies. Agricultural activities can negatively affect plant community biodiversity, root structure, plant litter production, the extent and timing of plant cover, and soil biotic community composition, all of which affect water infiltration and storage in the soil. Protection of groundwater and surface waters may be threatened by intensification as nutrients, agrochemicals, and dissolved salts increase [40]. In addition, agricultural activities are estimated to be responsible for 12–14% of global anthropogenic greenhouse gas emissions. Land-use change is the second largest global cause of CO<sub>2</sub> emissions, and some of this change is caused by conversion to agriculture [44]. About 49 percent of global anthropogenic emissions of methane (CH<sub>4</sub>)



and 66 percent of global annual emissions of nitrous oxide (N<sub>2</sub>O), both greenhouse gasses, are attributed to agriculture [26].

At the same time, alleviation of poverty through agriculture increases the wealth and income of those populations relying on agricultural production and improves their lifestyle. This, in turn, changes production and consumption habits (increased per capita meat consumption) through changes in the preference structure of consumers, increase in budget constraints, and improvements in production technologies and methods (such as increased mechanization or land use), exacerbating the irreversible dimension of the trade-offs.

#### 4. Concluding Remarks

The purpose of this paper is to highlight trade-offs when ESs contribute to alleviating poverty and increasing agricultural productivity. An important finding is that there is no analytical research, with some exceptions (i.e., [45]), nor a corpus of analytical studies on the fundamental intertemporal “ménage à trois”.

In this perspective, this paper wishes to stimulate critical debate and to highlight a gap in research, which aims at an integrated assessment of possible negative drawbacks generated by the positive impacts of ESs on poverty and agricultural productivity. In this perspective, instruments like ARIES (Artificial Intelligence for Ecosystem Services) [46] and InVest (Integrated Valuation of Ecosystem Services and Tradeoffs) [47] may help to provide an integrated assessment.

The suggestion of remedies to the highlighted problems is well beyond the purposes of this paper. However, some can be listed. First of all, learning how to strengthen the ecosystem linkages that encourage agro-ecosystems to deliver goods and services represents an important challenge. In this perspective, proper agricultural management and agro-ecological activities can increase soil protection and reduce erosion and runoff. Tillage, soil, and other conservation measures could conserve and improve the fertility of soil and minimize the loss of nutrients that are required by crop cultivation. Cover crops facilitate on-farm retention of soil and nutrients between crop cycles, while hedgerows and riparian vegetation may decrease erosion and runoff among fields. The incorporation of crop residues can keep soil organic matter, which promotes water retention and nutrient provision to crops. The introduction of protected areas may help in providing and keeping ES flows to agriculture. Cultivation practices should shift from dependency on non-renewable inputs and from chemical-based intensification to forms of biological intensification and other emerging technologies that, incorporating scientific principles of ecosystem management into farming practices, draw on biodiversity and natural resources to increase the productivity of ecosystem services.

Practices that reflect the shift from traditional inputs based on agrochemicals to biological intensification should focus on a plethora of activities, for instance (1) ensuring diversity and abundance of pollination services; (2) diversifying horticultural crops; (3) creating pest-suppressive conditions; and (4) supporting biodiversity.

In addition, investments by governments and other stakeholders in supporting the practices that sustain ecosystem services and provide incentives need to be implemented, for instance, strengthening microcredit activities for farmers in developing countries, because these practices represent a fundamental key to the success of the measures, as listed previously. Investments should also focus on the creation of true markets for water, which are scarce [48] and the economic value of hydrological ESs to agriculture is only partially valued and accounted for in most estimates.

Finally, in our opinion, and preliminary to all the discussed remedies, is the need to address further research to the design and application of integrated assessment analysis and tools. The complexity of the ménage à trois among ESs, poverty alleviation, and agricultural productivity enhancements from ESs lies in the paradox that ESs *prima facie* present positive stimuli that can bounce back as disruptive for the ecosystems in a second stage. To understand, capture, and measure the criticalities of that important (positive and

negative) nexus needs a lot of investigation. Much work has to be done across those lines to fill this knowledge gap.

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