CIAT
International Center for Tropical Agriculture
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CIAT's Ecosystem Services Strategic Initiative

Ecosystem Action

Ecosystem Action:

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CIAT Publication No. 406
Press run: 100
Printed in Colombia
September 2015

Quintero M; Sachet E; Wyckhuys K; Cordingley J; Kizito F; Cruz-García GS; Winowiecki L; Rajasekharan M; Valbuena D; Chirinda N. 2015. Ecosystem Action – CIAT's Ecosystem Services Strategic Initiative. Cali, CO: Centro Internacional de Agricultura Tropical (CIAT). 30 p.

The International Center for Tropical Agriculture (CIAT) – a member of the CGIAR Consortium – develops technologies, innovative methods, and new knowledge that better enable farmers, especially smallholders, to make agriculture eco-efficient – that is, competitive and profitable as well as sustainable and resilient. Eco-efficient agriculture reduces hunger and poverty, improves human nutrition, and offers solutions to environmental degradation and climate change in the tropics. Headquartered near Cali, Colombia, CIAT conducts research for development in tropical regions of Latin America, Africa, and Asia.
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Ecosystem Action is one of three global initiatives created under CIAT's new strategy for the period 2014–2020. The aim of these forward-looking, collaborative endeavors is to open new avenues for enhancing the development impact of CGIAR research.

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Introduction

Over the past decade, research and political sectors globally have focused their efforts on understanding the socioeconomic and environmental implications of the increasing loss of ecosystem services in degrading/degraded landscapes (Nkonya et al., 2011). Recognition of the implications of ecosystem degradation and biodiversity loss, experienced in the last decades, has led to more investments in research for understanding and demonstrating these implications, which is reflected in the increase in published research over the past few years (Figure 1). Some of these studies have already provided estimates on the importance of ecosystem services for poor people. Accordingly, The Economics of Ecosystems and Biodiversity initiative (TEEB, 2014) and ten Brink et al. (2011) estimated that **natural capital accounts for 40% to 90% of what is referred to as "Gross Domestic Product (GDP) of the poor."**

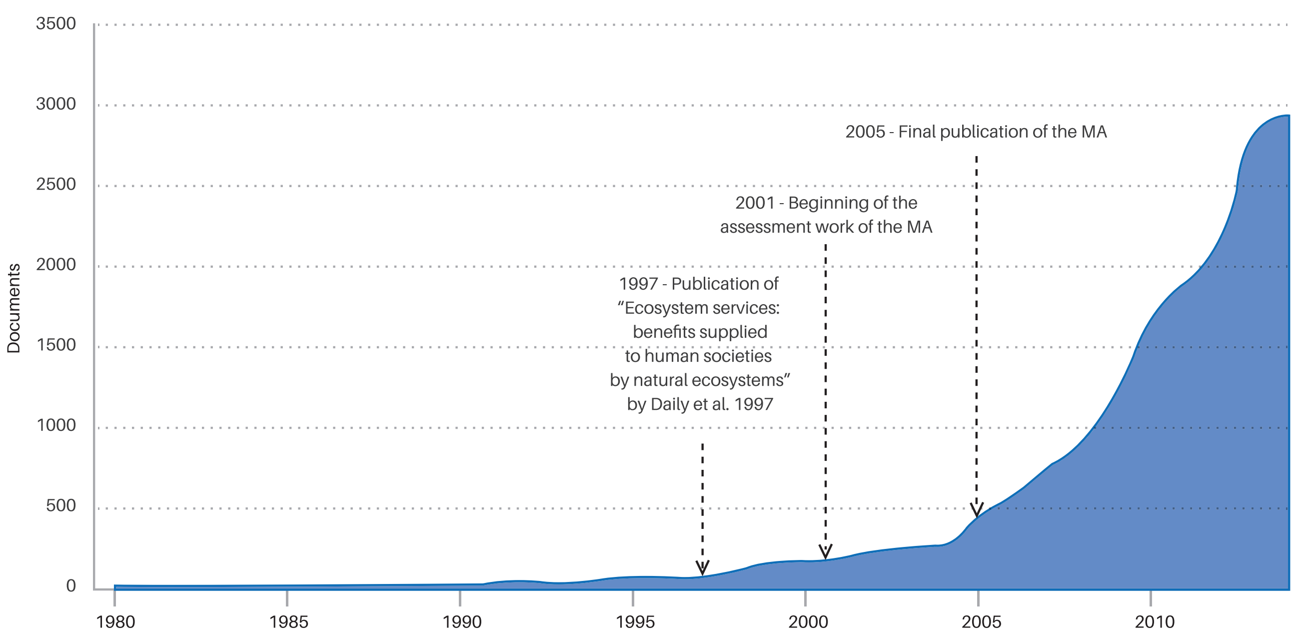

Figure 1. Number of publications with ecosystem services in title, abstract, and keywords in Scopus. (Millennium Ecosystem Assessment - MA).

Higher recognition of the implications of losing ecosystem services (ES) is also importantly demonstrated with the establishment of the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), which will gather evidence to support policy decisions on ecosystem management and restoration. The development of such a platform indicates that ecosystem services are receiving, and will receive, greater scientific and political attention, just as climate change has received through the creation of the Intergovernmental Panel on Climate Change (IPCC). Similarly, The Economics of Ecosystems and Biodiversity (TEEB) for Agriculture and Food initiative, launched in 2014, aims to review the economic interdependences between agriculture and natural ecosystems, with a focus on three areas: benefits of ecosystem services to agricultural productivity, impacts of agricultural production on ecosystem services, and the role of smallholder farmers in the provision of ES.

Likewise, *CIAT Strategy 2014-2020*[1] is guided by a vision of eco-efficient agriculture with three main objectives:

1. Make affordable high-quality food readily available to the rural and urban poor by boosting agricultural productivity and enhancing the nutritional quality of staple crops.
2. Promote rural income growth by making smallholder agriculture more competitive and market oriented through improvements in agricultural value chains.
3. Provide the means to make a more intensive and competitive agriculture both environmentally sustainable and climate smart.

Accomplishing these objectives requires integration of the capacities of CIAT's three research areas – Agrobiodiversity; Decision and Policy Analysis (DAPA); and Soils. Correspondingly, CIAT's strategic initiatives need to be implemented synergistically so that they can contribute to the overall goal of its strategy. The strategic initiatives[2] are:

- *Ecosystem Action* – Renewing rural landscapes for improved food security and livelihoods. It aims to enhance ecosystem services in agricultural landscapes as a means to improve the livelihoods and well-being of the rural poor.
- *LivestockPlus* – Fast-tracking tropical forages for twin-win agricultural systems. The initiative promotes forage-based livestock production to mitigate greenhouse gas (GHG) emissions, while improving the livelihoods of the rural poor through sustainable intensification of meat and milk production.
- *FoodLens* – Sharpening the focus of research on sustainable food systems. It develops more sustainable food systems that serve the needs of a rapidly urbanizing world.

This recent global focus on the need for evidence on the links between agriculture, livelihoods, and ecosystem services, particularly in poor rural areas, and CIAT's new strategic directions place the Center in a strong position to contribute to the global agenda for ecosystem services research for development and policy making.

Consequently, this document aims to (1) introduce CIAT's recent and current research related to ecosystem services in order to evaluate the potential and the perspectives of CIAT's ecosystem services research; (2) communicate in a consistent and integrated manner CIAT's current research on ecosystem services to the different research areas of the Center and to external stakeholders; (3) prompt dialogue with other research areas of CIAT to seek opportunities for mainstreaming ES in their research activities (e.g., activities oriented to designing sustainable intensification systems, water harvesting projects, improvement of crops and agronomic practices to close yield gaps, among others); and (4) introduce the research agenda for the Ecosystem Action Strategic Initiative oriented to respond to some of the knowledge gaps remaining in the field of ecosystem services for agriculture.

[1] CIAT Strategy 2014-2020 is available at: http://ow.ly/ugcuV

[2] More information at http://annualreport2014.ciat.cgiar.org/#latest-news

Ecosystem Services: Definitions and Approaches

Over the past decade, the ecosystem services (ES) concept has gained importance in the research and political agenda. During conceptualization, many frameworks have been proposed: (1) in the early 1970s, the concept of ecosystem functions was used to highlight societal dependence on ecosystems; (2) in the 1990s, the scientific literature mainstreamed ES into sustainable development research; and (3) by the end of the 1990s, ES (more as environmental services)[3] had settled into the political agenda promoting 'payment for environmental services' schemes (Kill, 2014). These trends, presented during the past years, have come along with diverse frameworks for ecosystem services. Some of the most important or applicable to understanding the linkages between agriculture, livelihoods, and ES are introduced below, including the recent ES framework proposed by the CGIAR Program on Water, Land and Ecosystems (WLE).[4]

The Millennium Ecosystem Assessment (MA) from the UN Consortium published in 2005 is one of the most used frameworks in the scientific literature, and has been one of the first major efforts to introduce the concept of ES into the policy arena. The MA framework divides ES into four categories: (1) supporting services (nutrient cycling and soil formation, for example); (2) regulating services (pest control, pollination, climate regulation, and water purification, for example); (3) provisioning services (food, fodder, fuel, timber, water, among others); and (4) cultural services (such as education, recreation, aesthetic value, among others) (Bommarco et al., 2013; Corvalan et al., 2005). Despite this framework being the cornerstone for putting ES at the top of the research and political agenda of many agencies and governments, variations in the ES definition have continuously emerged from the scientific community depending on the research context (Bommarco et al., 2013).

Costanza (1999) suggested considering ES as benefits that humans obtain from ecosystems. This concept focuses on both goods and services provided by ecosystems. Those goods and services that directly affect society are called "final services" by Fisher et al. (2009), who suggested another ES framework based on the terminology developed by Daily et al. (1997), Costanza (1999), and Corvalan et al. (2005). Fisher's framework suggests the classification of ES into three categories that are easier to understand and apply in decision-making processes (Figure 2). In this framework, the categories of intermediate and final services are proposed. Intermediate services represent the complexity of ecosystem functioning.

[3] There is no clear explanation between the use of environmental services or ecosystem services in the literature. The term "environmental" seems to be used when speaking of "payment for environmental services" while the concept "ecosystem services" is used for defining the theory.

[4] WLE's *Ecosystem Services and Resilience Framework* has been a collective effort of researchers from various CGIAR Centers, including CIAT, in order to guide the research agenda of this program in relation to the management of ES for a better management of natural resources in agricultural landscapes. The complete document is available at http://www.iwmi.cgiar.org/Publications/wle/corporate/ecosystem_services_and_resilience_framework.pdf

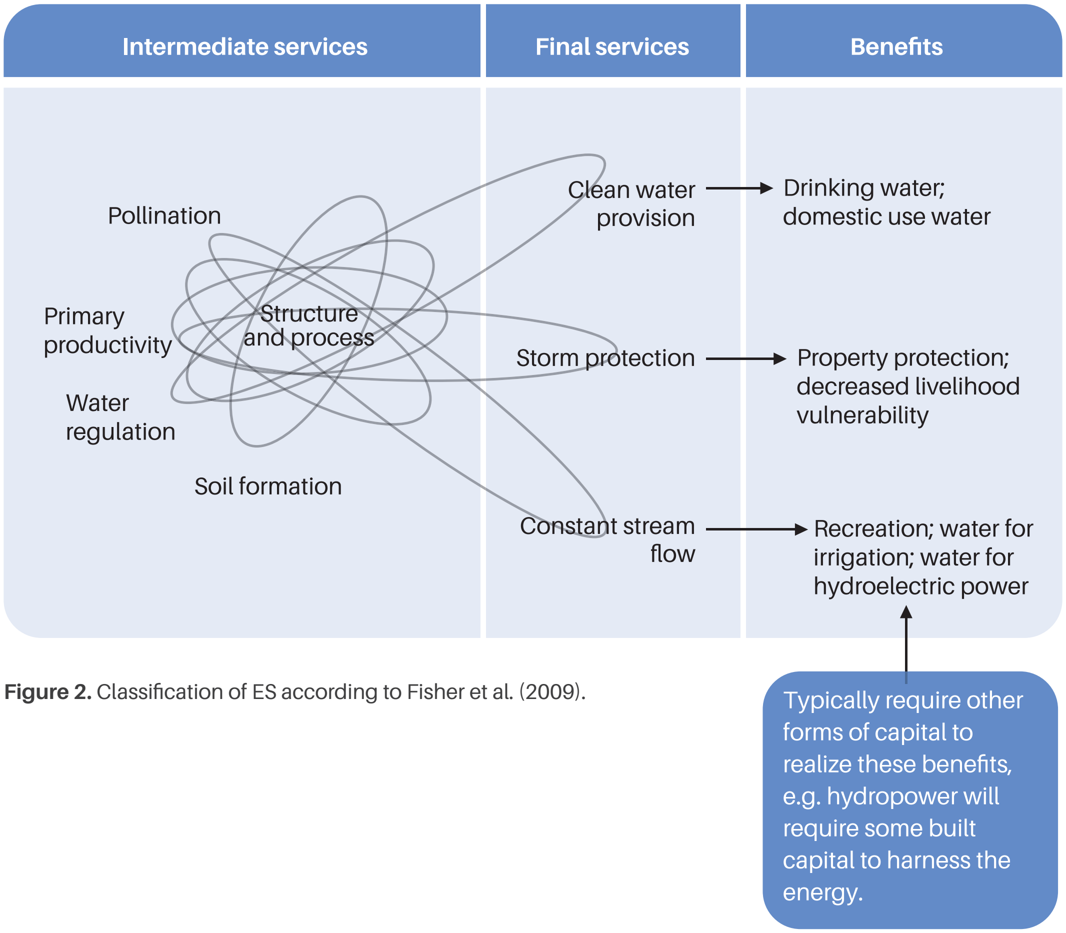

Figure 2. Classification of ES according to Fisher et al. (2009).

This functionality provides society with final services, such as constant water availability in watersheds, clean water, soil retention, carbon sequestration, etc., which are further translated into tangible benefits for society, such as reduced GHG emissions, soil losses, and water pollution; and water availability for food and energy production, among multiple others.

Finally, the CGIAR WLE Program has recently released a framework for ecosystem services. This framework aims to apply "ecosystem services and resilience concepts into development and resource management decisions in agricultural landscapes." The core principles of this framework are the following:

1. Meeting the needs of poor people is fundamental.
2. People and nature are inextricably linked and both are required to enhance ecosystem services to and from agriculture.
3. Cross-scale and cross-level interactions of ecosystem services in agricultural landscapes can be managed to positively impact development outcomes.
4. Governance mechanisms are vital tools to achieve equitable access to and provision of ecosystem services.
5. Building resilience is about enhancing the capacity of communities to sustainably develop in an uncertain world.

The Importance of Ecosystem Services in Agriculture

The interdependence between agriculture and ecosystem services is of high relevance as the demand for sustained food production grows. In fact, **crop yields rely on the provision of ecosystem services, which can be negatively or positively affected by agriculture**, depending on the practices applied for managing crop systems and agricultural landscapes. Consequently, farmers can be beneficiaries of ecosystem services or coadjutants in their provision.

From the standpoint of agriculture as an ES beneficiary, healthy (agro)ecosystems affect farmers positively by (1) supplying proper soils with sufficient nutrients and moisture conditions, and natural pollinators *(supporting services)*; (2) providing stable stream flows throughout seasons, and diversity of useful resources that farmers use for food, fuel, timber, and medicines *(provisioning services)*; (3) regulating the climate and pests and diseases as a result of biological and physical interactions that enhance biological control and water cycles *(regulating services)*; and (4) supporting cultural heritage, spirituality, and identity, and a sense of place, and providing a basis for education and recreation *(cultural services)*.

Moreover, Bommarco et al. (2013) presented the important relation between supporting and regulating ES and yield gaps (Figure 3). Indeed, supporting services (e.g., soil formation and nutrient cycling) and regulating services (e.g., pollination and biological pest control) are key determinants of crop production, and, through appropriate farming and landscape management practices, ES can contribute to safeguarding food security. For example, it has been estimated that **87 food crops in the world depend on animal pollinators, and this contribution is equivalent to 35% of global food production**.[5] Similarly, Klein et al. (2007) indicated that 75% of food crops depend to some extent on pollinators, especially crops that contribute importantly with some vitamins and micronutrients to the human diet (Eilers et al., 2011).

On the other hand, farmers can also be providers or coadjutants in the provision of ES. Stallman (2011) provided an overview of the different ES from and to agriculture, and the negative impacts of agriculture on ES (recently denominated as ecosystem disservices, ED) (Table 1). For instance, proper management practices at the crop field and landscape level may turn these disservices into ES, with agriculture becoming an ES provider benefiting other actors or sectors. Apart from being a food provider, agricultural systems and landscapes can contribute to cleaner water systems (e.g., through implementing better management practices that improve water quality and quantity at the landscape/watershed level), longer-term soil fertility, improved biocontrol, and reduced GHG emissions, among others.

[5] White House Fact Sheet: The Economic Challenge Posed by Declining Pollinator Populations. Available at: https://www.whitehouse.gov/the-press-office/2014/06/20/fact-sheet-economic-challenge-posed-declining-pollinator-populations

As agricultural land expands, it is critical to turn these areas into ES providers. This potential role of agricultural areas has been quantified for some ES, while for others, more science-based evidence is needed. For example, it is estimated that about 18–24% of global total carbon storage is in agricultural lands. In contrast, more research is needed to quantify the contribution of soil biodiversity and natural pest regulation to crop yield, and, furthermore, how landscape characteristics affect this relationship (Bommarco et al., 2013).

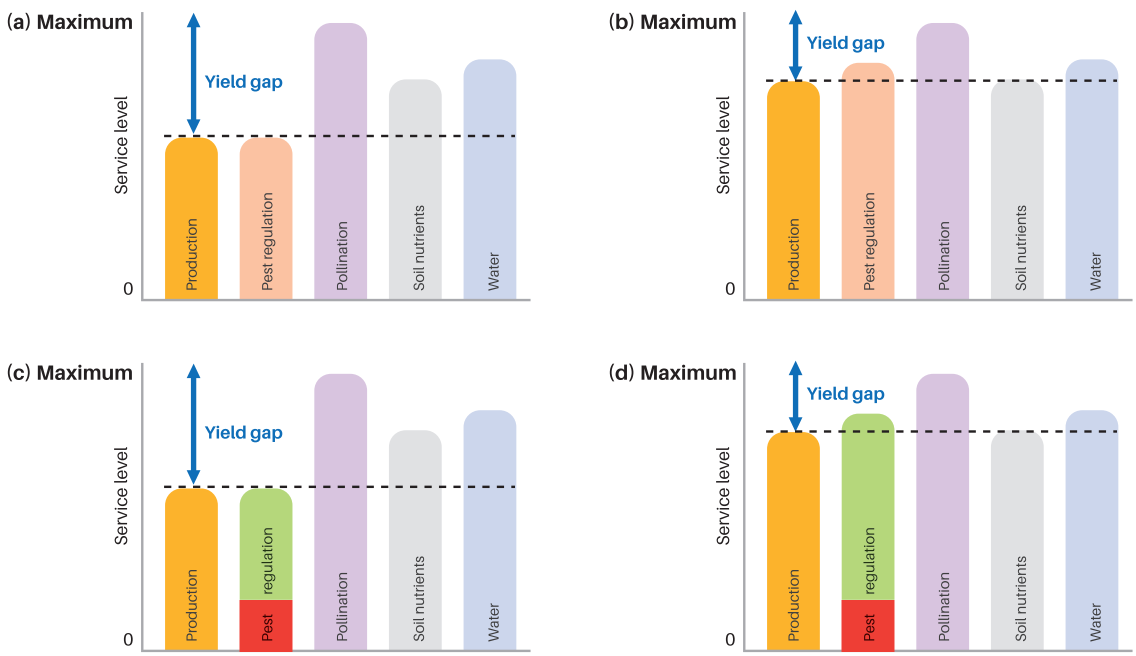

Figure 3. Conceptualization of the relationship between ES and crop production from Bommarco et al. (2013).

Table 1. Selected ecosystem services (ES) and ecosystem disservices (ED) from and to agriculture (adapted from Stallman, 2011).

ES type	ES from agriculture	ES to agriculture	ED from agriculture
Regulating services	Soil retention Pollination Pest control Water purification Habitat provision Atmospheric regulation Flood control Seed dispersal	Soil retention Pollination Pest control	Soil erosion Competition for pollination Pest outbreaks Nutrient runoff Pesticide runoff Habitat loss Greenhouse gas emissions Flooding Loss of seed dispersion
Supporting services	Soil structure Soil fertility Biodiversity Water cycling Nutrient cycling and retention	Soil structure Soil fertility Plant and soil biodiversity Soil water-holding capacity Soil nutrients	Soil compaction Soil fertility loss Biodiversity loss Soil water retention loss Inefficient use of water, thus reducing availability for other water users Eutrophication of rivers, estuaries, and lakes
Cultural services	Aesthetic enjoyment Recreation Spiritual well-being Cultural identity and sense of place Agro-tourism		Loss of aesthetic value Loss of recreation value Loss of well-being Loss of rural culture and lifestyles
Provisioning services	Food Fuel Fibers Medicines Construction materials		Decreasing crop yields over time Reduction in raw materials for industry Reduction of food diversity

These ES provided by agricultural lands can be rewarded by different society sectors via 'payment for ecosystem services (PES)' schemes or other types of incentive-based mechanisms. PES-type schemes have gained greater importance and support in their implementation. According to the Ecosystem Services Marketplace (2014),[6] **governments, businesses, and donors allocated in 2013 nearly US$6 billion to programs oriented to compensating land tenants that were managing their lands sustainably.** These incentives, primarily motivated by the concern of maintaining water quality and quantity and carbon stocks, have become an important source of income for about 7 million households that received these compensations or payments. Using the current behaviour of ES-based economic and financial mechanisms, Milder et al. (2010) estimated **"that by the year 2030, markets for biodiversity conservation could benefit 10–15 million low-income households in developing countries, carbon markets could benefit 25–50 million, markets for watershed protection could benefit 80–100 million, and markets for landscape beauty and recreation could benefit 5-8 million."**

In spite of the development and promotion of incentives for rewarding for ES provided through better land management, most of these initiatives are, at least in Latin America, rewarding more conservation actions than restoring/rehabilitation actions on agricultural lands (Quintero, 2010). This is caused, to a great extent, by the lack of land use/management practice options developed for areas with high potential to deliver ES (especially watershed services) and with a proper system to measure impact indicators in site-specific conditions (Célleri and Feyen, 2009). For instance, some management practices and farming principles are identified as alternatives for enhancing the provision of ES in agricultural systems as listed by the Food and Agriculture Organization of the United Nations (FAO).[7] However, the impact of these general alternatives needs to be evaluated in the specific conditions where PES-type schemes are proposed. These management practices and farming principles listed by FAO are as follows:

- Conservation agriculture (CA)
- Integrated rice management systems such as the system of rice intensification (SRI)
- Integrated pest management (IPM) for plant and animal diseases
- Integrated production and pest management (IPPM)
- Integrated plant nutrition systems (IPNS)
- Integrated weed management (IWM)

[6] www.ecosystemmarketplace.com/pages/dynamic/our_publications.landing_page.php

[7] www.fao.org/agriculture/crops/core-themes/theme/biodiversity0/en/#bio2

Ecosystem Services Research at CIAT: Current Situation

What does CIAT currently do on ES research?

Based on information provided by CIAT researchers, four main research focus categories are identified in ES-related projects. Sometimes, all categories are addressed by single research initiatives, and some other times research initiatives focus mostly on one or a few of these. This depends on the role of CIAT and partners in the research initiatives/projects (some dimensions are covered by partners). These categories help to visualize CIAT's strengths and potential aspects to be reinforced.

The main research focus categories are (1) quantification of ES, (2) understanding the biophysical processes behind ES provision, (3) quantification and valuation of off-site impacts of agriculture on ES, and (4) policy and institutional analysis for ES provision. Table 2 shows examples of research questions in each type of research focus category.

Table 2. Current research focus categories and questions of ecosystem services research at CIAT.

Research focus categories	Examples of research questions
Quantification of ES	How much carbon is stored in soils? To what extent does biological control contribute to (agricultural) pest suppression? How much is soil fertility increased in more biodiverse soil environments, etc.?
Understanding the processes behind ES provision	What mechanisms explain a reduction in methane emissions? What biological or physical processes are behind nutrient retention in agricultural landscapes?
Quantification and valuation of off-site impacts of agriculture on ES	What is the economic importance of impacting the provision of ecosystem services to others? How do ES provided by natural or managed lands affect others in the landscape, watershed, or even globally?
Policy and institutional analysis for ES provision	What is the enabling institutional and policy context for implementing incentive-based solutions for ES provision? What is the influence of information on ES in policy making?

These four research focus categories shape the impact pathways of the research activities in the sense that the target public is different. For example, research on the biophysical processes behind the delivery of ES could be of more interest to the academic sector and can contribute importantly to filling scientific knowledge gaps. On the other hand, research aiming at estimating the importance of ES delivered from agriculture to other sectors could be more oriented to promoting the recognition of these services by non-agricultural sectors of society and then promoting their support toward the protection of ES (e.g., a reduction in sediment losses in agriculture can positively affect the production of hydropower in a company located downstream) (an example is provided in Box 1).

In addition to research conducted on these four dimensions, a few research activities are oriented to conducting **meta-analysis and situational analysis at the country or global level** to understand the state of the art on knowledge about the provision of ES in agricultural landscapes and on the institutional context to promote action toward the protection of ES (some examples are provided in Boxes 2 to 3).

Box 1. Preserving Kenya's lifeblood

By building on the model that has taken shape in Peru and other Latin American countries, Kenya will soon get a taste of the mutual benefits that result when societies share responsibility for improving ecosystem services. The means by which Kenyan society will achieve this end is the Nairobi Water Fund, the first of its kind launched in Africa in 2015. It was developed by The Nature Conservancy through a collaborative effort with public and private sector partners, including CIAT, in the upper Tana River Basin. This area is a major water catchment for Kenya's capital city and provides hydropower for much of the country. Over the last 3 decades, it has undergone rapid changes, as a consequence of increasing population density and entrenched poverty. Unsustainable use of agricultural land, stone quarrying near river courses, and other activities have given rise to high levels of water runoff and soil erosion, incurring in high costs for downstream users of water supplies. Through well-targeted development of sustainable land management practices, the Water Fund will work to reduce erosion and sedimentation in the basin's predominantly rural upstream watersheds, thus ensuring that downstream urban residents have good quality drinking water as well as adequate water supplies for hydropower generation. CIAT's role in this effort is to determine what benefits can be expected from land management solutions and how these benefits can be distributed equitably.

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Other relevant aspects analyzed in function of the delivery of ES, although to a lesser extent, are the **impact of climate change** on the provision of ES (e.g., water yield in watersheds) and the **impact of ES on food security and nutritional health.** These two aspects are especially relevant as keys for contributing to the CGIAR outcomes and serve as pivots to interact closely with various CGIAR Research Programs (e.g., Climate Change, Agriculture and Food Security [CCAFS], Agriculture for Nutrition and Health, among others).

Box 2. Analyzing research trends on ecosystem services, food security, and human well-being

What is the state of the art of ES research? This wide question has been undertaken by the Ecosystem Services group with two major focuses: the trends of ES research in relation to food security and the trends of ES research in relation to human well-being.

The relationship between food security and ES has been broadly recognized, notably for rural impoverished communities around the world. However, the linkages between ES and food security are usually assumed, and it is unknown whether these assumptions are actually based on empirical research. In order to fill this knowledge gap, we are currently undertaking efforts to analyze what evidence exists on the multiple linkages between ES and food security. For that, we are reviewing the existing literature on the ES and food security interface, with a focus on case studies in small-scale rural communities. This effort is oriented toward identifying the geographical distribution of these case studies and their corresponding methodological approaches. In addition, this research aims at providing an indication on what types of ES are associated with each one of the four FAO pillars of food security (i.e., food availability, access, use, and stability).

Likewise, we are also reviewing existing research results that can provide insights into the linkages between ES and human well-being. Indeed, it is well known that ecosystems provide a wide array of services that are essential for human well-being. However, in order to better understand the linkages between ES and human well-being, it is also necessary to carefully understand the diversity of indicators that are used to conceptualize well-being. Thus, the objectives of this review are to analyze the use of well-being indicators and their respective conceptual frameworks, and to quantify the empirical studies that test the multiple linkages between ES and human well-being. These analyses will allow CIAT to answer the following questions: (a) which indicators of well-being have been proposed as part of ES research? (b) Which indicators of well-being are usually measured in empirical ecosystem services research, including case studies from around the world? (c) What knowledge gaps need to be addressed by future ES and well-being research? And (d) what are the implications for policy and decision-making?

Both studies will provide valuable information that will shed light on existing knowledge gaps in ES research and provide CIAT with a useful baseline to take into account for future ES studies.

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Box 3. National analysis on the bottlenecks that limit the implementation of schemes of rewards for ecosystem services in a watershed in Peru

One of the main reasons for the slow uptake of ecological approaches to land management is that their immediate benefits in terms of increased production and income often do not provide strong enough incentives for rural people to alter traditional practices. In a novel effort to overcome this obstacle, Peru's Ministry of the Environment (MINAM) and other organizations are promoting mechanisms for the equitable distribution of economic benefits from vital services provided by the country's diverse ecosystems. The scheme is based on a new law approved by the Peruvian Congress and executive branch in June 2014, which is now being put into effect.

MINAM's work on the novel reward scheme resulted from a pilot project carried out in the Cañete River Basin, with support from the CGIAR Research Program on Water, Land and Ecosystems through CIAT. A key contribution from research was to determine the value of ecosystem services, especially water, for a variety of sectors, including agriculture. The good news is that users of this resource clearly recognize its value and are willing to contribute financially to its preservation.

In search of ways to implement the reward scheme, MINAM and CIAT found a viable option with help from the International Fund for Agricultural Development (IFAD). IFAD has agreed to contribute start-up capital for the creation of a trust fund and also to cover operational expenses. Water users in the lower basin now have a way to make voluntary contributions. Communities in the upper watershed are already applying to the fund for project support focusing on the conservation of rural landscapes and restoration of degraded land.

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What ecosystem services is CIAT looking at, where, and for whom?

CIAT's current research capacity is oriented to studying a wide range of ecosystem services, including biodiversity maintenance (especially at the soil level); biological control; climate change mitigation (carbon stock assessments; quantification of GHG emissions); pollination; sediment retention; soil fertility (including nutrient cycling and soil formation); and water-related ecosystem services (including water yields, stream flow regulation, and water quality). From these, climate change mitigation and water-related ecosystem services are the ES most studied at CIAT (Figure 4), involving researchers from various research teams of CIAT located at the Soils, Decision and Policy Analysis, and Agrobiodiversity research areas (e.g., Forages). To a lesser extent, biological control and pollination services are studied in the Agrobiodiversity research area, especially by the cassava research team and the former Tropical Fruits Program. It is worth noting that, even though the Tropical Fruits research area was closed, the scientific capacity to assess biological control as an ecosystem service in agricultural landscapes remains in the Center (Figure 4).

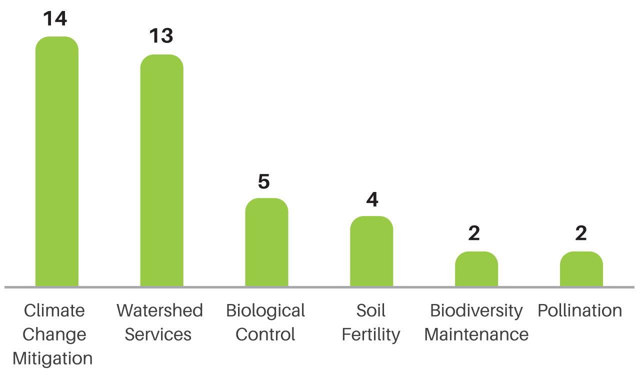

Figure 4. Ecosystem services targeted by research projects at CIAT (Note: the number above the columns denotes the number of current or recent projects related to each ecosystem service).

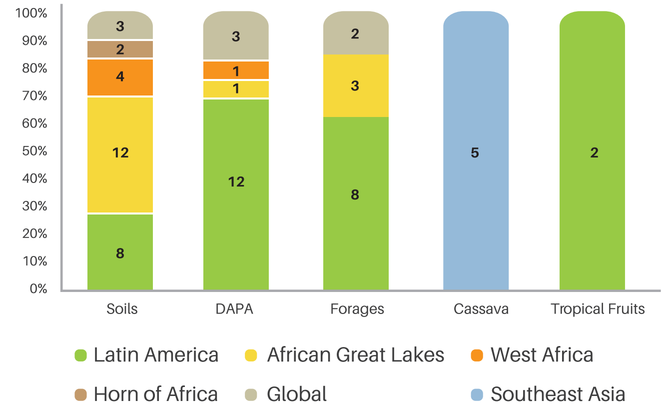

Figure 5. Distribution of CIAT ecosystem services research per CIAT's research themes/areas and regions.

ES research at CIAT is carried out in the three regions where CIAT works: Africa, Latin America, and Asia (Figure 5). Figure 6 presents the different countries where projects related to ES are reported and the research focus of these projects. Globally, most of the projects are about quantifying ES and understanding the biophysical processes behind their provision (see example in Box 4). Lesser efforts have been made on quantifying and valuing the impact of agricultural practices on environmental externalities (i.e., off-site impacts) and on researching the institutional and policy context required for improving ES for agriculture, and from agriculture to other sectors.

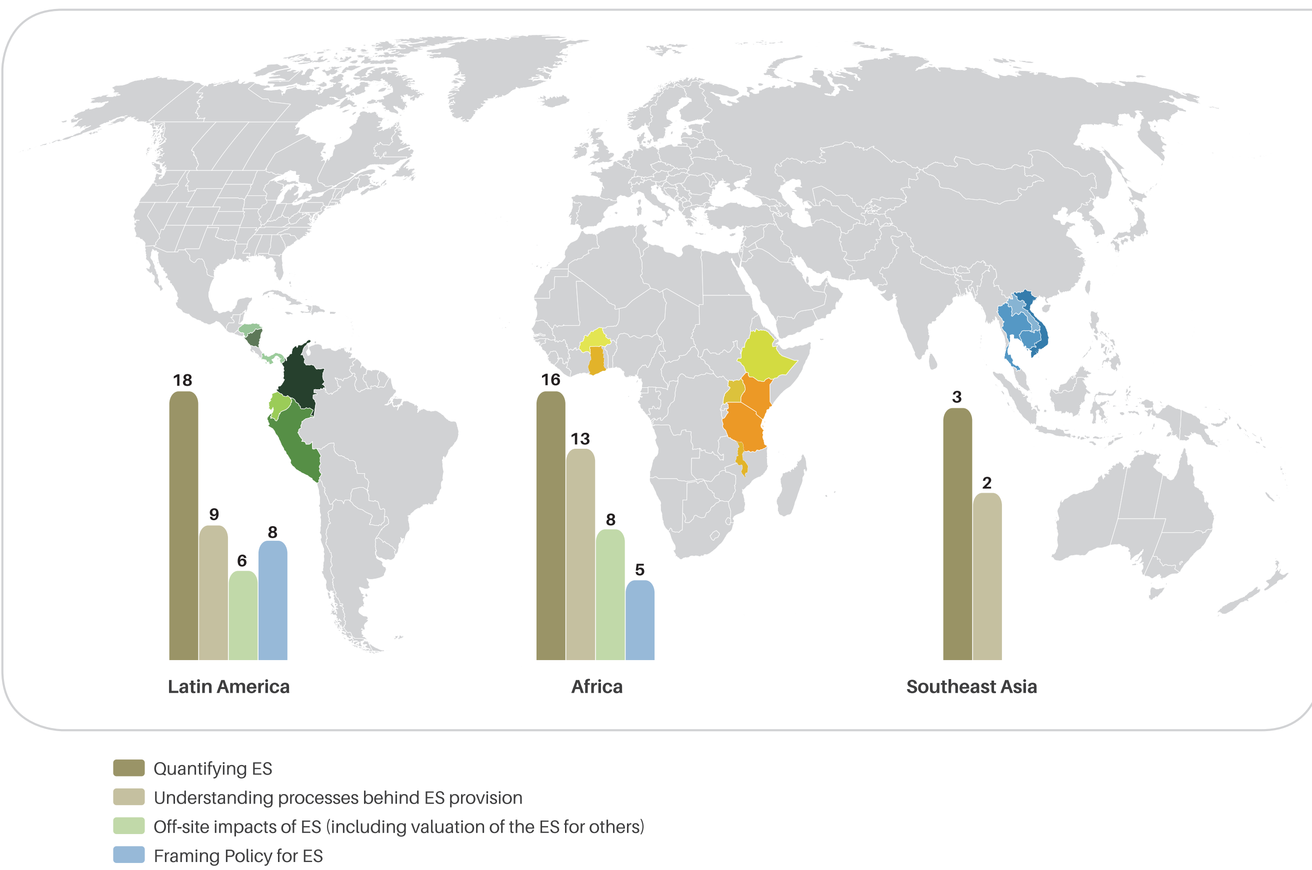

Figure 6. Distribution of the type of ecosystem services research made by CIAT per region. Numbers above columns indicate the number of projects in each research focus category: (1) quantification of ES, (2) understanding the processes behind ES provision, (3) quantification and valuation of off-site impacts of agriculture on ES, and (4) policy and institutional analysis for ES provision.

Box 4. Quantitative assessments of ecosystem services provided by soil

Soil provides multiple ecosystem services: provisioning services such as food, fiber, and fuel production; supporting services such as nutrient cycling and soil formation; and regulating services including filtering of toxins and pollutants, regulating the hydrologic cycle and the sequestration of carbon. In addition to potentially mitigating climate change, carbon sequestration and overall soil organic carbon content is an important indicator of the health of the soil, as it influences soil fertility (specifically by increasing the capacity of soil to exchange micronutrients (or cations), water holding capacity and physical properties. The UN Convention to Combat Desertification (UNCCD) and the UN Framework Convention on Climate Change (UNFCCC) both recognize that reduced soil organic carbon (SOC) content can lead to land degradation, and ultimately low land and agricultural productivity. Therefore, spatial assessments of SOC are important for quantifying ecosystem services as well as assessing potential agricultural productivity.

However, soil organic carbon content is influenced by many different confounding factors, including land use and inherent soil properties, all of which vary across space. Therefore, CGIAR researchers have been working to develop landscape-level approaches that simultaneously assess the various drivers of SOC across different spatial scales. Specifically, we have developed new methods for the accounting of SOC, which have been applied in East Africa (Vågen and Winowiecki, 2013; Winowiecki et al., 2015) and are now being implemented globally through the establishment of a network of land and soil health monitoring sites. By applying these methods, baselines of land and soil health are created allowing future impact assessments of interventions, while also understanding key drivers of land degradation and agricultural productivity.

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Figure 7 shows that most of the projects reported take place partly or entirely in Latin America (42%) and then in Africa (39%) and Southeast Asia (10%). About five projects/activities are carried out at the global scale. Most of these global activities (three out of five) are situational analyses that aim to give a general overview of the state of the art on ES research in relation to food security and human well-being, and on alternatives for land management and restoration.

Most of the next users mapped against ES-related projects are researchers and non-governmental organizations (NGOs). This could be explained by the dominant research focus (quantification of ES), which is more oriented to enriching the knowledge base in terms of the amount of ES in a given landscape or associated with a given production system. Fewer projects are oriented to informing policy-making and farmers' decision-making processes (Figure 8).

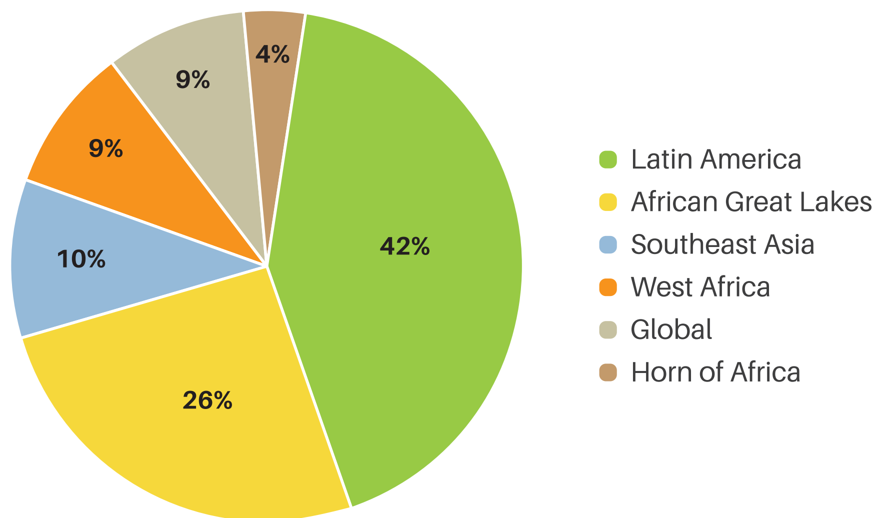

Figure 7. Distribution of CIAT's ES-related projects per region.

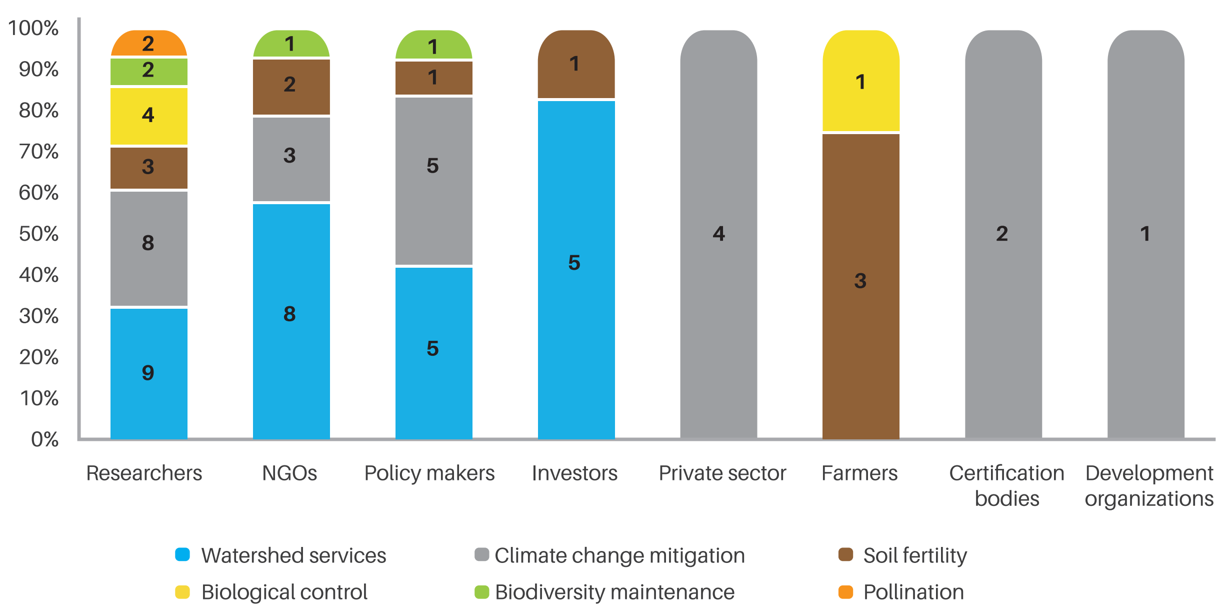

Figure 8. Next users targeted in ES-related projects at CIAT.

The contribution of CIAT's ES-related research to the CGIAR Research Programs

More than one-third of the ES-related projects reported by CIAT researchers are associated with the CGIAR Program on Water, Land and Ecosystems (WLE) (Figures 9 and 10), which focuses on water scarcity, land degradation, and ecosystem service issues. This is not surprising as it aims to address *"natural resource constraints at a river basin and landscape scale rather than the field to farm level"* with a broad agenda including manifold disciplines, scales, and geographic contexts. CIAT's current research on ES topics is also articulated to other CGIAR programs such as Climate Change, Agriculture and Food Security (CCAFS) and Humidtropics, which focus on climate change and agriculture, and integrated agriculture in humid lowlands, moist savannas, and tropical highlands, respectively.

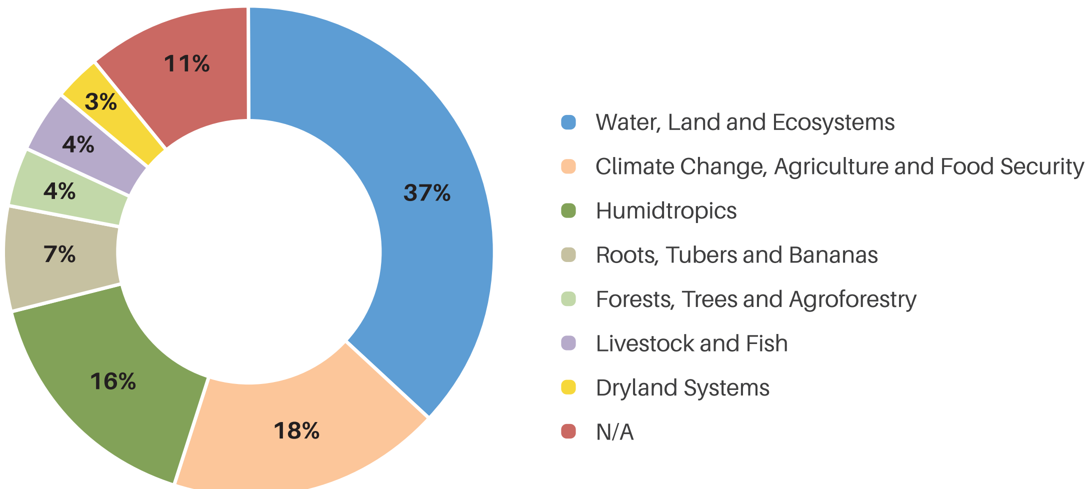

Figure 9. Contribution of CIAT's ES research to the CGIAR Research Programs.

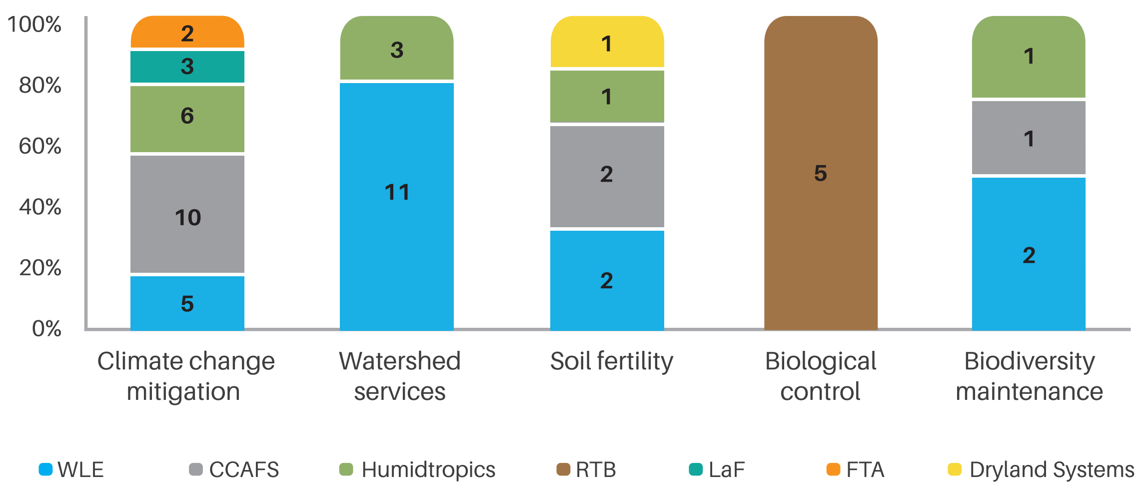

Figure 10. Distribution of ES research projects across CGIAR Research Programs. (WLE: Water, Land and Ecosystems; CCAFS: Climate Change, Agriculture and Food Security; RTB: Roots, Tubers and Bananas; LaF: Livestock and Fish; FTA: Forests, Trees and Agroforestry).

The Prospects for Ecosystem Services Research at CIAT

As previously mentioned, the recent global focus on the need for evidence on **the links between agriculture and ecosystem services,** particularly in rural poor areas, places CIAT in a strong position to contribute to this, and, consequently, to mainstreaming ecosystem services in development and policy-making processes. Until now, CIAT has developed important capacity to quantify ES in agricultural landscapes, especially soil-mediated ES (e.g., soil carbon sequestration, GHG emissions, water filtering, water-holding capacity, among others) and water-related ES at the watershed scale (e.g., stream flow regulation and sediment retention). To a lesser extent, CIAT's work has focused on the economic valuation of those services and institutional innovations to promote the participation of different sectors in the conservation and sustainable management of (agro)ecosystems that provide those services. Indeed, a few efforts have been intended to directly influence policy making for promoting the enhancement of ES provision. More efforts at CIAT are required to expand current capacity on the quantification of ES toward research for development and policy making. In this regard, the main gaps in research activities of CIAT are related to the following:

- The socioeconomic implications of losing ES across different scales and stakeholders (beyond the plot level).
- The effects of institutional innovations that promote ES conservation via financial and economic mechanisms (e.g., payment for ecosystem services-PES) on rural livelihoods.
- The analysis of current and expected drivers of land degradation and the effect on the provision of ES.
- The effect of enhancing ES in agriculture on reducing crop yield gaps.

Therefore, future efforts of CIAT should go beyond studying the linkages per se between agriculture and ES, but also focus on evaluating and **recommending land-use-based and management practice options that enhance the provision of ES, while increasing agricultural productivity (see examples in Boxes 5, 6, and 7).**

These efforts should include assessing the socioeconomic implications of these options that would inform the design of **development and policy actions** that intend to protect the sources of ES in agricultural landscapes.

Box 5. Helping nature along: a clampdown on invasive pests in Asia

Entomologists were among the earliest system thinkers in modern agricultural research, demonstrating the enormous impact that an ecosystem approach can have in research on staple crops. One especially noteworthy achievement involves biological control of the cassava mealybug, an insect pest that in recent decades has traveled to Africa from its area of origin in South America and has lately shown up in Southeast Asia as well, with devastating consequences. The spread of cassava mealybug forms part of a growing worldwide threat posed by invasive species to economies and ecosystems.

Extensive research at the International Institute of Tropical Agriculture (IITA) and CIAT has shown that the safest and surest way to clamp down on this pest is through the release of a parasitic wasp, which co-evolved with the mealybug in South America and naturally keeps the pest in check. This strategy has worked like a charm in Africa, saving billions of dollars in food supplies, and was applied a few years ago in Thailand as well. The wasps feed only on cassava mealybug, posing no threat to humans, animals, or other insects. In addition, biological control obviates the use of pesticides, which could cause serious environmental damage.

In response to the recent appearance of cassava mealybug in Indonesia, scientists from Bogor Agricultural University released about 3,000 wasps into a confined cage during September 2014, with support from CIAT and FAO. This is the first phase of an effort to subdue a major threat to the country's second most important staple after rice. This parasitoid release constitutes part of a broader CIAT-wide initiative to fully exploit biological control as a free, safe, and environmentally sound alternative to tackle some of the most pressing pest problems in developing-world agriculture.

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Box 6. Ecological anchor: Central America's Quesungual system

Some ecosystem approaches result from the fusion of traditional knowledge with new insights from science. Such is the case with Quesungual, an agroforestry system originally developed in the early 1990s by FAO with farmers and community-based organizations in Lempira Department of Honduras.

Quesungual includes different kinds of trees scattered across cropland at a density of up to 1,000 per hectare. The roots act as anchors, stabilizing hillsides, minimizing soil erosion, and improving nutrient uptake from deeper soil layers. Most of the trees are pruned at regular intervals, and the green cuttings are used as mulch to provide nutrients and retain moisture, thus giving crops some protection against failed rains. This also helps increase soil organic matter, which encourages biological activity and nutrient cycling while improving soil structure.

Some of the trees are kept so small that it is hard to spot them in the surrounding maize or sorghum crops. Others are left to grow big enough to provide timber and fruits. In addition to capturing carbon dioxide, many of the trees in the system fix nitrogen. The overall result is a more reliable and productive system – come rain or shine.

Already widely practiced in Lempira, Quesungual has spread and undergone further development in El Salvador and Nicaragua as a result of CIAT-coordinated efforts. Preliminary studies suggest that the system could work in other areas of the subhumid tropics as well. Wider adaptation and adoption of Quesungual require an active role for international organizations, working closely with national and community-based partners.

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Box 7. Linking soil restoration and the provision of ecosystem services in rural landscapes of Central America; linking scales and actors

The fragile, hilly landscapes of Central America are subject to ecosystem degradation and biodiversity loss with detrimental impact on food security, climate risk, and the their overall resilience. The provision of ecosystem services in rural landscapes of Central America is directly dependent on the decisions of smallholder farmers, which take place at farm and plot levels. However, indirectly, their decisions depend on socioeconomic context such as markets and policies that are often beyond their influence. Both levels of decision-making need to be taken into account to improve land management decisions. This means that the design and management of more resilient rural landscapes needs a close collaboration with farmers and other key actors, as well as a better understanding on the impact of more sustainable farming practices on the provision of ES of rural landscapes. In the hillsides of Central America, for instance, the impact of restoring soils and land by co-designing agroforestry systems combined with more sustainable agricultural practices (no burning, controlled grazing, and improved varieties, among others) is being assessed with farmers, local organizations, the public sector, national universities, and other key stakeholders.

Preliminary results in El Salvador showed that agroforestry systems can host almost 70% of the tree biodiversity found in rural landscapes; they can also store an additional 10–20 tons ha^{-1} of aboveground carbon compared to agricultural systems without trees, while still producing food and increased livestock feed for ensuring the rural livelihoods of family farmers. A better understanding of how local decision-making can influence processes at landscape scales is fundamental to better target how and where agroforestry systems can be scaled out and adapted to restore more resilient rural landscapes in Central America and the Caribbean. Moreover the role of markets and (sometimes conflicting) policies needs to be better understood to develop mechanisms and incentives that can help farmers to reach ecosystem restoration goals.

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The **main research question** that CIAT can contribute answers to is: How can the co-production of ES for more resilient agricultural landscapes contribute to the improvement of rural-urban community livelihoods and well-being?

This research question can be divided into several sub-research questions, such as:

- What is the level of dependence of agriculture on ES provided by natural systems embedded in agricultural landscapes?

- How are agricultural activities affecting ecosystem services that are crucial for rural-urban livelihoods?

- Which ecosystem services (beyond food production), provided in agricultural landscapes, are contributing the most to human well-being in rural-urban areas?

- What are the social and economic costs associated with the loss of ES in agricultural landscapes (including nonmonetary values when appropriate)?

- What are the effects of financial/economic incentives designed for enhancing ES provision for rural-urban livelihoods?

Research agenda

In order to answer these questions and position CIAT as a key player in ES research, CIAT should include the following specific topics in its research agenda, many of which are cross-sectional research areas.

Topics that CIAT should maintain and strengthen

- Development of tools and methodologies to quantify and map ES associated with different land-uses in agricultural landscapes.

- Economic valuation of ES that benefit agriculture and ES impacted by agriculture to determine the level of investment and incentives required for protecting ecosystem services provided in agricultural landscapes.

- Identification and assessment of alternative land-use and management practices based on their impacts on ES. A special contribution of CIAT could be in providing scientific evidence on the role of agriculture in both providing and using ES efficiently.

- Analysis of the socioeconomic consequences and bottlenecks for implementing financial/economic mechanisms (e.g., PES-type schemes), and providing recommendations about the most appropriate means by which we can ensure a more equitable distribution of the benefits and costs of improving ecosystem services.

New aspects that CIAT may start looking at (or that are emerging in the research activities of CIAT)

- Direct and indirect contributions of ES to food security, nutrition, and well-being in impoverished rural areas. These contributions are based on gender, age, and social status.

- The impact of plausible socioeconomic and climate change scenarios on ES provision.

- Regional and global analyses on the state of knowledge, policy, and action to improve the provision of ES in agricultural landscapes.

By incorporating all these research topics, CIAT will move from the current research agenda, focused mostly on the biophysical quantification of ES, to one that, although including this aspect, moves toward the socioeconomic and policy implications of land-use and land management strategies and institution-based measures to enhance ES provision.

A research agenda comprising these topics will respond to CGIAR priorities and contribute especially to various CGIAR Research Programs, including CCAFS, WLE, and FTA.

What ES should be targeted?

CIAT's research on ES will focus on (1) intermediary services provided by agricultural landscapes and that determine the delivery of final services important to other sectors – this will allow recognizing the interdependences between agriculture and other sectors as a means to pursue multi-sectoral co-management of agricultural landscapes; (2) intermediary services that directly affect crop yields and that can help to close, on a sustained basis, yield gaps in agriculture while minimizing the environmental impacts of agricultural intensification (e.g., supporting and regulating services that influence crop yield such as pollination, pest control, water retention, and nutrient cycling (Bommarco et al., 2013); and (3) intermediary and final services that are important for food security and nutrition and depend on the sustainable management of agricultural landscapes.

In Figure 11, services prioritized for this strategy are in bold and are shown based on the conceptual ES framework proposed by Fisher et al. (2009). This prioritization is based on ES that are important in any one of the three categories mentioned above and not covered by crop-specific research groups at CIAT (i.e., food production).

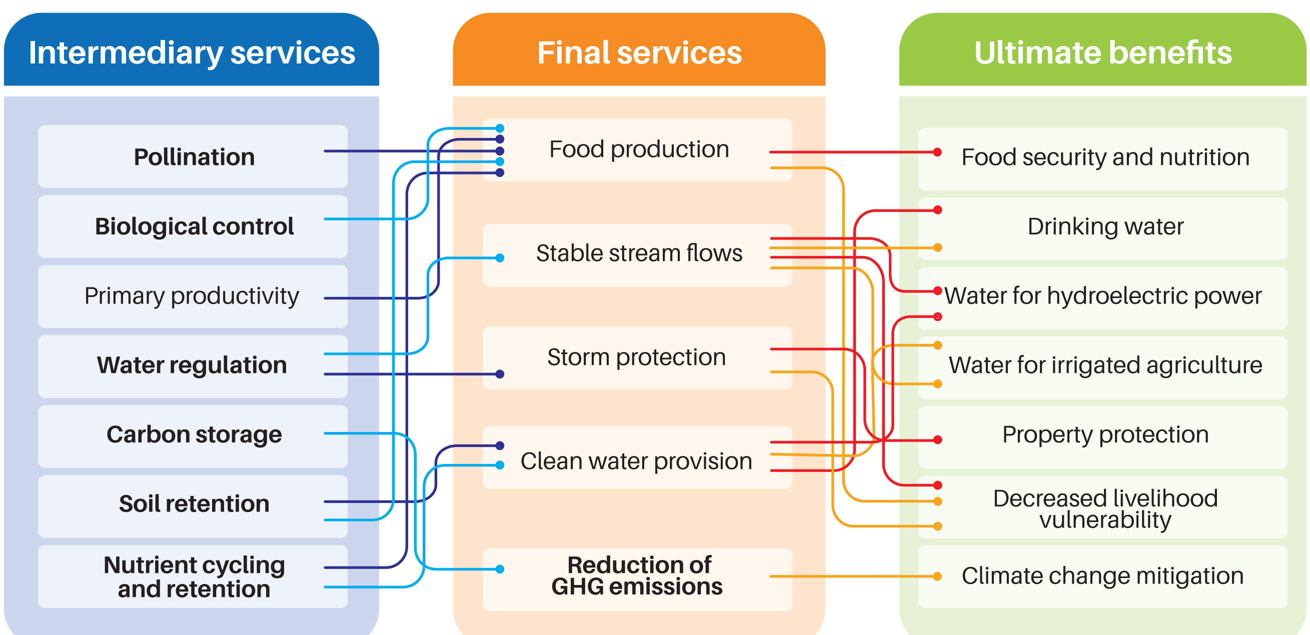


Figure 11. ES targeted by CIAT's Ecosystem Services Strategic Initiative (diagram adapted from Fisher et al. [2009]).

The strategy impact pathway

The impact pathway of this strategy interrelates (1) the expected outputs from ES research, (2) the outcomes led by the research outputs, (3) the overall impacts pursued with the delivery of the outcomes, and (4) the set of tools that will help to provide the expected outputs and outcomes.

Three main impacts are pursued by the ES strategy that all together contribute to the overall goal mentioned above. They are:

1. Policy and decision makers (NGOs, governmental organizations [GOs], private sector, civil society) incorporate ES information (e.g., Where are ES provided? How can their provision be enhanced with land-use-based options? What institutional innovations are required for ES investments?) when designing and implementing strategies for improved rural-urban landscape management.

2. Donor and scientific communities understand, recognize, and support CIAT's ES research.

3. Rural-urban communities' livelihoods and well-being are improved through ES-oriented actions (economic incentives, land-use investments, land-use policies, etc.).

Impact pathways to achieve these impacts are described below and in the Annex.

Policy impact

In order for ES to be incorporated in policy- and decision-making processes and strategies, the outcomes defined are the following:

- Policy makers recognize the linkages between ES, food security, and well-being, and are informed about source location and the value of ES for sustainable land management.

- Designers of agricultural and environmental conservation incentives know and use the information about the level of investment required for implementing sustainable land-use alternatives.

- The environmental sector of countries recognizes the double role of agriculture as a provider/user of ES.

Thus, as a research organization, CIAT needs to provide policy makers with a strong knowledge base and scientific evidence on the relationship between food security and ES, the impacts of different land-use options on ES provision, and the impacts of ES on agricultural productivity. However, sharing knowledge with a large audience is not sufficient for producing such a policy impact. It is clear that CIAT needs to link research efforts to specific impact pathways to ensure that scientific results are put into use in policy formulation and implementation. The formulation and implementation of nationally appropriate mitigation actions (NAMAs), Low-Emission Development Strategy (LEDS), Payment for Ecosystem Services (PES), land-use plans, and environmental investments are some of the opportunities for which research projects need to be engaged to ensure such policy-making influence.

A wide range of tools and approaches is needed to achieve these policy-oriented outcomes, such as biophysical and socioeconomic modeling, scenario analysis, policy networks, efficient and standardized data collection methods, reliable databases, and a communication strategy.

Donor and scientific community impact

CIAT's ES research positioning in the donor and scientific communities should be expressed as the following outcomes:

- Donors approach CIAT based on the impact of ES-related research outputs on decision-makers across scales and on policy making.

- CIAT's ES research is used as a reference for others' future scientific research (scientific recognition).

- CIAT scientists from different areas and regions cooperate together in ES.

These outcomes might result from the recognition of CIAT's capacity to conduct ES research, and this requires (1) communicating and presenting relevant evidence and examples of successful research, (2) sharing knowledge and methodologies through an efficient knowledge base, (3) publishing papers in peer-reviewed journals, and (4) co-designing projects integrating ES, food security, and well-being.

To do this, CIAT has as tools and resources its current networks (scientific network, donor network, and intelligence), reputation, presence in multiple locations, and the possibility of delivering open-access data and resources, in order to proficiently achieve this impact.

Impact on communities

CIAT's ES research should contribute to the improvement of tropical communities' livelihoods and well-being. The achievement of the following three outcomes may reflect this contribution:

- NGOs and farmers organizations actively implement the results of CIAT's ES research and lessons learned from successful experiences.
- Farmers are better able to optimize their own agricultural system while reducing impacts on ecosystem services.
- The linkage between ES, food security, and well-being is recognized, and action plans to protect these synergies are implemented.

The intended outputs leading to these outcomes are (1) research projects that include local communities' perspectives in relation to ES management, food security, and well-being components; (2) primary sex-disaggregated data collected and analyzed to understand how roles are differentiated when implementing sustainable land-use practices; (3) easy-to-use land-use-based interventions designed and validated; and (4) stakeholders' enhanced capacity for adopting recommended sustainable land-uses.

To achieve this, CIAT needs to ensure and strengthen its capacity to use social science and mixed biophysical methods (interdisciplinarity), conduct scenario analysis, create and use innovation platforms for disseminating results among next users, and reinforce and promote agricultural technologies/innovations through its NGOs and government networks.

How CIAT can operationalize this strategy

To accomplish these research objectives, three main strategies, from a practical perspective, would need to be pursued internally at CIAT:

1. Designing projects for which ES is the main focus and is applied, for example, to study land-uses, management practices, or policy interventions from the ES perspective.

2. CIAT's investment to periodically support regional and global analyses aimed at reviewing scientific and policy advances over time. This will help CIAT in reviewing its own ES strategy and to position itself at the international level as an organization with a global perspective on ES topics (taking advantage of the presence of CIAT in multiple locations).

3. Designing projects not strictly focused on ES, but with specific research activities on ES that add value and increase competitiveness and the impact potential of the project. For example, projects with a focus on assessing agronomic practices or germplasm can better inform the design of incentives for implementing eco-efficient agricultural alternatives by incorporating specific analyses on the impacts of these practices/materials on ES (and vice versa).

In any of the three cases above, the expertise from the different research areas in CIAT needs to be integrated to be able to respond to the proposed research questions and to truly implement one single ES strategy at CIAT.

Geographical and ecological scope

General criteria for targeting the scope of this strategy follow:

- Agricultural areas with major yield gaps and where, through better ES management, yield can be boosted.

- Crops with major yield gaps and that, by improving ES management, can produce more.

- Areas/crops where agriculture is producing negative environmental externalities that impose important costs on society (reductions in hydro-energy production potential, reductions in water for human consumption and food production, increases in GHG emissions), and there is potential to revert this through improved management practices.

Criteria for success (performance indicators for the strategy)

Performance indicators for this strategy should be constructed with targets achievable each year and would in aggregate contribute to the following larger long-term indicators:

- Validated land-use-based options that enhance ES from agriculture and reduce yield gaps.
- Improved biophysical indicators of ES delivery (e.g., soil organic matter [SOM], biological indicators, etc.).
- Influence on research-based policy making.
- Science-based evidence on the importance of ES (beyond crop production) for food security and nutrition.

For 2015 and 2016, the specific indicators that contribute to long-term targets are:

Science-based indicators

1. Validate two land-use-based options in Latin America and Africa to enhance ES from agriculture and to reduce yield gaps. Identify key indicators of ES delivery in those land-uses.
2. Advance the methodology for ES quantification, valuation, and trade-off analysis in Africa.
3. Document and publish links between ES and food security in Latin America and Africa.
4. Advance dialogue on policy interventions, particularly NAMAs in Colombia (in coordination with the LivestockPlus initiative). A senior policy expert in CIAT's Decision and Policy Analysis (DAPA) Research Area will provide leadership on this front.

Partnership and fund raising

1. In partnership with other Centers of the CGIAR Consortium (e.g., IWMI) and non-CGIAR organizations, expand activities in Asia, leveraging recruitment of a systems and landscape specialist.
2. Position CIAT in the area of ecosystem services through high-level institutional engagements with global initiatives and panels (e.g., IPBES, TEEB, ES partnerships).
3. Submit at least one new project with ES as the key entry point, integrating three research areas across regions.
4. Advance dialogue with the World Bank and Inter-American Development Bank (IDB) for tapping funds from climate change-related funds for projects on ecosystem services.

Potential external partners

Research partners

- CGIAR Centers (especially ICRAF, CIFOR, IWMI, and Bioversity International).
- National agricultural research centers (e.g., centers based in the Amazon region).

Partners to put research into practice

- Environmental NGOs (The Nature Conservancy, Conservation International, World Wildlife Fund, among others).

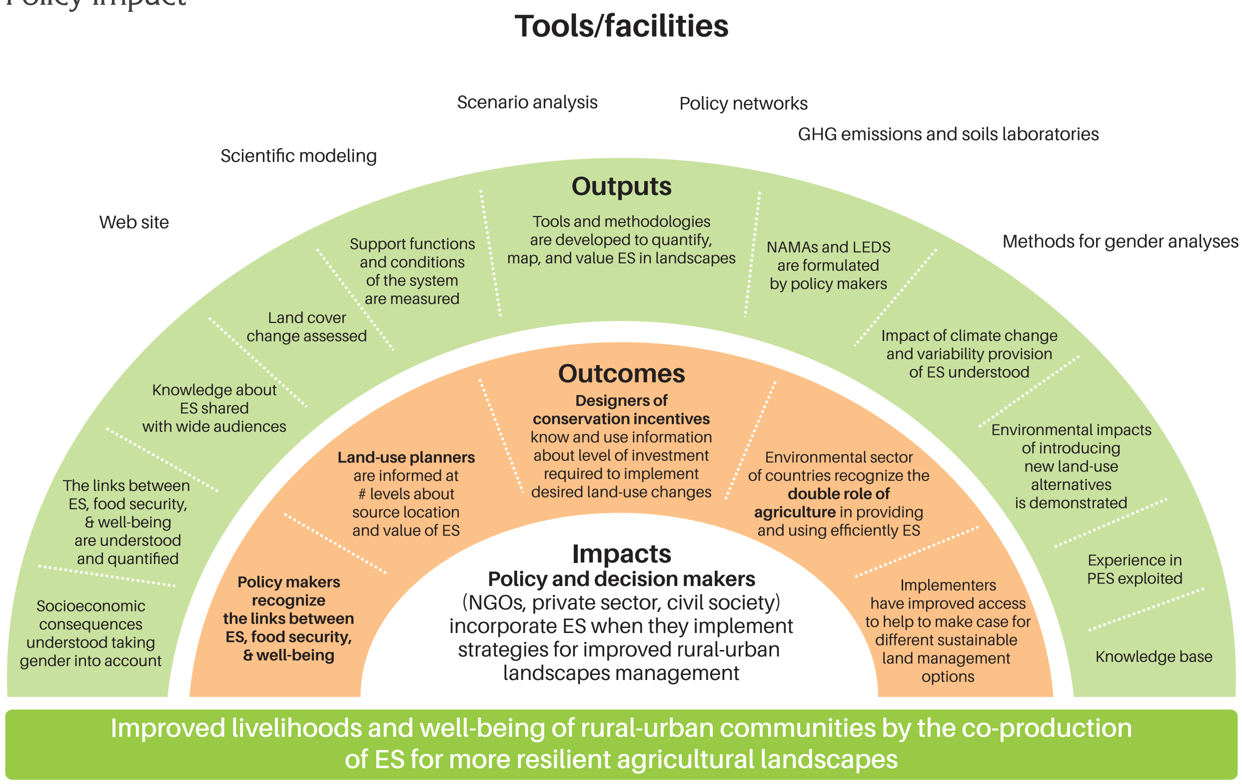
Next users as partners

- National policy makers (environmental and agricultural sectors).
- Global ES platforms advising global ES agendas
  - Ecosystem Services Partnership
  - IPBES
  - TEEB
- Local farming communities.

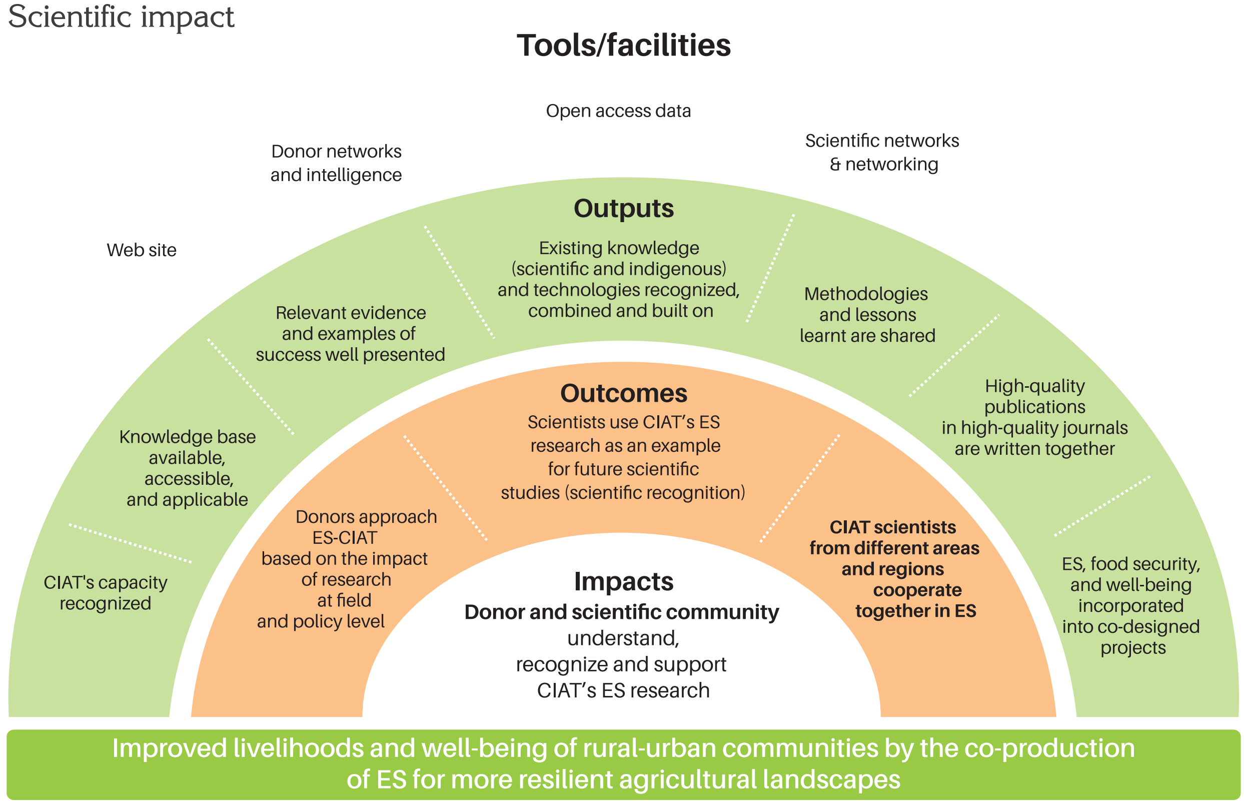
Annex

Theory of change diagram for the Ecosystem Services Strategic Initiative

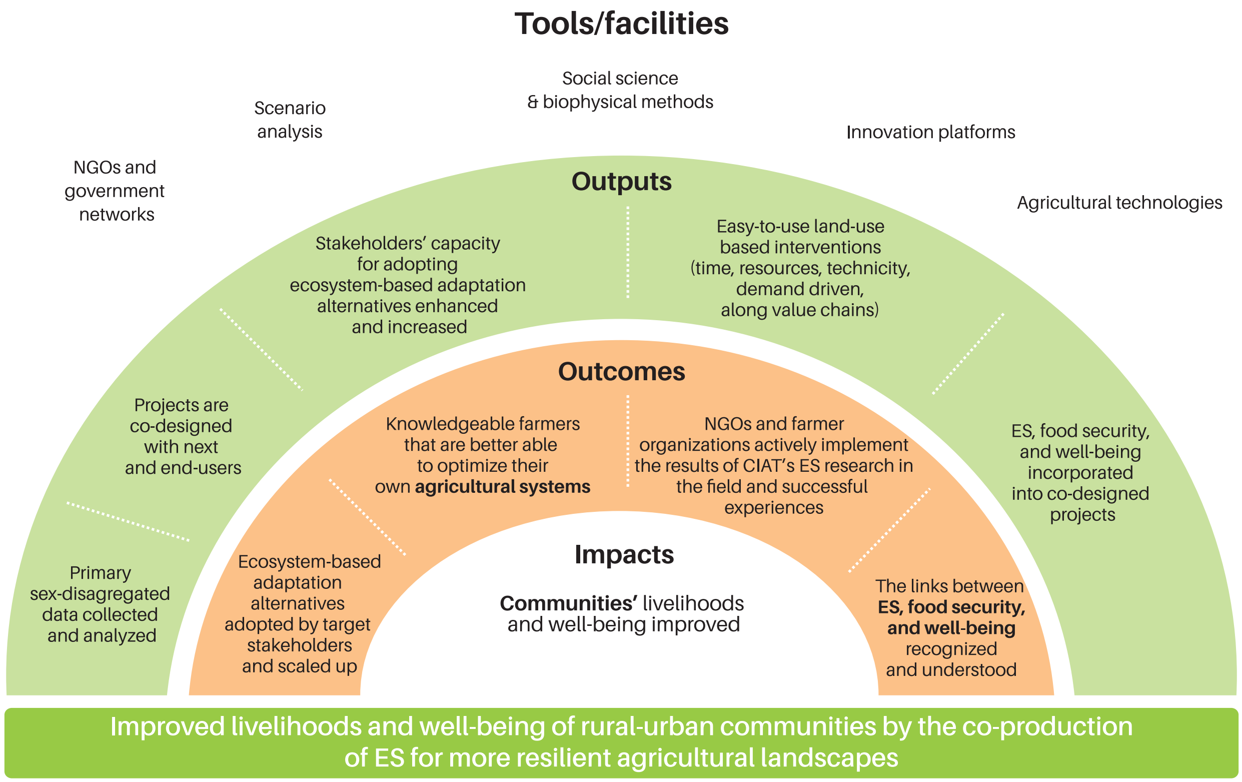
Policy impact



Scientific impact



Community impact



References

Bommarco R; Kleijn D; Potts SG. 2013. Ecological intensification: Harnessing ecosystem services for food security. Trends in Ecology & Evolution 28:230–238.

Célleri R; Feyen J. 2009. The hydrology of tropical Andean ecosystems: Importance, knowledge status, and perspectives. Mountain Research and Development 29:350–355.

Corvalan C; Hales S; McMichael A. 2005. Ecosystems and human well-being: Health synthesis. A report of the Millennium Ecosystem Assessment. (ed. MEA). World Health Organization. 53 p.

Costanza R. 1999. Ecological sustainability, indicators, and climate change. Paper presented at the IPCC Expert Meeting on Development, Equity and Sustainability. Colombo, Sri Lanka, 27–29 April.

Daily GC; Alexander S; Ehrlich PR; Goulder L; Lubchenco J; Matson PA; Mooney HA; Postel S; Schneider SH; Tilman D; Woodwell GM. 1997. Ecosystem services: Benefits supplied to human societies by natural ecosystems. Issues in Ecology No. 2. Ecological Society of America, Washington, D.C., USA. 16 p.

Eilers EJ; Kremen C; Greenleaf SS; Garber AK; Klein A-M. 2011. Contribution of pollinator-mediated crops to nutrients in the human food supply. PLoS ONE 6(6):e21363.

Fisher B; Turner RK; Morling P. 2009. Defining and classifying ecosystem services for decision making. Ecological Economics 68:643–653.

Kill J. 2014. Economic valuation of nature: The price to pay for conservation? A critical exploration. Rosa-Luxemburg-Stiftung, Brussels Office. Brussels, Belgium. 58 p.

Klein A-M; Vaissière BE; Cane JH; Steffan-Dewenter I; Cunningham SA; Kremen C; Tscharntke T. 2007. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B 274:303–313.

Milder JC; Scherr SJ; Bracer C. 2010. Trends and future potential of payment for ecosystem services to alleviate rural poverty in developing countries. Ecology and Society 15(2):4.

Nkonya E; Winslow M; Reed M; Mortimore M; Mirzabaev A. 2011. Monitoring and assessing the influence of social, economic and policy factors on sustainable land management in drylands. Land Degradation & Development 22(2):240–247.

Quintero M. (ed.). 2010. Servicios ambientales hidrológicos en la Región Andina – Estado del conocimiento, la acción y la política para asegurar su provisión mediante esquemas de pago por servicios ambientales. Instituto de Estudios Peruanos (IEP); Consorcio para el Desarrollo Sostenible de la Ecorregión Andina (CONDESAN). (Agua y Sociedad, 12; Serie Panorama Andino, 1). Lima, Perú. 273 p.

Stallman HR. 2011. Ecosystem services in agriculture: Determining suitability for provision by collective management. Ecological Economics 71:131–139.

TEEB (The Economics of Ecosystems & Biodiversity). 2014. The Economics of Ecosystems and Biodiversity (TEEB) for Agriculture & Food – Concept Note. 20 p.

ten Brink P; Badura T; Bassi S; Daly E; Dickie I; Ding H; Gantioler S; Gerdes H; Kettunen M; Lago M; Lang S; Markandya A; Nunes PALD; Pieterse M; Rayment M; Tinch R. 2011. Estimating the overall economic value of the benefits provided by the Natura 2000 Network. Final Report to the European Commission, DG Environment on Contract ENV.B.2/SER/2008/0038. Institute for European Environmental Policy / GHK / Ecologic, Brussels, Belgium. 222 p.

Recommended readings

About biological control

Allsopp MH; de Lange WJ; Veldtman R. 2008. Valuing insect pollination services with cost of replacement. PLoS ONE 3(9):e3128.

Bommarco R; Kleijn D; Potts SG. 2013. Ecological intensification: Harnessing ecosystem services for food security. Trends in Ecology & Evolution 28:230–238.

Hein L. 2009. The economic value of the pollination service, a review across scales. Open Ecology Journal 2:74–82.

Allen-Wardell G; Bernhardt P; Bitner R; Burquez A; Buchmann S; Cane J; Cox PA; Dalton V; Feinsinger P; Ingram M; Inouye D; Jones CE; Kennedy K; Kevan P; Koopowitz H; Medellín RA; Medellín-Morales S; Nabhan GP; Pavlik B; Tepedino VJ; Torchio P; Walter S. 1998. The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. Conservation Biology 12(1):8–17.

Ricketts TH; Daily GC; Ehrlich PR; Michener CD. 2004. Economic value of tropical forest to coffee production. Proceedings of the National Academy of Sciences of the United States of America 101:12579–12582.

About ecological intensification

Barrios E. 2007. Soil biota, ecosystem services and land productivity. Ecological Economics 64:269–285.

Bommarco R; Kleijn D; Potts SG. 2013. Ecological intensification: Harnessing ecosystem services for food security. Trends in Ecology & Evolution 28:230–238.

Costanza R. 1999. Ecological sustainability, indicators, and climate change. Paper presented at the IPCC Expert Meeting on Development, Equity and Sustainability. Colombo, Sri Lanka, 27–29 April.

Davies B; Baulcombe D; Crute I; Dunwell J; Gale M; Jones J; Pretty J; Sutherland W; Toulmin C. 2009. Reaping the benefits: Science and the sustainable intensification of global agriculture. Royal Society: London, UK. 72 p.

Padoch C; Sunderland TCH. 2014. Managing landscapes for greater food security and improved livelihoods. Unasylva 241, Vol. 64. 2013/2. p. 3–13.

Tilman D; Cassman KG; Matson PA; Naylor R; Polasky S. 2002. Agricultural sustainability and intensive production practices. Nature 418:671–677.

About the concept of ecosystem services

Daily G. (ed.). 1997. Nature's services: societal dependence on natural ecosystems. Island Press: Washington, D.C., USA. 392 p.

Daily GC; Alexander S; Ehrlich PR; Goulder L; Lubchenco J; Matson PA; Mooney HA; Postel S; Schneider SH; Tilman D; Woodwell GM. 1997. Ecosystem services: Benefits supplied to human societies by natural ecosystems. Issues in Ecology No. 2. Ecological Society of America, Washington, D.C., USA. 16 p.

De Groot RS; Wilson MA; Boumans RM. 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecological Economics 41:393–408.

Fisher B; Turner RK; Morling P. 2009. Defining and classifying ecosystem services for decision making. Ecological Economics 68:643–653.

Hooper D; Chapin III FS; Ewel JJ; Hector A; Inchausti P; Lavorel S; Lawton JH; Lodge DM; Loreau M; Naeem S; Schmid B; Setälä H; Symstad AJ; Vandermeer J; Wardle DA. 2005. Effects of biodiversity on ecosystem functioning: A consensus of current knowledge. Ecological Monographs 75:3–35.

Villa F; Bagstad KJ; Voigt B; Johnson GW; Athanasiadis IN; Balbi S. 2014. The misconception of ecosystem disservices: How a catchy term may yield the wrong messages for science and society. Ecosystem Services 10:52–53.

About ecosystem services related to agriculture

Barrios E. 2007. Soil biota, ecosystem services and land productivity. Ecological Economics 64:269–285.

Dale VH; Polasky S. 2007. Measures of the effects of agricultural practices on ecosystem services. Ecological Economics 64:286–296.

Eilers EJ; Kremen C; Greenleaf SS; Garber AK; Klein A-M. 2011. Contribution of pollinator-mediated crops to nutrients in the human food supply. PLoS ONE 6(6):e21363.

Klein A-M; Vaissière BE; Cane JH; Steffan-Dewenter I; Cunningham SA; Kremen C; Tscharntke T. 2007. Importance of pollinators in changing landscapes for world crops. Proceedings of the Royal Society B 274:303–313.

Lwasa S; Mugagga F; Wahab B; Simon D; Connors J; Griffith C. 2014. Urban and peri-urban agriculture and forestry: Transcending poverty alleviation to climate change mitigation and adaptation. Special Issue on Urban Adaptation to Climate/Environmental Change. Urban Climate 7:92–106.

Poppy GM; Chiotha S; Eigenbrod F; Harvey CA; Honzák M; Hudson MD; Jarvis A; Madise NJ; Schreckenberg K; Shackleton CM; Villa F; Dawson TP. 2014a. Food security in a perfect storm: Using the ecosystem services framework to increase understanding. Philosophical Transactions of the Royal Society B: 369:20120288.

Poppy GM; Jepson PC; Pickett JA; Birkett MA. 2014b. Achieving food and environmental security: New approaches to close the gap. Philosophical Transactions of the Royal Society B 369:20120272.

Power AG. 2010. Ecosystem services and agriculture: Tradeoffs and synergies. Philosophical Transactions of the Royal Society B 365:2959–2971.

Swift MJ; Izac A; van Noordwijk M. 2004. Biodiversity and ecosystem services in agricultural landscapes—are we asking the right questions? Agriculture, Ecosystems & Environment 104:113–134.

Swinton SM; Lupi F; Robertson GP; Hamilton SK. 2007. Ecosystem services and agriculture: Cultivating agricultural ecosystems for diverse benefits. Ecological Economics 64:245–252.

Tilman D; Cassman KG; Matson PA; Naylor R; Polasky S. 2002. Agricultural sustainability and intensive production practices. Nature 418:671–677.

Tscharntke T; Klein AM; Kruess A; Steffan-Dewenter I; Thies C. 2005. Landscape perspectives on agricultural intensification and biodiversity – ecosystem service management. Ecology Letters 8(8):857–874.

Wood S; Sebastian K; Scherr SJ. 2000. Pilot Analysis of Global Ecosystems: Agroecosystems. A joint study by the International Food Policy Research Institute (IFPRI) and World Resources Institute (WRI), IFPRI; WRI: Washington, D.C., USA. 111 p.

Zhang W; Ricketts TH; Kremen C; Carney K; Swinton SM. 2007. Ecosystem services and dis-services to agriculture. Ecological Economics 64:253–260.

About payment for ecosystem services

Daniels AE; Bagstad K; Esposito V; Moulaert A; Rodríguez CM. 2010. Understanding the impacts of Costa Rica's PES: Are we asking the right questions? Ecological Economics 69:2116–2126.

Dillaha T; Ferraro P; Huang M; Southgate D; Upadhyaya S; Wunder S. 2007. Payments for Watershed Services – Regional Syntheses. USAID PES Brief 7. United States Agency for International Development (USAID), Washington, D.C., USA. 18 p.

Engel S; Pagiola S; Wunder S. 2008. Designing payments for environmental services in theory and practice: An overview of the issues. Ecological Economics 65: 663–674.

Farley J; Costanza R. 2010. Payments for ecosystem services: From local to global. Ecological Economics 69:2060–2068.

Goldman-Benner RL; Benitez S; Boucher T; Calvache A; Daily G; Kareiva P; Kroeger T; Ramos A. 2012. Water funds and payments for ecosystem services: Practice learns from theory and theory can learn from practice. Oryx 46:55–63.

Goldman RL; Tallis H. 2009. A critical analysis of ecosystem services as a tool in conservation projects. Annals of the New York Academy of Sciences 1162:63–78.

Johnson JA; Runge CF; Senauer B; Foley J; Polasky S. 2014. Global agriculture and carbon trade-offs. Proceedings of the National Academy of Sciences of the United States of America 111:12342–12347.

Kill J. 2014. Economic valuation of nature: The price to pay for conservation? A critical exploration. Rosa-Luxemburg-Stiftung, Brussels Office. Brussels, Belgium. 58 p.

Koellner T; Sell J; Navarro G. 2010. Why and how much are firms willing to invest in ecosystem services from tropical forests? A comparison of international and Costa Rican firms. Ecological Economics 69:2127–2139.

Krishna VV; Drucker AG; Pascual U; Raghu PT; King E. 2013. Estimating compensation payments for on-farm conservation of agricultural biodiversity in developing countries. Ecological Economics 87:110–123.

Landell-Mills N; Porras IT. 2002. Silver bullet or fools' gold?: A global review of markets for forest environmental services and their impact on the poor. Instruments for Sustainable Private Sector Forestry series. International Institute for Environment and Development (IIED), London, UK. 272 p.

Milder JC; Scherr SJ; Bracer C. 2010. Trends and future potential of payment for ecosystem services to alleviate rural poverty in developing countries. Ecology and Society 15(2):4.

Narloch U; Drucker AG; Pascual U. 2011. Payments for agrobiodiversity conservation services for sustained on-farm utilization of plant and animal genetic resources. Ecological Economics 70:1837–1845.

Narloch U; Pascual U; Drucker AG. 2013. How to achieve fairness in payments for ecosystem services? Insights from agrobiodiversity conservation auctions. Land Use Policy 35:107–118.

Pagiola S; Ríos AR; Arcenas A. 2008. Can the poor participate in payments for environmental services? Lessons from the Silvopastoral Project in Nicaragua. Environment and Development Economics 13:299–325.

Reynolds TW; Farley J; Huber C. 2010. Investing in human and natural capital: An alternative paradigm for sustainable development in Awassa, Ethiopia. Ecological Economics 69:2140–2150.

Sommerville MM; Jones JP; Milner-Gulland E. 2009. A revised conceptual framework for payments for environmental services. Ecology and Society 14(2):34.

ten Brink P; Badura T; Bassi S; Daly E; Dickie I; Ding H; Gantioler S; Gerdes H; Kettunen M; Lago M; Lang S; Markandya A; Nunes PALD; Pieterse M; Rayment M; Tinch R. 2011. Estimating the overall economic value of the benefits provided by the Natura 2000 Network. Final Report to the European Commission, DG Environment on Contract ENV.B.2/SER/2008/0038. Institute for European Environmental Policy / GHK / Ecologic, Brussels, Belgium. 222 p.

Vågen T-G; Winowiecki. 2013. Mapping of soil organic carbon stocks for spatially explicit assessments of climate change mitigation potential. Environmental Research Letters. 8. DOI:10.1088/1748-9326/8/1/015011

Vatn A; Barton DN; Lindhjem H; Movik S; Ring I; Santos R. 2011. Can markets protect biodiversity? An evaluation of different financial mechanisms. Noragric Report No. 60. Department of International Environment and Development Studies (Noragric) at Norwegian University of Life Sciences (UMB), Norway. 105 p.

Winowiecki L; Vågen T-G; Huising J. 2015. Effects of land cover on ecosystem services in Tanzania: A spatial assessment of soil organic carbon. Geoderma. DOI:10.1016/j.geoderma.2015.03.010

Wunder S. 2005. Payments for environmental services: Some nuts and bolts. CIFOR Occasional Paper No. 42. Center for International Forestry Research (CIFOR), Jakarta, Indonesia. 24 p.

Wunder S. 2006. Are direct payments for environmental services spelling doom for sustainable forest management in the tropics? Ecology and Society 11(2):23.

Wunder S. (2007). The efficiency of payments for environmental services in tropical conservation. Conservation Biology 21(1):48–58.

Wunder S; Albán M. 2008. Decentralized payments for environmental services: The cases of Pimampiro and PROFAFOR in Ecuador. Ecological Economics 65: 685–698.

About watershed services

Baron JS; LeRoy Poff N; Angermeier PL; Dahm CN; Gleick PH; Hairston Jr NG; Jackson RB; Johnston CA; Richter BD; Steinman AD. 2002. Meeting ecological and societal needs for freshwater. Ecological Applications 12(5):1247–1260.

Célleri R; Feyen J. 2009. The hydrology of tropical Andean ecosystems: Importance, knowledge status, and perspectives. Mountain Research and Development 29:350–355.

Dillaha T; Ferraro P; Huang M; Southgate D; Upadhyaya S; Wunder S. 2007. Payments for Watershed Services – Regional Syntheses. USAID PES Brief 7. United States Agency for International Development (USAID), Washington, D.C., USA. 18 p.

Goldman-Benner RL; Benitez S; Boucher T; Calvache A; Daily G; Kareiva P; Kroeger T; Ramos A. 2012. Water funds and payments for ecosystem services: Practice learns from theory and theory can learn from practice. Oryx 46:55–63.

Quintero M. (ed.). 2010. Servicios ambientales hidrológicos en la Región Andina – Estado del conocimiento, la acción y la política para asegurar su provisión mediante esquemas de pago por servicios ambientales. Instituto de Estudios Peruanos (IEP); Consorcio para el Desarrollo Sostenible de la Ecorregión Andina (CONDESAN). (Agua y Sociedad, 12; Serie Panorama Andino, 1). Lima, Peru. 273 p.

CIAT Publication No. 406

Design and layout	Daniel Gutiérrez and Lorena García Payán
Production editing	Victoria Eugenia Rengifo
Printing	Velásquez Digital S.A.S. Cali, Colombia

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