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CGIAR RESEARCH PROGRAM ON Climate Change, Agriculture and Food Security CCAFS

Info Note

ACCESO in Honduras:

Mitigation co-benefits of perennial crop expansion, soil management, and livestock improvements

A series analyzing low emissions agricultural practices in USAID development projects

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Key messages

- The agricultural development project ACCESO reduced greenhouse gas emissions (GHG) and led to net carbon sequestration due to perennial crop expansion.
- Increased fertilizer use was a moderate source of emissions that was more than offset by reduced emissions from other ACCESO-supported practices, including improvements in soil, water, and fertilizer management, and in feed and grassland use by dairy cows.
- Compared to conventional practices, ACCESO-supported activities reduced emission intensity (GHG emissions per kilogram of output) for carrots (-106%), cabbages (-99%), maize (-99%), and potatoes (-98%) compared to conventional production methods. Emission intensity increased due to greater fertilizer use for plantain (55%) and coffee (247%).

About the ACCESO project

ACCESO was a 4-year Feed the Future (FTF) activity that began in 2011 and was implemented by Fintrac Inc. It aimed to increase nutrition and incomes of 30,000 smallholder farmer households by 1) introducing improved production practices; 2) creating market-driven programs to increase production and sales of high-value cash crops; and 3) expanding off-farm microenterprise and employment opportunities.

ACCESO worked in six departments of western Honduras: Intibucá, La Paz, Ocotepeque, Lempira, Copán, and Santa Bárbara (Figure 1).

ACCESO provided technical assistance and training at the household and community levels to increase capacity in agricultural production, marketing, postharvest, and value-added processing; link to market opportunities; prevent malnutrition; and improve management of natural resources and the environment.

Low emission development

In the 2009 United Nations Framework Convention on Climate Change (UNFCCC) discussions, countries agreed to the Copenhagen Accord, which included recognition that “a low-emission development strategy is indispensable to sustainable development" (UNFCCC 2009). Low emission development (LED) has continued to occupy a prominent place in UNFCCC agreements. In the 2015 Paris Agreement, countries established pledges to reduce emission of GHGs that drive climate change, and many countries identified the agricultural sector as a source of intended reductions (Richards et al. 2015).

In general, LED uses information and analysis to develop strategic approaches to promote economic growth while reducing long-term GHG emission trajectories. For the agricultural sector to participate meaningfully in LED, decision makers must understand the opportunities for achieving mitigation co-benefits relevant at the scale of nations, the barriers to achieving widespread adoption of these approaches, and the methods for estimating

emission reductions from interventions. When designed to yield mitigation co-benefits, agricultural development can help countries reach their development goals while contributing to the mitigation targets to which they are committed as part of the Paris Agreement, and ultimately to the global targets set forth in the Agreement.

In 2015, the United States Agency for International Development (USAID) Office of Global Climate Change engaged the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) to examine LED options in USAID's agriculture and food security portfolio. CCAFS conducted this analysis in collaboration with the University of Vermont's Gund Institute for Ecological Economics and the Food and Agriculture Organization of the United Nations (FAO), USAID/Honduras, and Fintrac, the implementing partner for ACCESO. The CCAFS research team partnered with USAID's Bureau of Food Security to review projects in the FTF program. FTF works with host country governments, businesses, smallholder farmers, research institutions, and civil society organizations in 19 focus countries to promote global food security and nutrition.

As part of the broader effort to frame a strategic approach to LED in the agricultural sector, several case studies, including this one, quantify the potential climate change mitigation benefits from agricultural projects and describe the effects of low emission practices on yields and emissions. Systematic incorporation of such emission analyses into agricultural economic development initiatives could lead to meaningful reductions in GHG emissions compared to business-as-usual emissions, while continuing to meet economic development and food security objectives.

The team analyzed and estimated the project's impacts on GHG emissions and carbon sequestration using the FAO Ex-Ante Carbon Balance Tool (EX-ACT). EX-ACT is an appraisal system developed by FAO to estimate the impact of agriculture and forestry development projects, programs, and policies on net GHG emissions and carbon sequestration. In all cases, conventional agricultural practices (those employed before project implementation) provided reference points for a GHG emission baseline. The team described results as increases or reductions in net GHG emissions attributable to changes in agricultural practices as a result of the project. Methane, nitrous oxide, and carbon dioxide emissions are expressed in metric tonnes of carbon dioxide equivalent (tCO_2e). (For reference, each tCO_2e is equivalent to the emissions from 2.3 barrels of oil.) If the agricultural practices supported by the project lead to a decrease in net emissions through an increase in GHG removals (e.g., carbon sequestration, emission reductions) and/or a decrease in GHG emissions, the overall project impact is represented as a negative (–) value. Numbers presented in this analysis have not been rounded but this does not mean all digits are significant. Non-significant digits have been retained for transparency in the data set.

This rapid assessment technique is intended for contexts where aggregate data are available on agricultural land use and management practices, but where field measurements of GHG and carbon stock changes are not available. It provides an indication of the magnitude of GHG impacts and compares the strength of GHG impacts among various field activities or cropping systems. The proposed approach does not deliver plot or season-specific estimates of GHG emissions. This method may guide future estimates of GHG impacts where data are scarce, as is characteristic of environments where organizations engage in agricultural investment planning. Actors interested in verification of changes in GHG emissions resulting from interventions could collect field measurements needed to apply process-based models.

Ubaldo Sagastume in his coffee field in Honduras

Photo credit: USAID

Agricultural and environmental context: Honduras

Honduras (112,090 km^2) has a population of over 8.7 million people and is the second poorest country in Central America. Approximately 60% of the Honduran population live below the poverty line and nearly 23% of children suffer from stunting (World Bank 2016a).

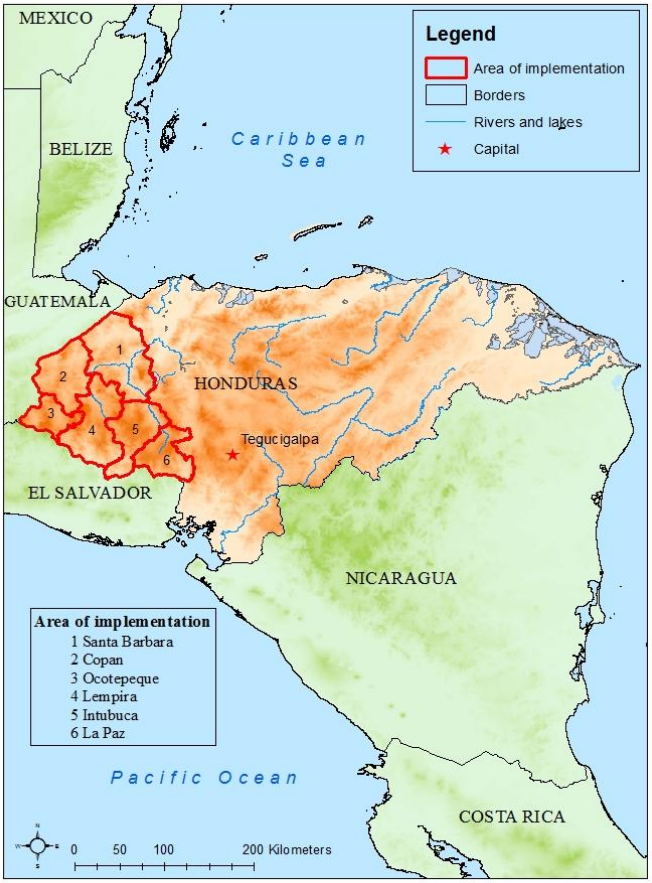
Agriculture provides nearly 14% of its Gross Domestic Product, employs about 36% of the labor force, and utilizes nearly 29% of the land (World Bank 2016a). Coffee is an important export and is a major contributor to foreign exchange reserves (GAIN Honduras 2016). Smallholder agriculture is prevalent; average farm size ranges from 2 to 5 hectares (ha) (Lowder 2014). Most smallholder farms are for subsistence or grow coffee (Holland et al. 2016, Baca et al. 2016). Subsistence farmers typically cultivate a mix of maize and beans for household consumption (Holland et al. 2016). Smallholder coffee farmers generate income from sales to local, national, and international markets. Both types of farms

are highly vulnerable to environmental shocks and climate change impacts (ibid).

Extreme weather events, agricultural diseases and pests, and drought related to the el Niño weather patterns were recent threats to subsistence farming and coffee production. Honduras is at high risk from storms and flooding, as evidenced by Hurricane Mitch in 1998, which destroyed at least 70% of the crops (World Bank 2009). In recent years, Honduran coffee farms have been damaged by coffee leaf rust. In the first year of the coffee leaf rust outbreak, the 2012/13 season, the International Coffee Organization (ICO) estimated that the disease affected 25% of all coffee trees, resulting in $230 million in lost sales and 100,000 lost jobs (ICO 2013). In addition, the 2015/16 el Niño-related drought, which was characterized by the United Nations as "the most intense drought in the country's history" (UNOCHA, 2016), distorted seasonal rainfall patterns.

In Honduras, climate change is projected to increase temperatures and decrease precipitation (World Bank 2016b). Decreases in precipitation will disproportionally impact subsistence farmers, who depend on rain-fed agriculture and have limited access to other income-generating opportunities and/or financial and technical assistance (Holland et al. 2016). Declines in yield are likely as coffee is particularly sensitive to temperature increases and variations (Baca et al. 2014, Holland et al. 2016). Honduras intends to reduce emissions in its agricultural sector through agroforestry systems and climate-smart agriculture, which it included in its submission to the UNFCCC's Paris Agreement (Richards et al 2015).

Figure 1. Area of implementation



In focus: sustainable intensification of diversified production systems

ACCESO promoted sustainable intensification as a strategy to improve nutrition and generate income. Crop yields improved, 67% to 259%, depending on the value chain, due to a broad range of technological and system improvements, including land preparation, raised beds, planting density, seed selection, transplanting systems, crop rotation, and weed control. Fertigation delivered nutrients at 95% efficiency through accurate timing and dosage, which increased agricultural productivity.

ACCESO interventions increased maize yield (259%) and reduced postharvest losses (-20% down to -10%) for an annual effective yield of 3.75 t/ha. Pre-intervention yields would have required over three times as much land to reach this production level. ACCESO's effective yield improvements for all agricultural crops would have required almost 50,000 ha more land to reach the same production using conventional practices.

ACCESO's increased yields were due, in part, to increased nitrogen fertilizer use, but with the trade-off that GHG emissions increased. In this case, the carbon sequestration in perennial crops more than offset increased emissions from fertilization. In the absence of perennial crops, this case study would have had a net increase in emissions due to increased nitrogen fertilizer usage.

Agricultural practices that impact GHG emissions and carbon sequestration

Emission analysis for ACCESO focused on maize, plantain, potato, cabbage, carrot, coffee, and dairy cow value chains. Perennial crop expansion, as well as improvements in soil, water, feed quality, fertilizer, and grassland, effect emissions and sequestration.

Table 1 shows estimates of the area adopted by each practice by the end of the project. A discussion of each practice follows, including a description of the intervention and its effects on the environment, the project plan for the intervention, and estimated impacts on emissions.

Table 1. Area of ACCESO-supported agricultural practices that impact GHG emissions by product (ha)

	Maize	Plantain	Potato	Cabbage	Carrot	Coffee	Dairy cows
Perennial crop expansion						8,099	
Soil management improvements	13,268	195	532				
Water management improvements				163	71		
Feed quality improvements							1,000
Fertilizer management improvements	13,268	195	532	163	71	10,747	
Grassland improvements							300

Perennial crop expansion

Background. Perennial cropping systems have a number of benefits. Compared to annual crops, they have deeper and larger root networks that serve to retain water and soil. These conservation measures for erosion and runoff keep soil, nutrients and water on the farm, an important local benefit, as well as keeping them from polluting water bodies (Glover et al. 2012). Perennial systems increase organic matter input to the soils, which enables them to hold more water and nutrients (Jose, 2009). From a global perspective, perennial crops increase terrestrial carbon by removing it from the atmosphere and storing it in plant biomass, thus mitigating carbon increases that reach the atmosphere from other sources. Carbon sequestration in coffee trees varies by growing conditions and management practices but the variation is less than that between annual and perennial crops. Perennials can also support tree, bird, insect, and mammal diversity compared to annual crops (ibid.). Adding perennial crops to a farm can improve household resilience by increasing the diversity of products for sale and home consumption.

Perennial crop expansion

In Honduras, the coffee rust outbreak has had a major impact on perennial crops. Some smallholder coffee growers lack resources to replant and are transforming former coffee areas to annuals.

Project plan. To support resilient coffee production systems, ACCESO promoted high quality coffee seedlings to farmers to replace rust-affected plants. Based on their monitoring data, the staff projected that 8,099 ha benefited from new planting and regeneration of coffee, at a reported density of 5,000 plants/ha, through project support. Soil carbon storage was not monitored here or in most USAID FTF activities because soil carbon takes years to show measurable differences and this requires intensive resources with respect to capital, capacity and facilities.

Impact on carbon sequestration. ACCESO's new coffee trees sequester carbon as they grow and average –10.50 tCO_2e/ha/yr over 20 years (Figure 2). By preventing conversion of degraded coffee tree areas to annual cropland, the analysis estimates soil carbon sequestration of -6.64 tCO_2e/ha/yr. Considering both soil and biomass over the full implementation area, these perennial crop dynamics result in sizeable annual carbon sequestration of –144,425 tCO_2e (Figure 3). Soil management improvements

Soil management improvements

Soil management improvements

Background. Improved soil management practices involve cropping, fertilizer, organic resources, and other amendments that are essential to maintain or increase productivity. These changes can also increase crop resilience to drought by increasing the rooting depth of crops, while reducing emissions from soils and fertilizers (Lal 2004; Cheesman et al. 2016). Many management practices that improve soil confer mitigation benefits for GHG emissions by increasing N recovery by crops and retention of nitrate in soils, thus limiting nitrous oxide (N_2O) production. Fertilizer uptake by plants is further enhanced when this practice is combined with organic inputs to the soils that also conserve and accumulate soil C, thereby mitigating

CO_2 emissions. Organic inputs can be as simple as incorporating stover from annual crops instead of burning it, depending on the soils.

Project plan. ACCESO promoted improved nutrient management, plant spacing, and seed in maize and potato systems. Plantain production systems benefited from the use of melaza (from sugar cane production) and other organic materials that improve organic matter and structure in soils.

Impact on emissions. For Honduras, the ACCESO soil management improvements were estimated to sequester carbon at the rate of –0.66 tCO_2e/ha/yr for a total of –7,762 tCO_2e (Figures 1 and 2). Soil carbon sequestration rates are variable in magnitude but their direction and magnitude relative to other interventions are well known.

Water management improvements

Water management improvements

Background. Targeted water management that focuses on efficient irrigation can increase crop yields. In turn, restoring plant residues to soils can increase carbon storage (Smith et al. 2007). Fertigation is the practice of delivering fertilizers and soil amendments through a drip irrigation system, which increases both plant water and nutrient availability. This practice delivers water and nutrients to the root area, thereby minimizing nutrient losses associated with immobilization, volatilization, surface runoff and leaching.

Project plan. ACCESO promoted fertigation on high-value vegetable crops, including cabbages and carrots.

Impact on emissions. For the climate conditions in Honduras, improved water management provided annual GHG benefits of –1.14 tCO_2e/ha (Figure 2) or –267 tCO_2e/yr for the project area (Figure 3). Soil carbon sequestration rates are variable in magnitude but their direction and magnitude relative to other interventions are well known.

Feed quality improvements

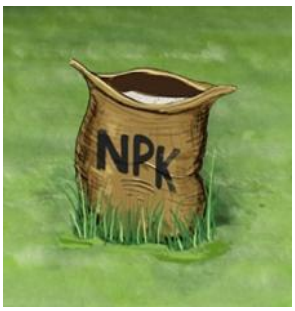
Feed quality improvements

Background. Improving feed quality increases animal productivity and reduces GHG emissions. Low-digestibility feeds (high fiber-to-starch ratios) result in higher enteric emissions per unit of meat or milk, and are found more commonly in systems with low productivity (Herrero et al. 2016). Livestock producers can affect GHG emissions by changing forage mix, and through greater use of feed supplements, which boost productivity (Gerber et al. 2013). Feedstocks, such as fodder trees, decrease enteric fermentation (methane production) per calorie compared with grass silages.

Project plan. ACCESO estimated that roughly 1,000 head of cattle benefited from improved feed due to the use of fodder trees (mainly Mulberry, *Gliricidia*, and *Boehmeria nivea*) and increased cut-and-carry systems. Roughly 0.3 ha of king grass was expected to be grown per head of livestock in order to complement overall forage availability.

Impact on emissions. Analysis shows that ACCESO's feed quality improvements reduce GHG emissions –0.06 tCO_2e/ha/yr or –64 tCO_2e/yr for the project area (Figures 1 and 2). In the absence of precise information on current and future feed composition, FAO used estimates by Smith et al. (2007) on GHG reductions following feed improvement by agroclimatic zone; thus these GHG emission benefits are associated with an intermediate to high level of uncertainty. More precise information on feed type (both before and after activity implementation) would improve the estimate.

Fertilizer management improvements



Fertilizer mgmt improvements

Background. Soil nutrient stocks are affected by the removal of nutrients as crops and stover and the input of nutrients from crop residues, fertilizer, manure and other sources. Farmers employ new techniques in fertilizer management to balance inputs and losses of nutrients in order to boost crop yields. Traditionally, efficient fertilizer management focused on the timing, type, placement, and quantity of nutrients to minimize nutrient loss and optimize crop nutrient uptake to increase yields. Today, the focus is broader; it includes practices such as intercropping and rotations, as well as perennials (a focus of this project) to build agroecosystems that minimize N losses, maximize plant use of available nutrients, build soil organic matter to hold nutrients, and minimize external nutrient inputs. As soil testing capacity increases, agricultural development projects are also focusing on appropriate macro- and micronutrient doses at increasingly refined scales (e.g., moving from countrywide recommendations toward individual farm levels).

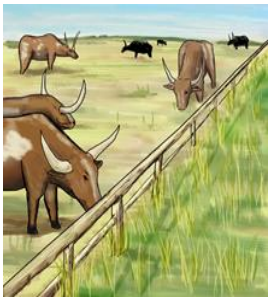
GHG emissions result from the production of fertilizers (Lal 2004; IFA 2009) and the conversion of nitrogen fertilizers to nitrous oxide (N_2O) in soils (Butterbach-Bahl

2013). Production of N_2O is generally proportional to the rates of N in fertilizer application. N_2O is so highly potent (298 times the global warming impact of CO_2) that even low rates of production have a meaningful influence on climate change. Fertilizer management can reduce emissions of N_2O (Myhre et al. 2013) as well as the emissions associated with the intensive energy usage in fertilizer production by reducing fertilization rates.

Project plan. ACCESO helped farmers identify and apply optimized fertilizer products and application rates. The activity promoted frequent fertilizer applications throughout the season rather than once or twice a year, and fertilizer rates based on soil analyses and adoption curves for each crop. The project promoted nutrient use efficiency through practices such as fertigation. Estimates presented here do not include changes in nitrous oxide (N2O) emissions from fertigation. ACCESO projected that most cropping systems increased average fertilization rates. Specifically, plantain production systems greatly increased planting density, which required increasing nitrogen fertilization from 91 kg N/ha (urea and NPK) to 355 kg N/ha (mainly ammonium nitrate). Maize crops increased nitrogen use from 45 kg N/ha to 55 kg N/ha, and coffee increased from 57 kg N/ha to 98 kg N/ha. Carrots and cabbages had moderate reductions in nitrogen application to 74 kg N/ha (carrots) and 107 kg N/ha (cabbages). Previously, potatoes were over fertilized, whereas ACCESO production practices called for 54 kg N/ha coupled with increased potassium use (from 125 kg K/ha to 379 kg K/ha).

Impact on emissions. Increased N fertilization rates led to an increase in annual GHG emissions from maize, coffee, and plantains (averaging 1.11 tCO_2e/ha/yr) (Figure 2). Lower fertilization rates on potatoes, cabbage, and carrots reduced emissions on average (–1.00 tCO_2e/ha). Emissions increased overall when the full area of implementation was considered (9,994 tCO_2e) (Figure 3). The estimated changes in average fertilization rates are associated with high levels of uncertainty, as the choice of a specific fertilizer dose depends on the individual farm household situation, including cost and access to cash or credit, land fertility, exposure to climatic shocks, and farmers' experience and preference regarding application rates.

Grassland improvements



Grassland improvements

Background. Improvement of grazing land management can influence the removal and growth of grasses, and this increases carbon storage in soils (Gerber et al. 2013, Herrero et al. 2016). Grazing land management practices that promote soil carbon accumulation include improved nutrient and water inputs, rotational grazing, and species composition (ibid). In Honduras, communities face shortages of livestock feed during the dry season. By providing adequate livestock feed during this period, livestock herders reduce pressure in the rangelands, which allows more time for the pastures to regenerate.

Project plan. ACCESO promoted grassland improvements by establishing cut-and-carry forage systems and live fencing with fodder trees. Project staff conservatively estimated that above-ground biomass carbon stocks on pasture land would double from 6.2 t biomass/ha to 12.4 t biomass/ha under the new practices. Such an increase would be equivalent to planting 40 trees of 155 kg in above-ground biomass along fields, or one tree every 10 m; at least 300 ha benefited from this practice.

Impact on carbon sequestration. The grassland improvements resulted in carbon sequestration with an estimated average of –0.57 tCO_2e/ha/yr or –171 tCO_2e/yr for entire activity (Figures 1 and 2). Site-specific monitoring data on initial levels of grassland degradation and changes in carbon stocks after project completion would increase the accuracy of these estimates.

Low emission program design considerations

This analysis of GHG emissions and carbon sequestration by agricultural practice raises issues that those designing or implementing other programs will need to consider in the context of low emission agriculture and food security for smallholder farmers, including:

- **Perennial crop expansion.** Under what circumstances is expansion of perennial crops feasible? What co-benefits of growing perennial crops could make such an expansion beneficial for development?
- **Soil management improvements.** Which soil management practices benefit yields while also increasing sequestration of carbon? Which practices can farmers adopt most easily? Which practices require training or technology improvements? Which practices should be adopted individually or as a bundle given biophysical, social, and economic circumstances?
- **Irrigation improvements.** What are the barriers to efficient irrigation for high value crops? How can drip irrigation practices be optimized for co-benefits such as reduced chemical inputs?
- **Livestock improvements.** What are the opportunities to improve feed quality and quantity through use of fodder trees and grassland?
- **Fertilizer management.** What is the potential for practices that improve the efficiency of nutrient use? What are the barriers to improved practices such as fertigation?

Summary of projected GHG emission and carbon sequestration co-benefits

ACCESO's perennial crop interventions led to carbon sequestration benefits estimated at –17.5 tCO_2e/ha/yr (Figure 2). At the activity scale, perennial crop establishment led to an estimated 144,425 tCO_2e/yr of carbon sequestration (Figure 3). Decreases in net emissions resulted from improved management of water (–1.14 tCO_2e/ha/yr), soils (-0.66 tCO_2e/ha/yr), grasslands (–0.57 tCO_2e/ha/yr), and feed quality for cattle (–0.06 tCO_2e/ha/yr). Over the area of implementation, soil management improvements led to carbon sequestration of –7,762 tCO_2e/yr (Figure 3). Increased fertilizer application in cropping systems had resulted in increased GHG emissions of 1.11 tCO_2e/ha/yr or 11,389 tCO_2e/yr. All other estimated GHG impacts were minor in comparison.

Figure 2. Impact of agricultural practices: Net GHG emissions on an animal/area basis

(tCO_2e/ha/yr or tCO_2e/head/yr)

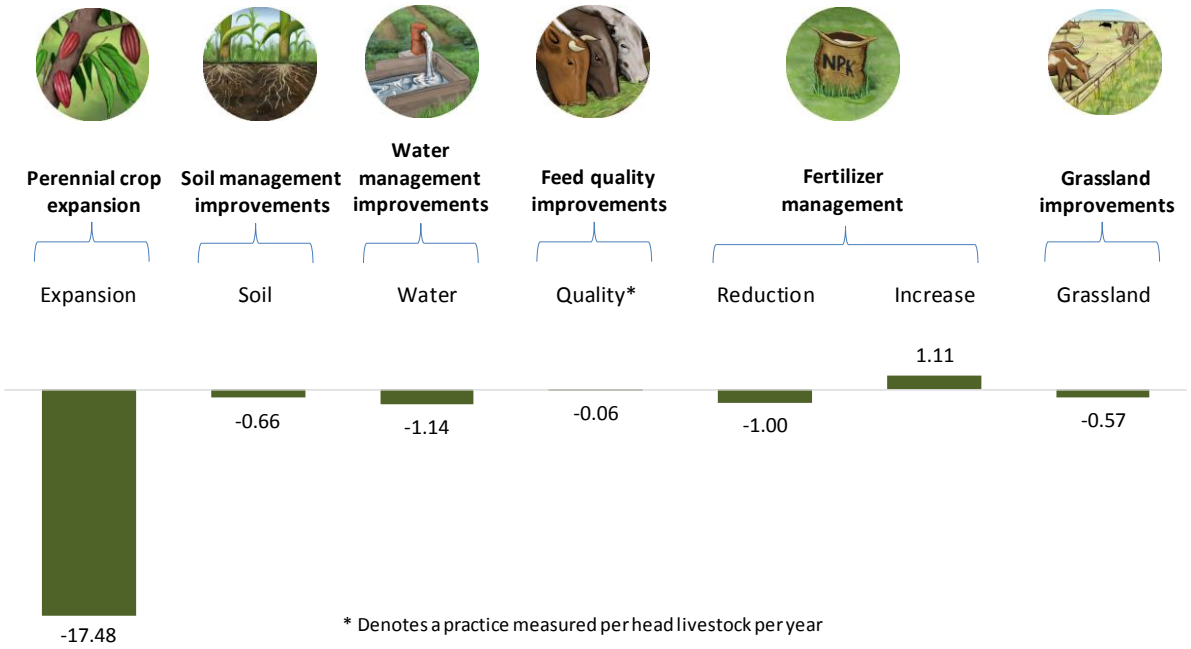


Figure 3. Impact of agricultural practices: Net GHG emissions on total animals/area of impact

(tCO_2e/yr)

GHG emission intensity

LED aims to decrease emission intensity (GHG emissions per unit of output), a useful indicator in the agricultural sector. Table 2 summarizes emission intensity for the targeted value chains without and with agricultural practices supported by ACCESO.

Annual yield. Maize, coffee, potatoes, plantain, cabbages, carrots and dairy cattle experienced notable yield increases. The 259% yield increase in maize was due to improved land preparation, seed selection, planting density, liming of soil, fertilizer improvements, and weed control. Improved liming, fertilization, pruning and pesticide management increased coffee yields 67%. Yields in the other value chains improved due to land preparation, raised beds, improved seeds, transplanting systems, crop rotation and irrigation.

Postharvest loss. ACCESO promoted practices to reduce postharvest losses. In maize, ACCESO supported improved storage (metal silos), processing (testing for humidity and aflatoxins), and transportation to markets. Reduced postharvest loss in the plantain value chain was due to improved harvesting and transportation in the field (use of plastic field crates). ACCESO quantified reduction of postharvest losses in maize (–10%) and plantain (–15%). In addition, the project introduced improved coffee processing innovations (drying with solar energy, reducing time between harvest and processing) and training on improved harvest techniques (picking only ripe cherries). However, since postharvest loss percentages shown in Table 2 measure increases in cacao quantity, and not improved product quality, the analysis does not capture the postharvest loss improvements.

Emission intensity. ACCESO's interventions resulted in reduced emission intensity for many supported value chains due to a combination of emission reductions and increased crop yields (Table 2). Emission intensity decreased for carrots (–106%), maize and cabbages (–99%), and potatoes (–98%). Emission intensity for plantain grew (55%) due to increased fertilizer use. Interventions to existing coffee production systems increased emission intensity (~250%) due to increased fertilizer use.

Table 2. Emission intensity by product

	Activity agricultural practices	Total GHG emissions per ha (tCO_2e/ha or tCO_2e/head*) (1)	Annual yield (t/ha or 1,000 l/head*) (2)	Postharvest loss (%) (3)	Remaining annual yield (t/ha or 1,000 l/head*) (4)	Emission intensity (tCO_2e/t product or tCO_2e/1,000 l milk*) (5)
Maize (soil management, fertilizer management)	No activity	0.47	1.17	20%	0.94	0.50
	Activity	0.01	4.20	10%	3.78	0.00
	Difference (%)	–0.45 (–97%)	3.03 (259%)	10% (–50%)	2.84 (304%)	–0.49 (–99%)
Coffee (fertilizer management)	No activity	–0.13	0.97	15%	0.82	–0.16
	Activity	0.33	1.62	15%	1.38	0.24
	Difference (%)	0.46 (345%)	0.65 (67%)	0% (0%)	0.55 (67%)	0.40 (247%)
Potato (soil management, fertilizer management)	No activity	3.27	10.43	12%	9.18	0.36
	Activity	0.17	24.94	12%	21.95	0.01
	Difference (%)	–3.10 (–95%)	14.51 (139%)	0% (0%)	12.77 (139%)	–0.35 (–98%)
Plantain (soil management, fertilizer management)	No activity	0.42	16.21	20%	12.97	0.03
	Activity	2.32	48.64	5%	46.21	0.05
	Difference (%)	1.90 (451%)	32.43 (200%)	–15% (–75%)	33.24 (256%)	0.02 (55%)
Cabbage (water management, fertilizer management)	No activity	1.26	25.94	25%	19.46	0.06
	Activity	0.03	45.40	25%	34.05	0.00
	Difference (%)	–1.23 (–98%)	19.46 (75%)	0% (0%)	14.59 (75%)	–0.06 (–99%)
Carrot (water management, fertilizer management)	No activity	1.26	15.56	25%	11.67	0.11
	Activity	-0.23	46.69	25%	35.02	–0.01
	Difference (%)	–1.49 (–118%)	31.13 (200%)	0% (0%)	23.35 (200%)	–0.11 (–106%)
Dairy cattle* (feed quality)	No activity	2.62	0.58	20%	0.46	5.70
	Activity	2.56	1.61	20%	1.29	1.99
	Difference (%)	–0.06 (–2%)	1.04 (180%)	0% (0%)	0.83 (180%)	–3.71 (–65%)

Notes:

1. Total GHG emissions per hectare specifies the emissions per hectare of product harvested. Total GHG emissions per head identifies the emissions per head of cattle.
2. Annual yield specifies the tonnes of product produced per hectare harvested each year or per 1,000 liters of milk per head of cattle each year.
3. Postharvest loss is the measurable product loss during processing steps from harvest to consumption per year.
4. Remaining annual yield is calculated by subtracting postharvest loss from annual yield.
5. Emission intensity is calculated by dividing the total GHG emissions per hectare or per 1,000 liters of milk per head by the remaining annual yield.

* Denotes product measured per head of livestock.

Methods for estimating emissions

A comprehensive description of the methodology used for the analysis presented in this report can be found in Grewer et al. (2016); a summary of the methodology follows. The selection of projects to be analyzed consisted of two phases. First, the research team reviewed interventions in the FTF initiative and additional USAID activities with high potential for agricultural GHG mitigation to determine which activities were to be analyzed for changes in GHG emissions and carbon sequestration. CCAFS characterized agricultural interventions across a broad range of geographies and approaches. These included some that were focused on specific practices and others designed to increase production by supporting value chains. For some activities, such as technical training, the relationship between the intervention and agricultural GHG impacts relied on multiple intermediate steps. It was beyond the scope of the study to quantify emission reductions for these cases, and the research team therefore excluded them. Next, researchers from CCAFS and USAID selected 30 activities with high potential for agricultural GHG mitigation based on expert judgment of anticipated emissions and strength of the intervention. The analysis focused on practices that have been documented to mitigate climate change (Smith et al. 2007) and a range of value chain interventions that influence productivity.

Researchers from FAO, USAID, and CCAFS analyzed a substantial range of project documentation for the GHG analysis. They conducted face-to-face or telephone interviews with implementing partners and followed up in writing with national project management. Implementing partners provided information, data, and estimates regarding the adoption of improved agricultural practices, annual yields, and postharvest losses. The underlying data for this GHG analysis are based on project monitoring data.

The team estimated GHG emissions and carbon sequestration associated with agricultural and forestry practices by utilizing EX-ACT, an appraisal system developed by the FAO (Bernoux et al. 2010; Bockel et al. 2013; Grewer et al. 2013), and other methodologies. EX-ACT was selected based on its ability to account for a number of GHGs, practices, and environments. Derivation of intensity and practice-based estimates of GHG emissions reflected in this case study required a substantial time investment that was beyond the usual effort and scope of GHG assessments of agricultural investment projects. Additional details on the methodology for deriving intensity and practice-based estimates can be found in Grewer et al. (2016).

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Info note series						
USAID project	Country	Agroforestry, perennial crop expan-sion	Irrigated rice	Land use, inc. reforestation & avoided degradation	Livestock	Soil, fertilizer management
Accelerating Agriculture Productivity Improvement	Bangladesh		X			X
ACCESO	Honduras	X			X	X
Agricultural Development and Value Chain Enhancement Activity II	Ghana		X			X
Better Life Alliance	Zambia	X		X		X
Chanje Lavi Planté	Haiti	X	X	X		X
Pastoralist Resiliency Improvement and Market Expansion	Ethiopia				X	
Peru Cocoa Alliance	Peru	X				X
Resilience & Economic Growth in Arid Lands-Accelerated Growth	Kenya				X	
Rwanda Dairy Competitiveness Project	Rwanda				X	

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