



Ecosystem services and adaptation for agriculture and food security: analysis of two decades (1991–2011) of financing by the Global Environment Facility

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Abstract

Investing in global environmental and adaptation benefits in the context of agriculture and food security initiatives can play an important role in promoting sustainable intensification. This is a priority for the Global Environment Facility (GEF), created in 1992 with a mandate to serve as financial mechanism of several multilateral environmental agreements. To demonstrate the nature and extent of GEF financing, we conducted an assessment of the entire portfolio over a period of two decades (1991–2011) to identify projects with direct links to agriculture and food security. A cohort of 192 projects and programs were identified and used as a basis for analyzing trends in GEF financing. The projects and programs together accounted for a total GEF financing of US\$1,086.8 million, and attracted an additional US\$6,343.5 million from other sources. The value-added of GEF financing for ecosystem services and resilience in production systems was demonstrated through a diversity of interventions in the projects and programs that utilized US\$810.6 million of the total financing. The interventions fall into the following four main categories in accordance with priorities of the GEF: sustainable land management (US\$179.3 million), management of agrobiodiversity (US\$113.4 million), sustainable fisheries and water resource management (US\$379.8 million), and climate change adaptation (US\$138.1 million). By aligning GEF priorities with global aspirations for sustainable intensification of production systems, the study shows that it is possible to help developing countries tackle food insecurity while generating global environmental benefits for a healthy and resilient planet.

Introduction

With world population projected to reach 9.5 billion by 2050, it has been suggested that as much as 70–100% more food will be needed in order to meet demands (World Bank, 2008). Sustaining and intensifying agricultural, livestock and fisheries production is, therefore, essential for achieving global food security. As defined by the Food and Agriculture Organization (FAO, 2002), food security “is a situation that exists when all people at all times have physical, social and economic access to sufficient, safe

and nutritious food that meets their dietary needs and food preferences for an active and healthy life.” Food security depends on three main factors — availability, access, and utilization, all of which are directly underpinned by ecosystem services.

Ecosystem services — provisioning, regulating, supporting and cultural — depend on efficient functioning of ecosystems, including the natural cycles and flows that underpin life on the planet (Millen-

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nium Ecosystem Assessment, 2005). From low-input and smallholder systems in most developing countries to the high-input and intensive systems of the developed world, ecosystem services play an important role in crop, livestock, fisheries and forest production. For example, supporting services (e.g. healthy soils, hydrological flows, and nutrient cycling) in production systems are essential for sustained productivity of food. Similarly, provisioning services (e.g. genetic resources) and regulating services (e.g. pollination) are key to the diversity and nutritional content of food crops and animals.

Harnessing the ecosystem services in production systems requires a careful and deliberate management of the natural assets (land, water and biota) to ensure long-term sustainability and resilience (Boelee, 2011; Bommarco et al., 2013). Investing in the management of ecosystem services that underpin productivity of agroecosystems is therefore an important priority in the global aspirations for achieving food security.

While much can be done to achieve food security by reworking global food systems, the need to increase food and feed production will likely increase pressure on the planet's land, freshwater, and biodiversity (Foley, 2011). It implies, however, that food production must be intensified to meet the demands of a growing world population. But agricultural intensification through increased irrigation and chemical fertilizers also tends to compromise the natural processes and services that underpin sustainability and resilience of production systems. Meeting the food security and sustainability challenges of the coming decades is possible, but will require considerable changes in nutrient and water management (Mueller et al., 2012). This reinforces the need for innovations that increase agricultural productivity, while sustaining or improving environmental goods and services in the face of climate change.

Sustainable intensification, through fostering best practices for crops, livestock, forestry and aquaculture, has been considered a key and desirable way to increase the productivity of existing land and water resources in food production (Godfray et al., 2010, Foley et al. 2011, Tilman et al., 2011). Much of the world experiences yield gaps where productiv-

ity may be limited by management (Foley, 2011). Increasing productivity in such cases involves the prudent and efficient use of production farm inputs, improved varieties and breeds, more efficient use of labor and better farm management. The challenge, however, is ensuring that all such intensification efforts are focused on existing production lands, including those under pasture (Phalan et al., 2011; Tschardt et al., 2012). When climate change is considered, practices may be shifted to lands more suited for livestock or crops, and through rehabilitation or conservation of existing production lands based on their likelihood of productivity in the short- and long-term (Vermeulen et al., 2012; Wheeler & von Braun, 2013).

The need for generating global environment benefits through investments in agriculture and food security is an important priority for the Global Environment Facility (GEF), created in 1992 to serve as financial mechanism of the Rio Conventions — the Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCCC), the United Nations Convention to Combat Desertification (UNCCD) and the Stockholm Convention. The GEF is the world's leading public financial fund dedicated to smart, environmentally sound choices that boost local economies and protect the planet. GEF provides financing to 146 recipient countries through the GEF Trust Fund, and two other trust funds that specifically support climate change adaptation (CC-A) in eligible countries: the Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (SCCF).

For the GEF Trust Fund, financing is through five focal area windows: Biodiversity (BD), Land Degradation (LD), International Waters (IW), Climate Change Mitigation (CC-M), and Chemicals and Waste (CW). Financing through LDCF is driven largely by least developed countries' urgent and immediate adaptation needs, identified and prioritized in country-driven plans known as National Action Plans for Adaptation (NAPAs). The LDCF is primarily leveraged by eligible countries to finance the full cost of urgent and immediate adaptation actions that reduce vulnerability and increase adaptive capacity to the impacts of climate change. The SCCF has adaptation as its top priority in all developing countries that are non-Annex I parties to the UNFCCC. Through its two



active financing windows, the SCCF supports adaptation measures in various development sectors.

Because of the importance of agriculture and food security as a development priority in many recipient countries, the GEF has been a major source of financing to address environment and natural resource management challenges. Yet there has been no systematic assessment of how GEF financing to generate global environmental and adaptation benefits supports agriculture and food security. This study addresses this need by analyzing GEF investments in the context of agriculture and food security projects financed over a period of two decades (1991-2011). The objective was threefold: a) synthesize GEF experience in supporting the agriculture and food security agenda of eligible countries; b) demonstrate the GEF's value-added for financing global environmental and adaptation benefits in the context of agriculture and food security investments; and c) establish a basis for increasing GEF role in fostering sustainability and resilience for food security.

The approach to GEF financing emphasizes targeted investments in projects that address objectives of the focal areas, including support to countries for the implementation of the Conventions for which the GEF serves as financial mechanism. The value-added of GEF financing is evident from the diversity of interventions in projects, and the potential for sustainability of outcomes for people and the global environment. Since the study did not include actual results from implementation of the projects, we do not draw any explicit conclusions about impacts of GEF financing. But by aligning focal area priorities with global aspirations for sustainable food production, we conclude that the GEF is well-placed to help feed the world while investing in our planet.

Analytical Approach

The underlying rationale for this study is that GEF financing for projects addressing agriculture and food security enables eligible countries to contribute global environment and adaptation benefits in production systems. Projects and programs included were therefore identified on the basis of their linkage to agriculture and food security; this,

in turn, was determined from actual investment of GEF resources in project components that explicitly target the maintenance or improvement of ecosystem services in production systems and in climate change resilience.

Identification of Projects and Programs

To ensure a comprehensive analysis of GEF investments in the context of agriculture and food security, we used three parallel portfolio assessments to identify projects and programs. These parallel assessments were necessary to ensure consistency with the approaches and priorities of GEF financing through the focal area and trust fund windows. The first was focused on projects and programs financed under the GEF Trust Fund, and primarily through the Biodiversity, Land Degradation and Climate Change Mitigation focal area windows that include land-based priorities. The GEF project database was initially screened using keywords that reflect direct links with priorities and activities in production systems, such as *agricultural production, food production, land use, agro-ecosystems, agrobiodiversity, crop production, genetic resources, livestock production, farm management, farmers, silvopastoral systems, agropastoral, integrated landscapes, and irrigation management*. A total of 308 distinct projects and programs were identified as appropriate for the period covered, of which only 96 were determined to be designed specifically in the context of agriculture and food security investments.

The second assessment was focused specifically on projects and programs financed through the International Waters focal area, which invests primarily in management of water resources that are transboundary in nature and involve multiple countries. For the period covered by this study, 51 projects and programs financed with the focal area resources were determined to have direct links to agriculture and food security. The third assessment was focused exclusively on projects financed under the LDCF and SCCF, for which climate change adaptation benefit is the priority. A total 78 projects (49 under the LDCF and 29 under the SCCF) approved during the period covered by the study were identified, of which 45 (28 LDCF and 17 SCCF) were determined to include interventions supporting food security. The projects primarily address climate change adaptation in the agriculture sector, focus-



ing on systems and capacities, best practices for both crop and livestock production and approaches to increase resilience of production systems.

Analysis of Trends in GEF Financing

The cohort of 192 projects and programs supporting agriculture and food security was included in the subsequent analysis of trends in GEF financing. We analyzed trends by replenishment phase, type of Trust Fund, focal areas (BD, LD, CC-M, CC-A, and IW), and geographical regions. We used the full amount of GEF grants and co-financing invested in all 192 projects and programs, from the pilot phase (1991-1992) through the first full year (2010-2011) of the fifth replenishment phase of the GEF Trust Fund. Projects financed from a single focal area window are considered as “stand-alone” projects, while those financed from multiple focal area windows are labelled “multi-focal area” (MFA). We analyzed regional trends based on the four GEF regions: Africa, Europe and Central Asia (ECA), Asia, and Latin America and Caribbean. In addition, we considered as separate all regional projects targeting specific geographies and global projects covering multiple countries.

Analysis of Financing Trends for Project Components

We conducted a detailed analysis of the 192 projects and programs to determine GEF financing for specific components and interventions supporting agriculture and food security. For GEF Trust Fund projects, we based the analysis on specific global environmental benefits associated with focal area windows from which resources are drawn. Global environmental benefits are essentially ecosystem services in production landscapes generated through management of land resources (e.g. soil and water conservation, soil carbon sequestration, improvements in vegetative cover); agricultural biodiversity (e.g. preserving genetic diversity, on-farm diversification); and aquatic ecosystems (e.g. protection of species and habitats for fisheries, sustainable flow and improved quality of water for consumptive use). For LDCF and SCCF projects, investments are associated with adaptation benefits in the agriculture and food security sector, such as reducing vulnerability and increasing resilience to climate variability and projected effects of climate change.

We analyzed financing for project and program components under four categories of direct relevant to agriculture and food security: sustainable land management, management of agricultural biodiversity (or agrobiodiversity), sustainable fisheries and water resources management, and climate change adaptation for food security. These categories are consistent with priorities of the different but complementary funding windows in the GEF. For the first three categories, GEF financing is focused on addressing global environment benefits in the context of crop and livestock production, as well as management of freshwater and fisheries. The fourth category of climate change adaptation includes GEF financing through the LDCF and SCCF.

Following the approach used to identify and select projects, we performed analysis of GEF financing separately for the GEF Trust Fund and the LDCF/SCCF. For projects and programs under the GEF Trust Fund, we derived grant amounts from the Results-based Management (RBM) framework. Project components in the RBM framework were considered relevant if the target outcomes and outputs focused directly on safeguarding ecosystem services (provision, regulating, supporting and cultural) and enhancing resilience of production systems. We counted the full amount of GEF grant for each component as contribution toward supporting agriculture and food security. For most of the projects and programs, there were components framed to accommodate a diversity of interventions in an integrated and cross-cutting manner at appropriate scales. Therefore, the breakdown of GEF grants allocated for specific components was aggregated across all projects irrespective of focal area, and whether the project was designed as stand-alone or multi-focal area.

Findings

Together, the 192 projects and programs with links to agriculture and food security accounted for a total GEF financing of US\$1,086.8 million and an additional US\$6,343.5 million in co-financing during the period covered by the study (Figure 1).

Trends in GEF financing

Financing trends over the years since the GEF's inception showed a steady increase during the first

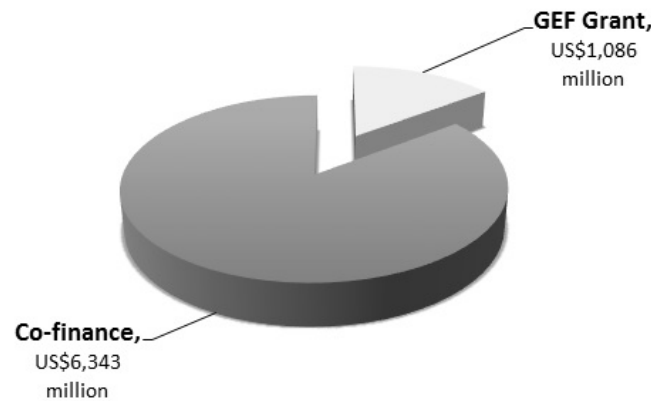


Figure 1: Total GEF Grant and Co-finance for all projects and programs with links to Agriculture and Food Security [Note: Total GEF amount includes grants from the LDCF and SCCF]

Table 1: Breakdown of GEF financing and Co-finance by Replenishment Phase and Trust Fund (Note: LDCF and SCCF funding only started during the GEF–3, and GEF–5 amount includes only projects and programs approved during the first full year of the Replenishment Phase)

Replenishment Phase / Trust Fund	Number of projects	GEF Amount (US\$)	Co-finance (US\$)
Pilot	4	15,056,300	10,230,000
GEF-1	5	28,592,764	105,305,500
GEF-2	25	124,704,706	346,177,783
GEF-3	36	208,186,812	980,919,418
GEF-4	69	285,166,757	2,165,149,224
GEF-5	8	217,831,857	1,905,366,429
LDCF	28	126,062,669	310,069,981
SCCF	17	81,241,762	520,284,507
TOTAL	192	1,086,843,627	6,343,502,842

three replenishment phases, but a significant jump during the fourth phase (Table 1). The fourth GEF replenishment phase (GEF–4) accounted for 69 projects, with US\$285.1 million (26.2 %) of the total GEF funding, and US\$2,165.1 million (34.1%) of total co-financing.

The major increase in GEF financing between GEF–3 and GEF–4 coincides with the start of the first full replenishment phase during which GEF resources

were allocated to a dedicated LD focal area. This focal area specifically targets maintenance of ecosystem services in production landscapes through sustainable land management. While only 19 of the stand-alone BD and LD focal area projects were financed during GEF–3, the number increased to 30 during GEF–4. At the same time, the number of MFAs jumped from six during GEF–3 to 15 in GEF–4. The proportionally high amount for GEF–5 is due mainly to three major programs that will eventually

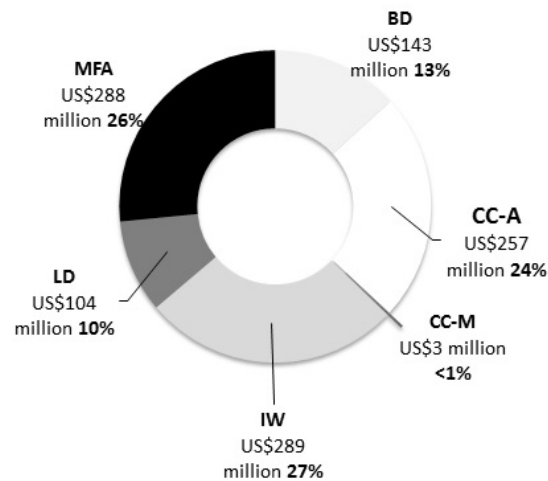


Figure 2: Amounts and Proportional breakdown of GEF Financing by Focal Area (Note: CC-A includes all financing for climate change adaptation; MFAs include financing from multiple focal areas)

be delivered through separate sub-projects. These observations are further supported by the focal area trends in GEF financing.

GEF financing under the International Waters (IW) accounted for the largest single focal area funding with US\$289.09 million, representing about 27% of total GEF grants (Figure 2). Since inception of the GEF, the IW focal area has been the primary entry point for GEF investments in freshwater and coastal marine ecosystems; these focus mainly on mobilizing intergovernmental or regional agreements on policies and actions for sustainable management of shared aquatic systems. Hence the focal area plays a major role in management of fisheries and in safeguarding transboundary water resources that underpin production systems in developing country regions.

Financing for stand-alone projects under the BD focal area accounted for US\$143.9 million (13%) of the total GEF grant. The BD focal area has been a significant entry point for projects addressing agricultural biodiversity (or agrobiodiversity), with a focus on needs and priorities for protection of genetic resources (crops and livestock breeds), management of below-ground biodiversity and harnessing pest control and pollination services in production systems. Hence, some components of agrobiodiversity projects related to soil health also have direct relevance for the LD focal area.

In addition to stand-alone projects under the LD

focal area accounted for US\$104.7 million (10%) of total GEF financing, even though the focal area only became fully operational during GEF-3. The projects are designed to ensure a direct focus on sustainable land management interventions that generate global environment benefits while supporting the livelihood needs of poor land users. As a result, components in some of the projects also contribute to Biodiversity focal area objectives through conservation of agrobiodiversity.

Overall financing for CC-A amounted to US\$257.4 million (24%) of the total GEF grant. As noted previously, CC-A focal area investments are directed towards building climate resilience in the agriculture and food security sector. CC-A projects address both the vulnerability of production systems and the practices associated with those systems. The CC-M focal area accounted for only US\$3 million of the total GEF grant, which was through a single stand-alone project on “Alternatives to Slash-and-Burn”. This project was designed to assess potential of alternative land use practices such as agroforestry, that generate carbon benefits while increasing on-farm productivity in the tropical forest margins. In addition to the stand-alone focal area investments, 30 multi-focal area (MFA) projects, three MFA programs, and one multi-trust fund program were designed to leverage GEF resources from multiple GEF windows based on their objectives. These projects account for US\$288.5 million (26 %) of the total GEF grant, with contributions from the BD, LD, IW, and CC-M focal areas. In principle, MFA

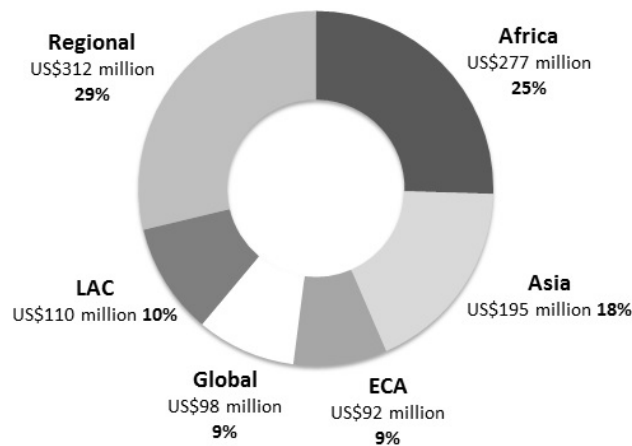


Figure 3: Amounts and Proportional distribution of GEF Financing by Geographical Regions (Note: CC-A includes all financing for climate change adaptation; MFAs include financing from multiple focal areas)

Table 2: GEF financing for components supporting Agriculture and Food Security (Note: Figures in parentheses are percentages of the total)

Type of Investments	GEF funding ('000 \$)
Sustainable Land Management	179,317.9 (22)
Management of Agricultural biodiversity	113,432.8 (14)
Sustainable Fisheries and Water Resource Management	379,819.2 (47)
Climate Change Adaptation for Food Security	138,119.4 (17)
Total Investments	810,688.9 (100)

and MTF project frameworks reflect priorities of the different focal areas from which GEF resources were used. However, most multi-focal area projects are often designed with integrated approaches that lead to multiple environment benefits. This helps to streamline investments for maximizing synergies during project implementation and fostering innovations in management of natural resources (land, water and biodiversity) to maintain ecosystem service flows in production systems.

Regionally, the breakdown of GEF financing shows countries in Africa accounting for US\$277.1 million (25%) of the total grant, followed by those in Asia with US\$195.9 million (18%), LAC with US\$110.2 million (10%) and ECA US\$92.5 million (9%) (Figure 3). These trends are consistent with global needs for addressing food insecurity since the world's largest

population of hungry and malnourished people reside mainly in Africa and Asia. The majority of countries in these two regions are well placed to leverage GEF resources for investment in the agriculture and food security sector.

In addition to country-specific projects, there were 25 regional projects with links to agriculture and food security, with 12 focused on the Africa region, six in Asia, five in LAC and two in the ECA region. The total grant of US\$312.5 million (28.7%) invested through regional projects mainly targeted specific eco-regions or multiple countries within the four geographical regions. The financing is also leveraged for thematic and cross-cutting initiatives that contributed knowledge for planning and decision-support. For example, several major regional projects were designed to strengthen knowledge



management for agrobiodiversity (genetic resources) in Africa, the Middle East and North Africa, Central Asia and the Andes Region.

The emphasis on eco-regional or multi-country projects is a primary feature of IW focal area financing, which enables governments to cooperatively address systemic threats to water and fisheries resources that extend beyond national boundaries. IW projects benefited all four geographical regions, including coverage of major lake and river basins. Global projects, which accounted for only US\$98.4 million (9%) of the total GEF grant, mainly addressed thematic issues that generate knowledge resources to support country-level efforts. There were thirteen such projects, of which six were under the IW focal area and covering issues related to management of fisheries and nutrient pollution. In the terrestrial realm, global projects also targeted knowledge needs for managing pollinators and below-ground biodiversity in production landscapes.

Trends in GEF Financing for Project Components and Interventions

The analysis of all 192 projects and programs included in the study showed that GEF grants allocated to specific components supporting agriculture and food security amounted to an aggregate total of US\$810.6 million, about 75 % of the total GEF financing (Table 2). Sustainable fisheries and water resource management used the largest amount of GEF Trust Fund resources: US\$379.8 million, or 47% of the total GEF financing. This is followed by sustainable land management (22% of the total grant supporting agriculture and food security), climate change adaptation (17%) and management of agricultural biodiversity (14%).

Sustainable land management:

GEF investments for sustainable land management offer direct opportunity to generate multiple environmental benefits in the context of agriculture and food security. The investments mainly target on-farm productivity of crops and livestock through improved management of land, soil, water and vegetative cover. As a means to ensure long-term sustainability of outcomes, GEF financing also supports an enabling environment for SLM, such as improvements in policy options, marketing, and extension and training programs. Because of the emphasis

on integrated natural resource management, GEF financing for SLM often includes resources from the LD, BD CC and IW focal areas through multi-focal area projects. The projects using GEF resources for SLM covered a range of interventions, including soil and water conservation to reduce erosion and improve fertility; community-based landscape management, to promote collective action by land users, and creation of enabling environments or removal of barriers for land users to implement SLM. GEF support makes it flexible for countries to strengthen or create systems that help address this problem as part of agriculture and food security investments.

Management of Agricultural Biodiversity:

Agrobiodiversity is a key attribute of production systems, and includes soil fauna (below-ground biodiversity) that keep the soil healthy; genetic resources of crop and livestock used by farmers and herders; and the indigenous knowledge and traditional practices that help maintain ecosystem services (Perrings et al., 2006; Jackson et al., 2007). Although most GEF financing for agrobiodiversity is through the BD focal area, investment in soil health also used LD resources through multi-focal area projects. The investments contribute toward in situ conservation of genetic resources and soil fauna, reduction of pest and disease incidence through biological control (e.g. application-integrated pest management), harnessing pollination services and development of markets as incentives for maintaining crop diversity on farms. GEF financing was also invested in knowledge management and institutional strengthening for conservation of germplasm and awareness-raising on the importance of agrobiodiversity. Investment in institutional development, policies and regulatory frameworks helps protect indigenous varieties and knowledge for sustainable use of agrobiodiversity. At the same time, it also ensures that smallholder farmers can maintain land use practices that preserve and promote agrobiodiversity, which also contributes to SLM.

Sustainable Fisheries and Water Resources Management:

Fisheries management is crucial for poverty reduction in freshwater and coastal communities throughout the developing world, and GEF financing through the IW focal area helps safeguard the



aquatic habitats and fish diversity for the sustainability of the sector. At the same time, sustainable agricultural systems and efficient water management practices help sustain irrigation needs and reduce pollution from agricultural areas. The level of financing is consistent with the scale of interventions necessary to tackle these challenges, which involve transboundary ecosystems and multiple countries. By working at the transboundary scale, regional knowledge-sharing and cooperative frameworks can better prepare neighboring countries in the event of crisis, such as floods and droughts. It can also allow neighboring countries to better manage migratory fish populations as climate change makes their distribution less predictable. The interventions for GEF financing include management of commercial fish stocks through ecosystem-based sustainable approaches; integrated ecosystem management of coastal and marine environments; improved governance and cooperation of transboundary freshwater lake, river basins, and aquifers to reduce pollution, unsustainable withdrawals and other conflicts; improved agricultural practices and governance to reduce chemical toxins and nutrient pollution from fertilizers that result in the poor water quality and eutrophication of lakes, rivers, coasts and marine environments.

Climate Change Adaptation for Agriculture and Food Security:

GEF financing for CC-A is through the LDCF and SCCF, and is linked directly to country priorities identified in the NAPAs and other national plans and strategies. LDCF and SCCF funds directed towards food security and agriculture were invested in six main categories of interventions: i) creation of enabling environment for CC-A at all levels, including development of policies and regulatory frameworks based on sound climate risk information; ii) promoting best practices for resilience in crop and livestock production systems, including demonstration and diffusion of resilient crop varieties, improvement in land and water management, grazing and post-harvest processes as a response to specific climate change vulnerabilities; iii) integrated approaches for the resilience of agro-ecosystems and livelihoods, including management of natural ecosystems and agro-ecosystems for generation of adaptation benefits, as well as livelihood diversification to enhance climate change resilience; iv)

financial schemes to support resilient agricultural practices, including financial services for transferring risks and scaling-up proven, climate-resilient practices and technologies; v) weather-index based insurance; and micro-finance services to support implementation of new climate-resilient practices; and vi) knowledge management and dissemination, including synthesis of lessons learned through direct investments to build climate-change resilience in the agriculture sector and establishment of platforms for dissemination of such information.

Discussion

In the context of fulfilling its mandate as financial mechanism of the Rio Conventions, the GEF is playing an invaluable role in supporting eligible countries to build sustainability and resilience into agriculture and food security investments. A major result from this study is that GEF financing reflects consistency between priorities of the different funding windows and the global aspirations for environmental sustainability and resilience in production systems. Managing land, water and biodiversity in an integrated manner is key to ensuring sustainable flow of ecosystem services that underpin agriculture and food security needs in a changing climate (Power, 2010; Scherr et al., 2012).

The agriculture, livestock and fisheries sectors are major sources of anthropogenic stressors on the natural environment. The progressive deterioration of existing crop and rangelands, and of freshwater and marine systems, undermines food security for millions of poor people around the world. Safeguarding ecosystem services and building resilience in production systems is therefore a priority for developing countries where a significant proportion of the population depends on agricultural, livestock and fisheries management. GEF investments under the different focal areas create opportunities for developing countries to leverage global environment benefits in the context of agriculture and food security investments.

Sustaining Ecosystem Services Flows in Production Landscapes

The GEF plays an important role in promoting innovations to sustain flows of ecosystem services that underpin productivity of agricultural and rangeland



systems. Trends in financing suggests that GEF support for ecosystem services in production systems is largely through sustainable land management (SLM) investments that seek to combat land degradation. GEF investment in SLM fosters a diversified portfolio of interventions from farm-level to wider landscapes, with a focus on maintaining or improving the productivity of drylands, rain-fed and irrigated systems. Interventions such as crop diversification, crop rotation, conservation agriculture, agroforestry and small-scale irrigation schemes, as well as water harvesting and water-saving techniques, are helping farmers in many developing countries to secure fragile production lands from further deterioration (Lin, 2011). As a result, potential gains in soil health and quality will enable sustained productivity of farm lands, while maximizing ecosystem service flows. Furthermore, arresting soil erosion and siltation in the production landscapes will also reduce the risk of sedimentation in aquatic systems.

In most developing countries, SLM represents a major opportunity for sustainable intensification of existing farmlands through efficient management of nutrients (e.g. combining organic and inorganic sources of fertilizers), integrated management of land and water resources, and diversification of farming systems (e.g. combining crops, trees and livestock). This approach ensures improved management of agro-ecosystem services across production systems and reduces pressure on natural areas, especially those under threat from agricultural expansion (Tscharntke et al., 2012). At the same time, it reduces the various externalities that arise from conventional approaches to intensifying production, such as the overuse of inorganic fertilizers and pesticides that lead to eutrophication and sedimentation of surface water bodies. This particular benefit of SLM is also relevant to the IW focal area, especially in geographies where the affected water bodies are transboundary in nature, and for which collaborative engagement by countries involved is crucial.

GEF financing also helps to improve and sustain the economic productivity, as well as environmental sustainability, of rangeland and agro-pastoral systems. Specifically, GEF financing targets SLM priorities such as improved grazing management

and livestock fodder alternatives, as part of investments to enable livestock producers to maintain sustainable livelihoods through effective planning; animal selection, nutrition and reproduction; and herd health. The GEF also supports interventions that safeguard rangelands from risk of degradation, through actions such as reducing water and wind erosion, resolving wildlife–livestock–crop conflicts and creating fodder-banks. While the types of interventions are influenced by the context, the ecosystem service benefits are consistent with respect to keeping the rangelands productive and healthy (Reed et al., 2015).

A major global environment benefit of SLM is the potential for reducing greenhouse gas (GHG) emissions and increasing carbon sequestration in agricultural and rangeland systems, as a contribution to climate change mitigation (Lal et al., 2007). SLM interventions that improve soil and land quality also contribute to increasing soil organic carbon, as well as above-ground biomass accumulation. For most developing countries, the synergy between climate change mitigation and food security is best manifested in projects that demonstrate these multiple environmental benefits. However, while increase in soil carbon is a useful indicator of SLM achievements, the value-added for climate change mitigation is likely to vary considerably depending on type of agro-ecosystem and production practices. Therefore, climate change mitigation through SLM will likely impose tradeoffs for food security and livelihoods (Power, 2010). This implies that emphasis on GHG emissions and carbon sequestration as global environment benefit from SLM may not always be appropriate for projects targeting food security.

Agrobiodiversity — Preserving the Global Heritage

The study has shown that GEF financing plays an important role in safeguarding the genetic diversity of major food crops around the world, including fruits and vegetables that are important sources of nutrition in developing countries. This is achieved through projects that foster in-situ conservation of important crop genetic resources, livestock breeds, landraces and crop wild relatives; and through conservation and management of globally important agricultural heritage systems (e.g. Koohafkan and Altieri, 2011). GEF investment in these projects ensures that the genetic resources and associated



management practices are sustained for posterity, while future options for agriculture and food security are maintained. Sustainable production of important food crops that have benefited from GEF financing include rice in Asia, date palms in the North Africa, coffee in Eastern Africa, and potatoes in the Andes region.

Agrobiodiversity also embodies the range of supporting functions associated with management of pests, diseases, and pollination in production systems (Bommarco et al., 2013). GEF financing helps in development of “diversity rich” solutions to manage pest and disease pressures for small and marginal farmers around the world. Maintaining local crop genetic diversity on-farm not only contributes to sustainable production and farmers’ livelihoods, but also reduces the uses of pesticides. The use of genetic diversity can also be applied as part of Integrated Pest Management — an ecosystem-based approach to preventing and controlling pest damage that combines techniques such as biological control and habitat manipulation (Gurr et al., 2003). GEF financing has also helped to value pollination as an important service in agro-ecosystems, thereby contributing to the conservation and sustainable use of pollinators globally.

A third aspect of agrobiodiversity is the important attribute of soils in production landscapes, where the living components (e.g. microbes, mycorrhizal fungi, earthworms) play important supporting functions, such as decomposition of organic matter, nutrient cycling and disease control (Brussard et al., 2007). By investing in knowledge and tools for conservation and management of below-ground biodiversity, the GEF is helping improve and maintain healthy soils for crop and livestock productivity. This enables land users to harness the services provided by the soil organisms as natural assets, while contributing to their preservation.

Safeguarding the Aquatic Commons

Sustaining hydrological services is a growing challenge in the agriculture and food security sector, and for which GEF financing has been leveraged to target specific agro-ecosystems around the world. In the period from 1991 to 2011, 22 transboundary river basins, eight lake basins, five groundwater systems and 16 large marine ecosystems, have benefit-

ed from GEF financing; this has led to development of regional treaties, protocols and agreements for sustainable management of the resources. Strategic action programmes emerging from intergovernmental cooperation include targeted interventions to ensure long-term availability and flow of freshwater, and fisheries resources for consumptive use by the countries. GEF financing is contributing to implementation of action programmes for major lake and river basins such as Lake Victoria, which is a lifeline for over 30 million people.

The agriculture and food security linkages of integrated water resources management are mainly demonstrated through projects focusing on fisheries management, irrigation flow and control of nutrient pollution. GEF financing for collaborative fisheries management by governments helps improve the health of fish stocks, protect breeding zones for fish species and support development of policies and institutional frameworks to tackle the economic drivers of overfishing. In coastal areas, the GEF targets projects that advance ecosystem-based approaches to balance the demand for fish resources with the need for species and habitat conservation.

Safeguarding water in irrigated systems is key to ensuring long-term sustainability of food production. GEF financing specifically advances Integrated Water Resource Management (IWRM), which combines innovative technologies for irrigation with options and incentives to reduce demand for water in agricultural systems (Boelee, 2011). This approach ensures the needs of farmers are met, while reducing waste of scarce water resources. GEF financing for IWRM also plays a major role in tackling nutrient pollution from excessive use of chemical fertilizers in irrigated systems. Nitrogen pollution is an emerging global problem because of its link to coastal “dead zones” resulting from poor management of irrigated lands and floodplains. GEF investment in the Danube River basin is a model of regional cooperation for water quality improvement based on achievements in controlling nutrient pollution through IWRM.

Climate Change Adaptation and Resilience

GEF investments in adaptation help developing countries deal with a myriad of challenges related to climate change and variability. The emphasis is



on increasing adaptive capacity of farmers and enhancing resilience of production systems (Howden et al., 2007; Lin, 2011). The first step towards making agriculture and food production resilient to climate change is the creation of awareness among farmers and policymakers of climate variability and projected changes. The second step is to understand the inadequacy of business-as-usual agriculture practices and policies in maintaining food security. Third is to use the available climate information to design agricultural systems that are resilient to climate variability and change. In almost all projects, LDCF financing supports integration of assessed climate risks into agriculture-related policies at all levels and practices. This helps improve the existing decision-making schemes at national to local levels, and to alter farm and crop management according to the expected changes.

Projects have introduced use of drought-resilient crop varieties and supported farmers with appropriate extension services that provide help with the new techniques. In water-scarce areas, climate change adaptation funds have provided infrastructure and training for infield rainwater harvesting; medium-range weather forecast systems have been developed to deal with uncertain rainfall. In some cases, the integrated approach to natural resource management is applied for addressing food security risks posed by climate change. In Bangladesh, for example, LDCF financing is helping diversify livelihoods and create project ownership by promoting small-scale aquaculture and fruit farms among the mangroves protected and rehabilitated for storm protection.

Climate change adaptation projects also engage local communities in on-the-ground activities. In addition to creating project ownership, the projects promote climate-informed management of natural resources as a long-term strategy for safeguarding and improving livelihood options. Other development opportunities, such as community-based ecotourism, alternative livelihood options, expansion of suitable insurance schemes for the agriculture sector and payment for ecosystem services, can protect investments in uncertain climate conditions. In some regions, they also offer new and sustainable sources of income for local communities. The success of these opportunities depends on the

design of incentive mechanisms that facilitate implementation of integrated land, water and forest management practices with full understanding of ecosystem flows and food production (Vermeulen et al., 2012). Harnessing these options will also require certain conditions to ensure empowerment, equity (including gender) and rights of the communities. The projects funded through LDCF and SCCF pay special attention to gender; progress is tracked through gender-disaggregated indicators. The different needs, responsibilities and interests of women and men should continue to be considered in efforts of building climate resilience in production landscapes.

Conclusion and Recommendation

This study demonstrates a strong link between the GEF mandate for investing in global environmental and adaptation benefits, and the global aspirations to foster sustainability and resilience for food security. It shows that the GEF is directing considerable amounts of resources to this development priority through its various financing windows, addressing the potential for harnessing and sustaining ecosystem services in production systems. This suggests that GEF financing creates opportunities for developing countries to integrate environmental management and adaptation needs in the agriculture and fisheries sectors. As shown in the analysis, a wide range of global environment benefits is possible based on the type of interventions eligible for GEF investment in the four categories, with direct links to priorities of focal areas through which the financing is allocated (Table 3).

The GEF role as financial mechanism of the Conventions will continue to gain importance as all developing countries seek to address environment and development goals in an integrated manner. Consequently, potential increases in development financing for agriculture and food security will create new opportunities for the GEF to target global environment and adaptation benefits in production systems. This assessment has shed some light on how the GEF mandate directly supports global aspirations for environmental sustainability and resilience in the agriculture and fisheries sectors.



Table 3: Potential Global Environmental and Adaptation Benefits from GEF investments linked to agriculture, fisheries, and food security

Investment Category	Typology of Interventions for GEF Project Support	Potential Global Environment / Adaptation Benefits	GEF Focal Area(s)
Management of Agricultural Biodiversity	· Collection and conservation of germplasm, knowledge management and awareness-raising	· Conservation of indigenous and adaptive crop genetic resources	BD
	· Practices and technologies for optimal use of crop genetic diversity	· Maintenance of pollinators and "biocontrol" species on farms	LD
	· Development of policies at national and regional levels	· Preservation of indigenous knowledge, practices and production systems	CC-A
	· Institutional development at national, regional levels and community levels	· Diversification of crops on farms and in existing production systems	
	· Methods to improve productivity	· Maintenance and improvement of soil health and quality (i.e. below-ground biodiversity)	
	· Improve agricultural marketing services as incentives for conservation	· Increased vegetative cover and soil carbon in production landscapes	
	· Extension, demonstration and training activities for scaling-up	· Reduced demand for clearance of natural habitats (deforestation)	
Sustainable Land Management in Crop and Rangelands	· Knowledge base on SLM best practices in agricultural lands	· Diversification of farms and existing production systems	LD
	· Micro-irrigation, and soil and water conservation	· Maintenance and improvement of soil health	IW
	· Institutional capacity development for sustainable land management	· Sustained flow of water resources for irrigation	CCA
	· Innovations to reverse land degradation and restore degraded lands	· Increased tree and vegetative cover in crop lands	CC-M
	· Community-based land management	· Increased soil carbon sequestration	
	· Ecosystem and pasture management	· Reduced erosion and siltation risks in water bodies	
		· Preservation of indigenous knowledge and practices	
		· Sustainability of grazing lands and pasture systems	



Investment Category	Typology of Interventions for GEF Project Support	Potential Global Environment / Adaptation Benefits	GEF Focal Area(s)
Sustainable Fisheries and Water Resources Management	· Fisheries management	· Conservation and maintenance of fish diversity	IW
	· Integrated water resource management in lake basins	· Sustainability of fish stocks and reduced risk of depletion	BD
	· Integrated coastal management	· Improved quality and flow of freshwater	CC-A
	· Large marine ecosystem	· Reduced risk of siltation and pollution in freshwater bodies and coastal marine areas	
	· Persistent toxic substances	· Increased protection of aquifers and wetlands	
	· Integrated water resource management in river basins		
	· Integrated water resource management in aquifers		
	· Learning and capacity building		
Climate Change Adaptation for Food Security	· Institutional capacity development at national, local and district level for planning and management of climate change adaptation	· Reduced vulnerability of crop and livestock production practices	CC-A
	· Mainstreaming climate change adaptation in the agricultural sector	· Increased resilience of crop and livestock production systems and agro-ecologies	
	· Knowledge management, codification of best practices for adaptation to climate change	· Maintenance of adaptive crop and livestock resources	
	· Development of early warning systems, hydro-meteorological databases		
	· Research development/piloting of resilient adaptation systems		
	· Water resources management in agricultural sector		
	· Community-driven initiatives to enhance livelihood and coping strategies		
	· Demonstration and technical guidance, dissemination of knowledge on adaptation and food security		



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Conflict of Interests

The authors hereby declare that there is no conflict of interests.

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