THE ECONOMICS OF LAND DEGRADATION

An assessment of the economics of agroecological farming in Haiti

A case study of the Northern Part of Haiti's Central Plateau

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Context

Rampant poverty and food insecurity

Haiti is the poorest country in the Latin America and the Caribbean region and has one of the highest levels of food insecurity in the world. Nearly half the population does not have enough to eat (WFP, 2023) and Haitians import approximately 60 percent of the food that they consume (IFAD, 2022a).[1] The increasing severity of acute food insecurity in Haiti is fueled by a rise in gang violence and worsening civil unrest, which has led to disruptions in market functioning and supply, exacerbated by the upward trend in international staple food prices (Famine Early Warning System Network, 2023).[2] While Haiti was once richly forested and highly biodiverse, its colonial, plantation economy was based on an extractive model that has continued after independence in 1804 (Groundswell International, 2017). Government and international donor programs intermittently extend projects around the countryside, but there is limited coordination between these programs, and the agricultural sector is largely characterized by the absence of government extension services and needed investments (Murray and Bannister, 2004; Bellande, 2010; Groundswell International, 2017; IFAD, 2022b). These factors are further compounded by climate hazards, political instability and a depreciation of the Haitian gourde against the US dollar (Famine Early Warning System Network, 2022).

Reversing a vicious circle with agroecology

To end the vicious circle of poverty, lack of appropriate investments into farming and poor agricultural productivity, the NGO, Partenariat pour le Dévelopement Local (PDL), has embraced agroecology to strengthen peasant associations across the north of Haiti's Central Plateau basin, with the vision that **enhanced rural prosperity is a key cornerstone for revitalizing the entire country**. Central to agroecology is the agency of farmers and their organizations to experiment, innovate, adapt, and spread agroecological principles and practices to local ecosystems. Techniques include, but are not limited to, the use of contour barriers, composting and use of manure, integration of crop residue instead of slash and burn, maintaining permanent soil cover, intercropping and crop rotations, agroforestry, the planting of living fences to protect against free grazing and development of community seed banks. More importantly, it is the process of farmer-focused research and development, as much as any specific set of techniques, that is prioritized when implementing and upscaling agroecology.

Individual farmers are witnessing the benefits of agroecological farming and showcasing their experience to neighbors and their peasant association networks. Whilst funding remains a major challenge to the up-scaling of agroecological farming, policies are also needed to incentivize changes. This requires adequate governance structures, clear land tenure rights, participatory decision-making processes, and evidence that agroecology pays-off (Chazdon et al., 2015; Adams et al., 2016). Needless to say, many of the valuable ecosystem services provided by agroecological farming systems – e.g., restoration of water and carbon cycles and enhanced disaster risk resilience – remain hidden, as they are not transacted in markets. Even when products are sold, such as timber, fruits, nuts and agricultural produce - the economic returns that are generated are not necessarily known to farmers and even less, to policy makers. This situation leads to under-investment in agroecology, often coupled with counteracting policies. In order to efficiently and sustainably manage agricultural landscapes therefore, it is critical to

1 World Food Programme (WFP) (2023). Haiti country brief. Accessed 10.02.2023 from URL. https://www.wfp.org/countries/haiti#:~:text=Haiti%20has%20one%20of%20the,million%20are%20highly%20food%20insecure.

2 Famine Early Warning System Network (FEWS), (2023). Socio-political instability, inflation and fuel shortages contribute to Emergency (IPC Phase 4) food insecurity in Cité Soleil. Accessed 10.02.2023 from URL: https://fews.net/central-america-and-caribbean/haiti/food-security-outlook/october-2022

Harvesting cassava from an agroecological farm. Photo by Ben Depp.

quantify and value the goods and services that are delivered by different farming systems – and ensure that resources are allocated to the systems that provide the highest returns to society.

Objective

In the context of these challenges, the objectives of the present study are to:

1) Develop a comprehensive assessment tool – that combines qualitative and quantitative data collection at the farm household level, using household survey data and focus groups;

2) Apply this tool in the northern part of Haiti's Central Plateau to demonstrate the potential benefits of implementing agroecological farming for improved livelihoods, the regeneration of soils, and enhanced land productivity.

Methods

To assess the benefits that are generated from agroecological and conventional farming systems, as well as the drivers and constraints to the uptake of agroecological farming - a detailed valuation survey was implemented with 330 farmers between June and July 2021. The survey catered to both conventional and agroecological model farmers, hereafter referred to as 'model farmers'. The population from which the sample was selected included farmers that are members of PDL supported peasant associations, in the communal sections of Bois Neuf, Sans Souci and La Belle-Mère, found within the communes of Saint Raphael, Mombin Crochu and Pignon respectively, counting a total population of approximately 30,000 people, including 5,000 households[3] and 3,000 peasant association members.

Results

Farmers in the study have an average of 1.6 ha of arable land, with a minimum of 0.5 ha and a maximum of 4 ha. Agroecological 'model' farmers (those that registered within their peasant association as being a model farmer) typically have one main plot dedicated to model farming, and another two plots of similar size dedicated to conventional farming.

3 Assuming there is an average of 6 members per household as revealed in the household survey-

The main crops grown in the three communities are black beans, maize, pigeon peas, cassava, sugarcane, and banana. In La Belle-Mère farmers reap a large share of their income from the cultivation of sugarcane, whilst in Bois Neuf and Sans Souci, farmers main crops are black beans and pigeon peas. Farmers also have a range of trees on their farms. Main forest products include coconut, cashew nuts, lemon, orange, mango, avocado, corossol (soursop) and cachiman (custard apple).

Focusing on the value of produce from their main parcel of land, gross income from crop and tree crops exceed US$1,600 per hectare (ha) for agroecological farmers, whereas conventional farmers are barely making more than US$900 per ha. Model farmers however, also have higher level of expenditures. Deducting input and labour costs, average net crop and forest income is in the order of US$1,231 to US$1,596 for agroecological farmers, compared to US$616 to US$806 for conventional farmers (table E1). The average net income from model farm plots is almost double that which conventional farmers obtain.

Understanding drivers of land productivity

A regression analysis was further performed to control for potential differences between agroecological and conventional farmers, that are not observed in simple bi-variate comparisons and to understand what are the main drivers of agricultural productivity. It revealed that agroecological farmers in the sample are not doing better due to their underlying characteristics (education, supporting networks, distance to their plots), but because they spend more on quality seeds, agricultural labour for weeding, and adopting agroecological practices. Intercropping, was found to be the main driver of increased land productivity, showing for example that if a farmer increases multi-cropping from 2 to 6 crops for a given parcel of land, expected gross crop income rises from US$700 to US$1,680[4] per hectare per year. When holding everything else constant, a typical agroecological farmer has a gross crop income that is US$437 higher than an average conventional farmer.

Conclusion and policy recommendations

Empirically the findings clearly demonstrate that farmers can reap higher net-income per hectare of land dedicated to agroecological model farming, relative to conventional farmers, despite their higher production costs. As for the perceived benefits, an overwhelming majority (98%) of the farmers stated that they will continue to undertake agroecological farming, and the same 98% also plan to expand the area they have dedicated to model farming. Agroecological model farmers were also found to have higher land productivity, as measured by satellite imagery, using the Normalized difference vegetation index (NDVI).

In conclusion, agroecology is a promising approach to tacking poverty and food insecurity in Haiti. An

Table E1: The average per hectare net income estimates for model and conventional farmers in Le Belle-Mère, Bois Neuf and San Souci

	La Belle Mère		Bois Neuf & Sans Souci	
	Model farmers	Conventional farmers	Model farmers	Conventional farmers
Average gross crop income (USD/ha)	$1,931	$800	$1,541	$882
Average gross forest income (USD/ha)	$233	$127	$124	$35
Input costs (USD/ha)	$454	$85	$298	$203
Labour costs (USD/ha)	$113	$32	$110	$82
Average net crop and forest income (USD/ha)	$1,596	$806	$1,231	$616

*Hired or family labour costs for ploughing, weeding, harvesting, planting and agroecological soil conservation barriers; Input costs include seeds, tree seedlings and rental of ploughs. La Belle Mère has more flat land with higher demand for ploughing.

4 based on 1 Gourdes = 0.0139 USD in December 2020.

agroecological transition will require innovative resource mobilization and an enabling environment that prioritizes the agency of farmers and their organizations, backed by economic and social support from the Haitian government.

Issues of importance, are, but not limited to the need for:

- **Designing new policies and fiscal instruments,**
  - For example, payments for environmental services and the use of fiscal transfers from central to local governments based on ecological criteria to invest in landscape restoration.
  - Targeted agricultural subsidies and grants, for community-led management of inputs and assets (e.g., community savings and credit cooperatives; seed banks, tree nurseries, grain reserves; composting facilities; appropriate machinery and labor saving tools for soil conservation barriers, terraces, water harvesting, storage, and small scale irrigation; rotating livestock schemes; post-harvest storage, valued added processing and local market access and linkages.
- **Supporting investments to strengthen the agency and capacity of farmer organizations** and NGO's to implement agroecological innovation and research, linked to farmer-to-farmer extension.
- **Unlocking patient capital at reasonable interest rates,** through blended finance solutions that can mobilize commercial capital.
- **Improving land tenure for farmers** so they can reap the rewards from soil and water conservation, farm diversification, agroforestry, and other on-farm investments.

Finally, the adoption and scaling of agroecological production by peasant associations will require public-private-NGO partnerships at both national and local levels. Specific reforms and economic instruments of interest should be evaluated, designed, and implemented in the context of the overall fiscal, economic, political, and administrative systems in Haiti. The study presented here provides ample evidence to support the scaling of agroecological approaches, which would in turn create significant economic stimulus and multiplier effects throughout the northern region, lower the reliance on imported food, and bring a suite of co-benefits (carbon sequestration, biodiversity protection, green infrastructure and ecosystem based disaster risk resilience) to be analyzed in a future study.

CHAPTER

01 Introduction

Haiti is the poorest country in Latin America and the Caribbean, and registers some of the highest rates of income inequality worldwide. Poverty levels are higher in rural areas, with almost 90 percent of the rural population living below the poverty line. Agriculture is the primary income-generating activity for rural Haitians (World Economic Forum (WEF), 2011; Bargout and Raizada, 2013). It contributes up to 25 percent of the gross domestic product (Singh and Cohen, 2014) and accounts for half of the labour force. Coffee and cacao are Haiti's principal export crops and, while the broader economy has been steadily growing, agriculture's contribution to the economy has been declining since the 1980s. Food production, however, is not keeping pace with population growth (World Economic Forum (WEF), 2011) resulting in Haitians currently importing approximately 60 percent of the food that they consume (IFAD, 2022a).

1.1 Agricultural productivity in Haiti

Productivity is constrained by a long trajectory of historical factors and current conditions. While Haiti was once richly forested and highly biodiverse, its colonial, plantation economy was based on slavery, human exploitation, and ecological extraction. An extractive model has continued after independence in 1804, without sufficient reinvestments or regeneration into the agricultural sector (IFAD, 2022b). While recent government and international donor programs intermittently extend projects around the countryside, there is limited coordination between these programs, and the agricultural sector is largely characterized by the absence of government extension services (Murray and Bannister, 2004; Bellande, 2010; Groundswell International, 2017).

According to Cantave Jean-Baptiste, (2022), Executive Director of *Partenariat pour le Développement Local* (PDL), a Haitian NGO, the lack of functioning of basic government roles and services has become more acute since the 2010 earthquake that led to some 300,000 deaths (Jean, Mary and Lei Win, 2022). Infrastructure that supports agriculture and the marketing of agricultural products is also underfunded, and road infrastructure is poor (Bellande 2010; Murray and Bannister 2004; IFAD 2022a). Moreover, post-harvest losses are considerable, often as the result of a lack of storage and processing facilities. In the absence of agricultural banks and extremely limited access to credit facilities, rural households have few means for mitigating these losses, or investing into other productive assets (such as livestock and conservation structures), and key production factors (such as fertilizers, seeds, and irrigation water) (Beaucejour, 2016). Isolation, inaccessible public services, and lack of production factors are major causes of vulnerability, poverty, and food insecurity in rural areas (IFAD, 2022a). These factors are compounded by climate hazards, political instability, depreciation of the Haitian gourde against the US dollar, etc. (Famine Early Warning System Network, 2022). In the light of these challenges, PDL has worked since its inception in 2009 - and based on the over 35 years of prior experience of the founder Cantave Jean-Baptiste with similar programs and approaches - to strengthen rural communities and peasant associations across the north of Haiti's Central Plateau basin, with the vision that enhanced rural prosperity is a key cornerstone for revitalizing the entire country.

1.2 Principles of agro-ecology

PDL's work is rooted in principles of agroecology, initially defined as t*he application of ecological concepts and principles to the design and management of sustainable agroecosystems, or the science of sustainable agriculture* (Gliessman, 1990, 1997, 2018). Today, the definition of agroecology has grown to become *the ecology of the entire food system* (Francis *et al.*, 2003), which integrates research, education, action and change that brings sustainability to all parts of the food system (Gliessman, 2018). As a practice, it is based on sustainable use of local renewable resources, local farmers' knowledge and priorities, wise use of local biodiversity to provide ecosystem services and strengthen resilience, and solutions that provide multiple environmental, economic, and social benefits (European Association for Agroecology, 2022). Central to agroecology is the agency of farmers and their organisations to experiment, innovate, adapt, and spread agroecological principles and practices to local ecosystems. It is thus the process of agroecological, farmer-focused research and development, as much as any specific set of techniques, that is prioritised.

PDL is a founding partner of Groundswell International, a network of partner organisations across ten countries in the Americas, West Africa, and South Asia, that supports action-learning and program implementation to strengthen and scale agroecology and sustainable, local food systems. In applying agroecological principles, PDL and Groundswell International view farmers as the key agents of change and co-creators of knowledge. In Haiti and other contexts, based on grounded experience supporting smallholder farming communities, both organizations affirm the 13 agroecological principles consolidated by the international High Level Panel of Experts on Food Security and Nutrition (HLPE) in July 2019, on the basis of the 10 elements proposed by the FAO in 2018, as well as the gradual transformation agri-food systems from farm to wider societal levels (Gliessman, 2014). The interrelation between principles, transformation levels and their scale of integration is shown in Figure 1 below.[1] Application of these principles by PDL and Groundswell, in the challenging context of Haiti, is described in chapter 2.

1.3 Objectives of the study

Whilst PDL is witnessing the benefits of agroecological farming on a day-to-day basis, there was a desire to assess the economic consequences of this work formally and objectively, and to understand the potential repercussions on livelihoods and conditioning factors. In the light of this, the present study was conceived:

- To estimate per hectare incomes of agroecological and conventional farmers, using a representative household survey with conventional and agroecological farmers, and carefully designed land use budgets to elicit quantities of production outputs and inputs, and the values of these for the main land parcel under consideration.
- To analyse the main drivers of land use productivity amongst both conventional and agroecological farmers.
- To assess a farmer's own perception regarding the degree of success of their agroecological farm plots, evidence on repercussions on food security, and ability to market their produce.
- To understand potential constraints to further up-scaling agroecological model farming practices.
- The data and analysis aim to serve both local communities, national practitioners and decision makers, and international actors interested in Haitian development.

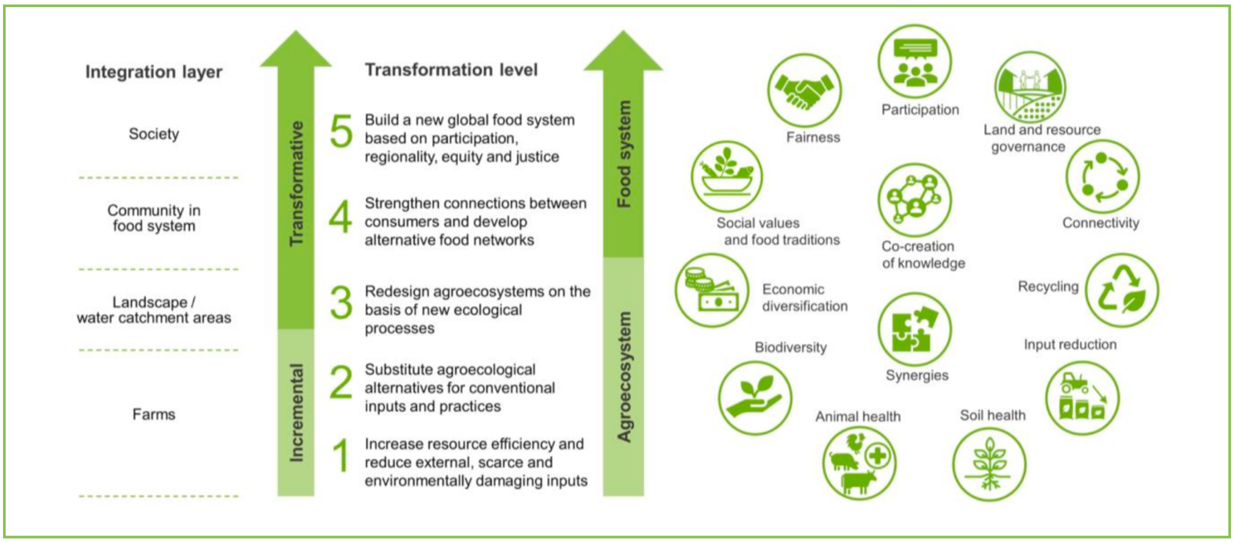


Figure 1: 13 principles building on the 10 elements of FAO (2018) and 5 levels of agroecology (Gliesman, 2014)

1 https://www.giz.de/en/downloads/giz2020_en_Agroecology_SV%20Nachhaltige%20Landwirtschaft_05-2020.pdf

02 Case-study area and study context

Haiti has a hot and humid tropical climate characterised by diurnal temperature variations that are greater than the annual variations; temperatures are modified by elevation. Average temperatures range from about 25°C in January and February to about 30°C in July and August[2]. Regarding rainfall, there is usually a dry season from December to February and a rainy season from April to October, with two pronounced rainy peaks at the start and end of the season, and a decrease in July[3].

Haiti is highly vulnerable to natural disasters and climate change. The Northern and Southern peninsulas are particularly exposed to tropical storms, hurricanes, floods, and landslides due to deforestation and lack of soil conservation. For example, the country in general and the program territory assessed in this study in particular have been affected in recent years by Hurricane Mathew in 2016 and two extended drought periods in 2018 and 2021. In the coming years, temperatures are expected to increase, rainfall to decrease, and extreme climatic events to become even more frequent and intense. The combined impact is expected to further increase already severe soil degradation and decrease yields of irrigated crops. Storms also damage or destroy crops, plantations, livestock, and infrastructure (IFAD, 2022a). Another major problem is deforestation. According to the Ministry of Agriculture, Natural resources, and Development in Haiti (MoNARD, 2010) the removal of forest resources is three to four times higher than regeneration levels; the slopes of 25 out of 30 of the country's water basins are bare; and less than 2% of the country's once densely forested surface area, remains covered.

In Northern Haiti, about 145,000 farm households depend on agriculture (Molnar *et al.*, 2015). Weak or non-existent extension support, untimely input availability, and fragmented value chains are among the many conditions that impede agricultural systems in Haiti (Smucker *et al.*, 2005; Bayard, Jolly and Shannon, 2007; Smucker, 2007; Sperling, 2010). Fertiliser and farm chemicals are not available when needed and producers are averse to outlays that they can ill afford (Molnar *et al.*, 2015). According to Jean Louis Valere, a farmer and community leader with a peasant association that PDL supports in Bois Neuf: "*Life was really beautiful... but people left primarily because the land couldn't produce anymore, due to the lack of trees ...and now we have soil erosion* (Groundswell, 2017).

To create an alternative to this situation, PDL's starting point is to strengthen the capacity and agency of family farmers and peasant associations, to manage their own development processes in a way that is not dependent on external programs (Jean-Baptiste, 2021). It entails the creation and strengthening of peasant associations and the building of leadership among women, men, and youth. It is these peasant associations, then, who work to spread agroecological farming and build local economies, as explained further in the next chapter. This study concentrates on three of the peasant associations and Communal Sections (see Figure 2) with whom PDL is working, out of 14 it has supported since 2009. These peasant associations and Communal Sections were chosen to assess the role of agroecological farming across different cropping systems (communities either specialised in beans or sugar cane), whilst allowing for sufficient observations to compare conventional farming versus an agroecological model. In the longer-term, it is envisaged to extend the current assessment to other communities, where crops such as rice and maize are prioritized, and use earth observation and satellite imagery to further assess the consequences of agroecology on land use productivity and other land use characteristics enhancing disaster risk resilience.

2 https://www.weather-atlas.com/en/haiti/bois-neuf-weather-september

3 https://www.climatestotravel.com/climate/haiti

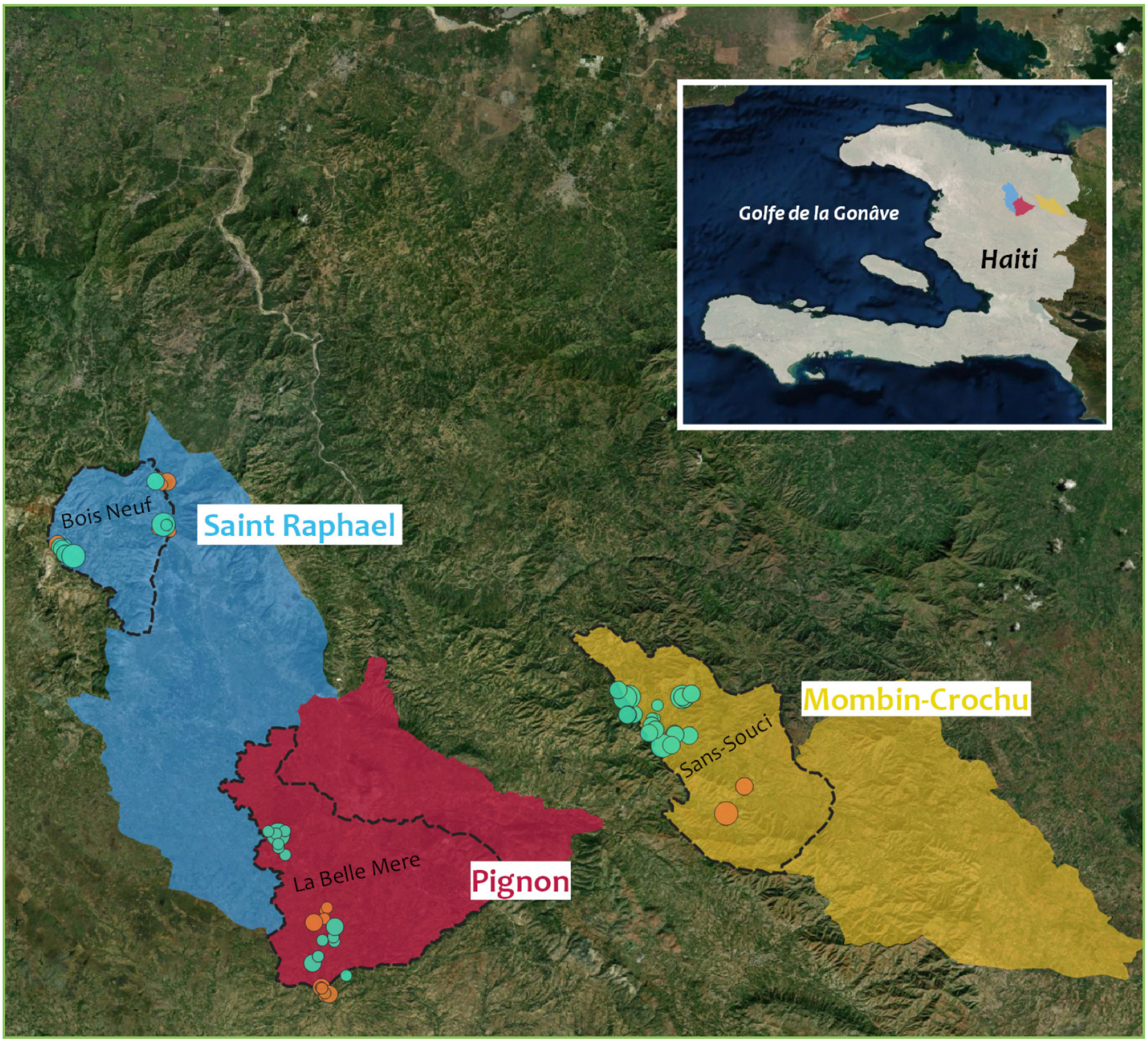


Figure 2: Case-study area, municipalities and municipal sections. Sampled model farming plots are green, and sampled non-model farming plots are orange. Credit: Luis Costa

2.1 Institutional structure and the roll-out of agroecological model farming

When initiating work in a new community, PDL facilitates participatory reflection sessions and discussions to form *gwoupman*, or solidarity groups of 8-15 women and men who organize around shared interests. As individuals begin to work together within *gwoupman,* and to coordinate activities between *gwoupman* in the same village, PDL uses participatory methods to allow wider communities to identify their existing assets and diagnose and prioritise problems and opportunities for improving community wellbeing and regenerating soils and production. The overarching organisational unit is that of inter-village organisations, or so-called peasant organisations that link 30 to 50 *gwoupman* across 10-25 villages, and have approximately 800 to 2,000 members each. The three Communal Sections and peasant organizations analysed in this study, Bois Neuf, Sans Souci and La Belle-Mère, represent a peasant association population of 4,000 to 5,000 people.

Since 2009, PDL staff have supported and strengthened some 14-peasant associations, comprising about 15,000 members. Peasant associations hold annual assemblies to plan and assess their activities, report on community-mobilised assets (savings and credit funds, seed banks, etc.), and democratically elect leaders. The peasant associations are organised as shown in figure 3.

At the first level, there are *gwoupman,* the solidarity groups of 8-15 women and men that mobilise their own resources in a small joint savings and credit fund based on trust and reciprocity. Each *gwoupman* works to invest this initial fund in sustainable farming and economic activities that will generate more resources, such as grain storage, micro-loans, small livestock breeding, etc. At the next level, *blocks* are village-level committees that serve to link together 3-5 *gwoupman* in a community, sometimes more. They set up other committees to coordinate activities among *gwoupman*, such as the promotion of sustainable agriculture, seed banks, grain reserves, savings and credit funds, and community health initiatives. Finally, Central Coordinating Committees (KKS in Creole) coordinate peasant associations and their activities across 10-25 villages within Bois Neuf, Sans Souci and La Belle-Mère. They are led by regularly elected leaders emerging from the *gwoupman* and village levels.

The Central Coordinating Committees coordinate the spread of agroecological or sustainable farming practices, allowing for practical training and information sharing sessions across and within villages. For example, within a village the farmers come together on a single farm to learn how to mark contour lines and build soil conservation barriers, with the simple "A-frame" apparatus. Then they return to their own farms and communities to test these same ideas. Some farmers take responsibility as volunteer agricultural promoters to share successful techniques with other farmers. Through this community organisation, family farmers can implement and scale agroecological practices while creating a circular economy and improved social solidarity and food security (Jean-Baptiste, 2009).

By working together in these inter-village peasant associations, people are also better able to address needs that go beyond the capacity of individual families (e.g., preventing cholera, growing savings and credit coops, preventing soil erosion and landslides, promoting reforestation, controlling free grazing of animals, negotiating productive relationships with other actors, etc.). Peasant associations are generally able to function with a high level of autonomous capacity within five to seven years. For more information on the Peasant Associations, the reader is referred to "Fertile Ground: Scaling Agroecology from the Ground Up" (Groundswell, 2017).

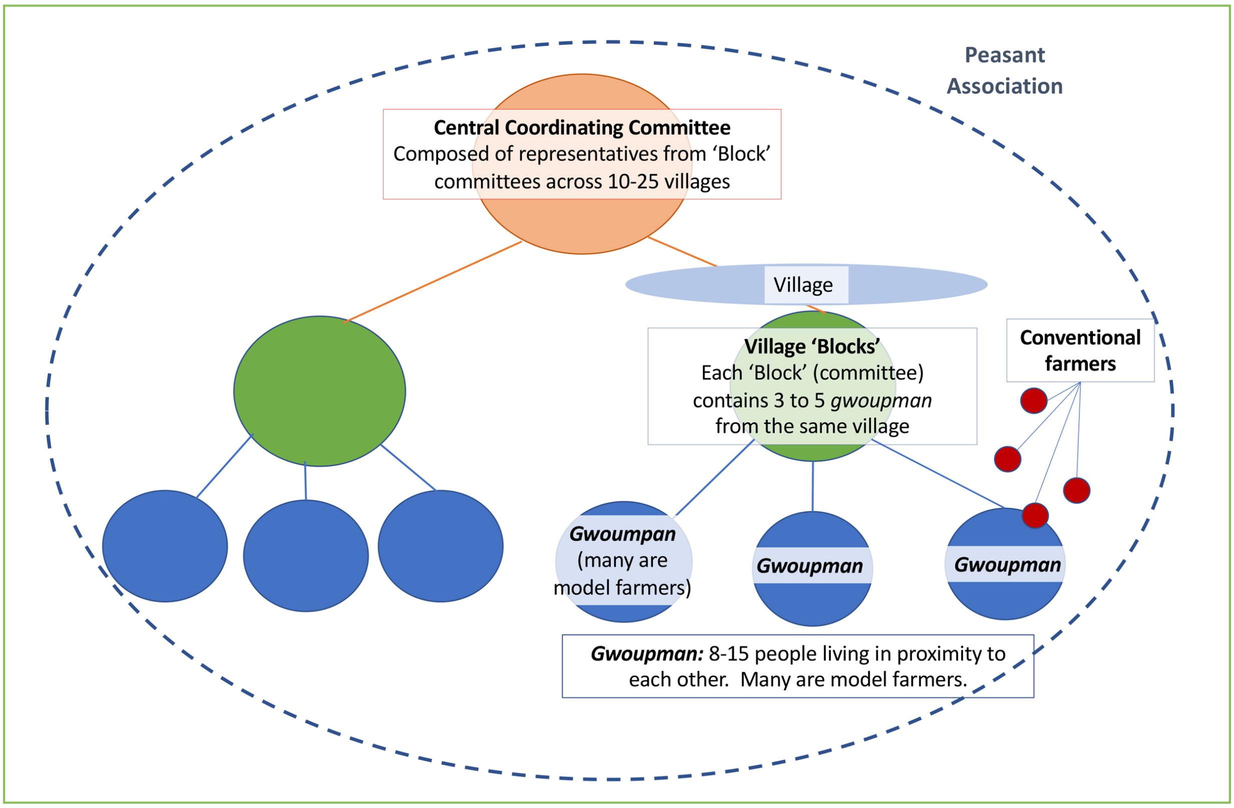


Figure 3: Organisation of peasant associations. Credit: Vanja Westerberg

Farmers building stone soil conservation barriers. Photo by Cantave Jean-Baptiste.

2.2 Agroecology within the Peasant Associations

In promoting learning processes to improve agroecological production within the peasant associations, PDL aims to create a long-term balance between smallholder production systems, soil fertility, and the conservation and regeneration of natural resources. The farming strategies build on existing farmer knowledge and practices (e.g., qualities of local crop varieties, diversification, seed saving) while also fostering learning and changes to existing farming practices (e.g., stopping the conventional practice of "slash and burn" and introducing soil conservation). As alternatives, farmers test and promote a combination of agroecological techniques that address five major issues: control of soil erosion; increasing soil organic matter and fertility; improving access to and management of quality seed; improved on-farm crop diversity and management (inter-cropping, rotation, optimal plant spacing); and improved plot maintenance (e.g., through timely weeding, control of local pests and diseases, etc.).

Table 1: Focus group details from Gustave 2021

Focus Groups	Interval
Data collection period	November 2020
Years that farmers have undertaken model farming	5-6 years
Participant numbers	7-16 individuals
Communities	Bois Neuf, La Belle-Mère and Sans Souci
Focus group participants	Agricultural volunteer promoters, model farmers and conventional farmers

2.3 Focus group insights - conventional and agroecological model farming

To prepare for the household survey, three focus groups were implemented in November 2020, one each in Bois Neuf, Sans Souci, and La Belle-Mère, with 7-16 participants per focus group. Both members of peasant organizations supported by PDL, as well as non-members, participated. Key findings with respect to what it means to be model farmer, as well as the drivers and constraints to adopting model farming, are explained in the following discussions. For full transcript of the focus groups, the reader is referred to Gustave (2021).

A model farmer is defined by peasant associations as a farmer that adopts several agroecological principles and practices. As such, it was the peasant association that provided the list of association members that were considered as model and conventional farmers, and which subsequently informed the data sampling process. PDL facilitates processes with all peasant associations to define key principles, criteria and practices that are common for model farmers, but these are understood and adapted by peasants locally. Each association expresses in language that makes sense to them what it means to be a model farmer.

For example, the farmers' association of the Sans Souci village has decided that a model farmer must '*make the earth speak'* (Groundswell, 2017). During the focus group from Bois Neuf, farmers said "*we halved our use of seeds, but have been able to double our production!"* Model farmers also emphasize more species variety. Typically, banana, sweet potatoes and manioc are planted behind the soil conservation barriers (*ramps*), with maize and green beans planted in the remaining land. In Bois Neuf, focus group participants say: *A model garden fights against hunger* (Jaden model kouri dèyè grangou" / le jardin modèle lutte contre le faim"). Model farmers make use of crop rotations, fallowing, intercropping, composting, planting of trees and do not practise slash of burn (Gustave, 2021).

In the village of La Belle-Mère, a model farm, is a farm with many different species that one can rely upon for food for the family. It is a farm with permanent cultures such as trees. You find bananas, fruits, and forestry species. Farming practices include: "*the careful selection of seeds, increased distances between the plants, not burning organic matter or residue and hoeing. It is a tidy garden, with a living hedgerow"* (Gustave, 2021). Furthermore, a model farmer must practice soil conservation; place five anti-erosive structures on each 0.25 *carreau* of land[4]; cultivate a diverse variety of foods, such as sweet cassava, cassava, pigeon peas, sweet potato, yam, ginger, sugar cane, maize, beans, bananas, tarot, eddoes, etc.; produce enough or generate adequate income to be food secure; and plant fruit and forest trees on their farm for food, fodder, fuelwood, and construction (Groundswell, 2017).

2.3.1 Conventional and agroecological model farmers within the study

Agroecological model farming has different meanings amongst the peasant farmer association members, and it is understood differently based on local realities (Lefranc, 2022). This again reflects the farmer-centered and participatory dynamic of agroecological innovation. It is also important to note that not all peasant association members supported by PDL adopt agroecological 'model farming' practices, either because they have not received training, or because of other constraints discussed in the focus groups (below). We refer to these as 'conventional farmers' and they serve as a base upon which to compare the economic viability of agroecological versus model farming within the peasant associations.

2.3.2 Perceived constraints to the uptake of agroecological farming

According to Bois Neuf focus group members, as a rule of thumb, agroecological farmers are *"those that have benefited from training programmes led by PDL who adopt model farming." However, the level of adoption within the population as a whole is not high."* As highlighted by another focus group participant: "*You need to have the technical knowledge and take time to produce the soil conservation structures and respect tree planting distances. Sometimes, neighbours will imitate the practices undertaken by model farmers and want to become a model farmer. But there are also some members that continue to practise 'slash and burn'."*

In La Belle-Mère, focus group members also insisted on the importance of having participated in training programs to be able to undertake model farming. Given the general belief among farmers of the importance of plowing, there is a perception that some

4 1 hectare = 1.6 carreau

Farmers restoring degraded landscape. Photo by Ben Depp.

model farm designs do not allow for ploughing, and so farmers do not think it is possible to apply model farming everywhere[5]. You need to have time and money to be able to finance the soil conservation structures and the hedgerows. Model farming plots also require more labour and therefore tend to be those located closer to the households' homes. It is therefore limited, according to some focus group members in La Belle-Mère, the extent to which agroecological model farming can be implemented on more distant conventional plots.

As for other concrete difficulties related to the implementation of model farming, farmers mentioned: the planting and maintenance of hedgerows; free roaming livestock that eat the hedgerows and enter the farms; finding crop residue to create soil conservation barriers (ramps); and the overall belief that model farming is more time consuming because you need to repair and increase the number of soil conservation structures every year.

2.3.3 Perceived benefits from agroecological model farming

Farmers expressed a range of motivations for undertaking agroecological farming strategies, of which the primary purpose is income diversification. For example, in the La Belle-Mère focus group discussion participants highlighted that the planting of avocado trees on the model farming plot allows for the sale of wood and avocados, worth HTG 2,000 to 3,000 per year. They also serve as windbreaks for crops, aid in the fight against drought, and the tree leaves provide fertilisers for the soils. In terms of observed results: "*You can earn more money; plants are bigger and resist droughts better*" (Gustave 2021).

The focus group findings underscore some of the challenges associated with the adoption of agroecology. It is more labour and knowledge intensive and ideally requires training, though there are significant benefits to be enjoyed from the adoption of agroecology. In the following chapter, we discuss the methods that have been employed to assess and value the benefits in closer detail and in Chapter 4 we present the results.

5 For plots that have peri-annual crops such as sweet cassava and sweet potato, it is not possible to plough every year. For other diversified plots with plantain/banana and papaya etc., however, the density is managed in a way to still need the farmer to plough, allowing the integration other seasonal crops such as beans, corn, etc. (Lefranc 2022, personal communication)

03 Methods

To understand the economics of agroecological model farming and the implications for farmer livelihoods, we relied on interviews with PDL field staff, including agronomic engineer Ronel Lefranc, Director Cantave Jean-Baptiste, and agronomic engineer and consultant William Gustave; focus groups with farmers led by William Gustave; and quantitative analysis of household survey data. The data and information from these sources have been used to build land use budgets for both model and conventional farmers. Statistical regression analysis was then used to understand and explain the differences in land use productivity between model and conventional farmers.

3.1 Data collection and questionnaire design

To understand the value of 'model farming', a detailed valuation survey was implemented with 330 farmers between June and July 2021. The survey catered to both model and conventional farmers with the objective of assessing:

- Differences in socio-demographic characteristics between model and conventional farmers
- The economic value of adopting agroecological model farming
- Drivers and constraints to the uptake of agroecological model farming

The population from which the sample was selected included farmers that are members of PDL supported peasant associations, in the communal sections of Bois Neuf, Sans Souci and La Belle-Mère, found within the communes of Saint Raphael, Mombin Crochu and Pignon respectively, counting a total population of approximately 30,000 people (5,000 households[6] and 3,000 peasant association members).

To achieve a confidence level of 95% with a margin of error of 5%, a stratified representative sample was constructed by randomly drawing approximately 60 agroecological model and 50 conventional farming households from PDL's household member database within each of the three communal sections of Bois Neuf, Sans Souci and La Belle-Mère[7]. As such, it should be acknowledged that the results presented in this paper, are representative of members of peasant associations (agroecological farmers or not) and not the entire population.

Face-to-face interviews were conducted on the farms with one representative household member, using tablets and Computer Assisted Personal Interviewing (also known as CAPI) software. Each interview lasted on average 45 minutes and was carried out by four undergradua te agronomy students from Episcopal University of Haiti in Port au Prince, with training and guidance provided by Altus Impact.

Table 2: Household survey locations, population size and peasant associations

Municipality / commune	Communal section	Peasant association name	Population	# of peasant association members	Major crops
Saint Raphael	Bois Neuf	IGPDB	5,196	500	Black bean
Mombin-Crochu	Sans Souci	IPDS	11,552	1,500	Black bean
Pignon	La Belle-Mère	IPDL	14,369	1,000	Sugar canel/ Cassava

6 Assuming there is an average of 6 members per household as revealed in the household survey (Angelsen *et al.*, 2014)

7 As a rule of thumb, minimum 300 observations are needed to reach a 95% confidence level for sample statistics of population sizes of 1000 or more.

Woman agroecological farmer Haiti. Photo by Ben Depp.

3.2 Socio-demographic characteristics of farm household

The data and information used for this study come from expert interviews, focus groups, and household surveys with farmers. A total of 330 households were surveyed in the municipalities of Bois Neuf, Sans Souci et La Belle-Mère. The characteristics of conventional and model farmers are shown in Table 3. In terms of the gender of the household heads, it is seen that there are more female headed households (48%) amongst the model farmers, compared to the conventional farmers (28%). There is a higher fraction of seasonal migrants (13%) amongst conventional farmers compared to model farmers (3%) which is not surprising, considering that seasonal farmers are less likely to reap the long-term return from model farming. The household size, as well as the age distribution is alike for the two groups. An average household has six members, of which one third are less than 16 years old and nearly one out of four (24%) are above 50 years old.

There are more literates amongst model farmers (51% vs 43% for conventional farmers), however, this difference is not statistically significant. According to The World Fact Book (Central Intellegence Agency, 2021), Haiti has a literacy rate of approximately 61%, but data from the household survey (Table 3 below) suggest that literacy in the northern region may be lower than national average. About one third have completed primary school education, but about half the sample have received no schooling at all.

3.3 Defining agroecological model farmers

The analysis focuses on the farm-level by comparing the per hectare returns from agroecological model farming versus conventional farming amongst PDL supported peasant organisation members. Model farmers are identified as households who have received training and support from PDL to build their model farms, and who practise agroecological farming as validated through block coordination and field visits to their farm. Agroecological model farmers also include peasant association community members who have adopted agroecological farming through farmer-to-farmer spread of knowledge, although they were not directly trained and supported by PDL. Conventional farmers are those that have declared to not undertake model farming. For the purposes of this study, we only interviewed conventional farmers who are members of the peasant associations.

3.4 Using land use budgets to assess the value of agroecological model farming

To assess the economic value of model farming versus conventional farming, we relied on households' self-reported physical quantities of harvested

Table 3: Socio-demographic characteristics of the survey respondents

Survey responses Bois Neuf, Sans Souci et La Belle-Mère	Conventional farmers	Model farmers
Household head is female (q4.3)	28%	48%
Main respondent is female	30%	47%
The household is a member of a farmers' association	87 %	97 %
Household head is a seasonal migrant	13 %	3 %
Household head is literate	43 %	51 %
Age of the household head (4.6)	51	52
Number of household members	6 (min 2; max 14)	6 (min 2; max 15)
Household members < 16 years	36 %	34 %
Household members between 16 and 50 years	40 %	42 %
Household members > 50 years	24 %	24 %
Number of years the respondent has lived in the community under consideration	21 (min 6; max 54)	18 (min 3; max 35)
The household head has lived in the community their whole life	95 %	83 %
The household head is literate (8)	43%	51%
Percentage of households classified as model vs conventional farmers, as defined by PDL when sampling households	46% (n=138)	54% (n=162)
Educational level	**Conventional**	**Model**
No education	46 %	46 %
No-formal education	11 %	11 %
Completed primary school	28 %	33 %
Completed high school	5 %	5 %
BAC, or completed tertiary or higher education	2 %	3 %
Not applicable	9 %	3 %

products (whether for their own household use or for sale) and inputs used in the 12 months prior to the interview[8]. The analysis therefore focuses on the income that farmers derive from a whole year of farming their main plot of land. This means that two main agricultural seasons stretch from February to August and September to Februay, are captured as part of the analysis. However, to the extent that model farmers are continuously growing and harvesting crops on a given plot of land throughout the year, it makes less sense to talk of agricultural seasons for model farmers. Box 1 explains further.

The focus is therefore the total net-income that a farmer obtain from his main plot for a 12-month period. To assess this, land use budgets were designed and pre-tested as part of the household surveys. Focus groups served to elicit the price at which the given goods usually sell at farm/forest gate or on local markets (i.e., within village).

In the case of model farmers, the land use budgets related to their main plot of land dedicated to agro-ecological model farming, hereafter referred to as the 'model farm' (after "le jardin modèle"[9]). In the case of conventional farmers, pre-testing showed that it was easier for farmers to assess how output and input quantities with reference to all their parcels of land under cultivation. An average conventional farmer has 2 parcels of land across 1.6 hectares, while an av-

8 from June 2020 to June 2021 - second season of 2020 and first season of 2021

9 Peasant farmers use the term 'jardin' in Haitian creole, which can be translated as 'farm' or 'garden.'

Farmers hoeing land. Photo by Ben Depp.

erage model farmer has 3 plots (1 model and 2 conventional, with some limited improved agroecological practices applied on their conventional plots as well) (see table 4 for more detail).

Given the wide-ranging number of farming practices and crop combinations undertaken by both conventional and model farmers, we did not dispose of sufficient information to establish a generalised 'cash-flow' over time for model and conventional farmers. Instead, we compare the net-benefits per hectare of land under the two farming schemes. To do so, we estimate net crop income and forest income over year t, as per equation 1 through 5.

1) Gross forest income = Σ $\text{Quantity}_t \times \text{Price}$

2) Gros crop income = Σ $\text{Quantity}_t \times \text{Price}$

3) Net crop incomet = Σ $\text{Quantity}_t \times \text{Price}_t$ – input cost_t – labour costs_t

4) Input cost = Σ Q × P (seeds, fertilisers, hired labour, rental of ploughing equipment etc.)

5) Total labour cost = Number of days (weeding, land preparation and harvesting) × daily wage + food cost for workers

Input costs refer to; seeds, fertilisers, pesticides, and rental of ploughing equipment (*charrues*), own labour and hired labour costs for planting, weeding, harvesting, and ploughing, and labour costs for the agroecological practices such as crop residue conservation barriers (ramps).

CHAPTER

04 Results -The economics of agroecological model farming

4.1 Description of the farming systems

Farmers generally have between 0.5 hectares (ha) and 4 ha of farmland (Figure 4). The average landholding is 1.6 ha of land for both model and conventional farmers (2 *kawo*). On this land, agro-ecological model farmers typically have one plot for their model farming and two conventional farming plots. As such, model farmers typically dedicate 1/3rd of their land to agroecological model gardening. The average size of the main plot of land dedicated to either model or conventional farming is 0.6 hectares (0.5 *Kawo*). The average walking distance to a model garden is 25 minutes (mean of 35), whilst the average walking distance to their main garden plot amongst conventional farmers is 47 minutes. Conventional farmers have a median landholding of 1.6 ha (average of 1.9 ha) on an average of two plots (median of 2), see table 4.

Most conventional and model farmers are cultivating land that is privately owned (Table 5). Both model and conventional farmers appear to have quite good tenure security, with 94% of farmers expressing that they consider having strong land tenure rights (Table 6). This is important to note as according to LeFranc (2021), farmers are more likely to commit to sustainable practices on land they are sure to reap benefits from in the long term (i.e., planting trees, soil conservation structures etc.).

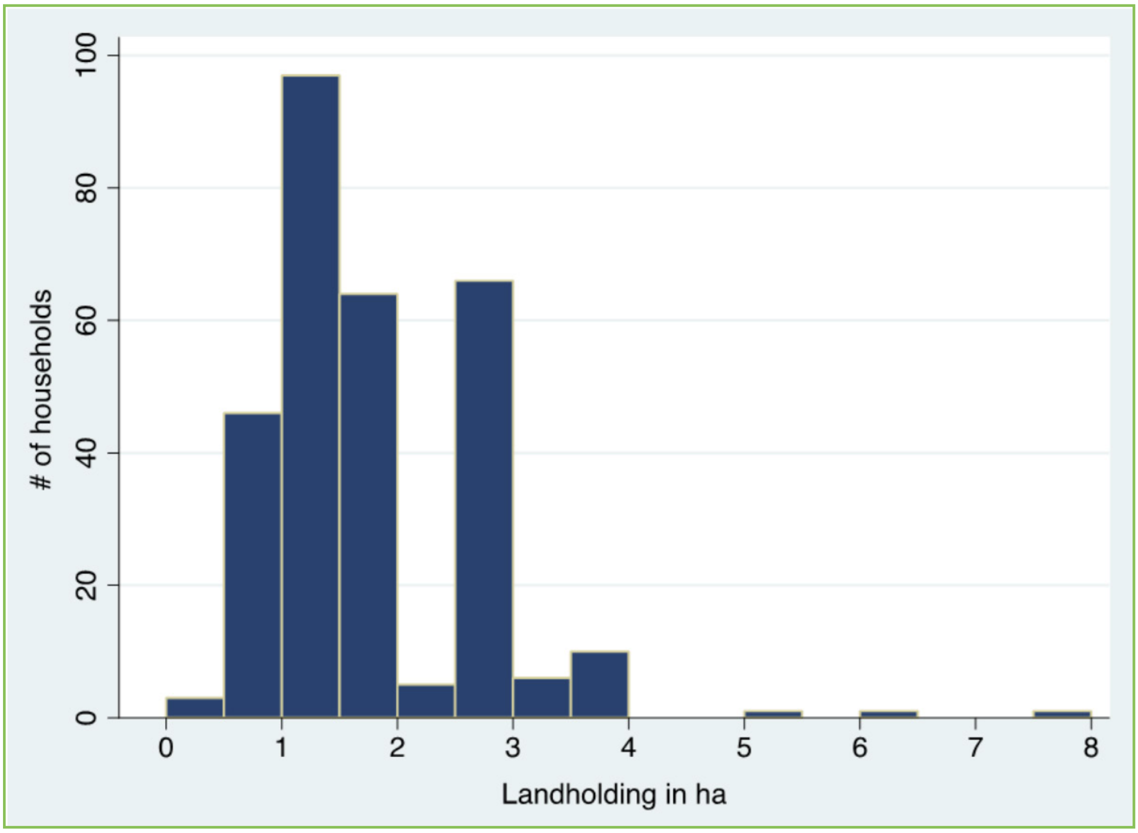


Figure 4: Distribution of farm sizes amongst the interviewed farmers

Table 4: Farm-level characteristics of model and conventional farmers

Model farmers (n=156)	Model		Conventional	
	median	sd	median	sd
Total landholding amongst farmers	1.6	(0.8)	1.6	(1.0)
Landholding dedicated to model farming	1	(0.4)		
Plots dedicated to model farming	1	(0.4)		
Size of main model garden plot (ha)	0.6	(0.4)		
Landholding dedicated to conventional farming	1.6	(0.8)		
Plots dedicated to conventional farming	2	(0.8)	2	(0.8)
Size of main conventional farming plot (ha)			0.6	(0.3)
Distance to the main plot in minutes of walking	25	(29.6)	45	(26.0)

Table 5: How the farmers obtained the land that they cultivate

How did you get these lands?	Model farmers	Conventional
	%	%
Private land	75	71
Inherited private land	16	26
Private land that you rent	9	3

Table 6: Extent of land tenure among model and conventional farmers

To what extent do you consider you have rights over the land you use?	Model %	Conventional %
Strong	94%	94%
Medium	2%	4%
Weak	3%	1%

4.2 Model farming in the study area

Figure 5 illustrates the degree of uptake of agroecological farming practices amongst all interviewed farmers, as revealed by the household survey. As can be seen, both conventional and model farmers undertake some agroecological practices. Model farmers employ on average 4 agroecological practices, compared to 3 in the case of conventional farmers (see Table 7). For some agroecological practices, the extent of uptake is greater amongst model farmers – these include using conservation barriers with straw, fewer seeds when seeding, respect for seed planting distances, careful selection of seed and plants, fencing of a plot and integration of crop residues into the soil.

However, the simple 'employ/do not employ' questions do not reveal the degree to which farmers implement a given agroecological practice, such as intercropping. In analysing the land use budgets from the household survey, model farmers in La Belle-Mere are seen to have an average of six different crops per model plot over a year (table 8), while conventional farmers cultivate an average of three different crops on their conventional land.

In Sans Souci and Bois Neuf, model farmers have an average of five different crops on their model farming plot (table 8). Figure 8 compares the degree of intercropping amongst model and conventional farmers (the full sample, independently of where they are based). As can be seen, conventional farmers have a maximum of four different crops on any

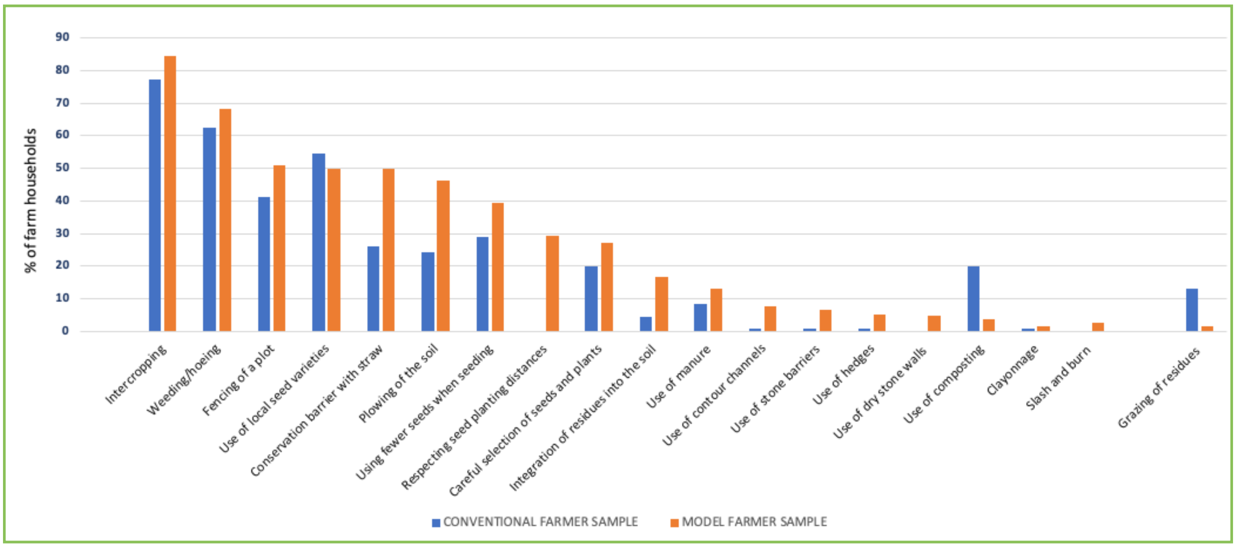


Figure 5: Uptake of agroecological and selected conventional farming practices amongst model and conventional farmers

Table 7: The Number of agroecological practices adopted by model and conventional farmers

Number of SLM practices	Mean (sd)	Median	min	max	N
Model farmers	4.0 (2.2)	4.0	0	9	162
Conventional farmers	3.0 (1.7)	3.0	0	6	138

given land plot, while a significant number of model farmers have 5 or more different crops on any given plot. There is also evidence (Table 9) that more model farmers are engaged in tree-planting, and that they have a higher overall tree density (in the 11-20% canopy cover category) on their cropland relative to conventional farmers (Table 10).

Other farming practices that are not strictly associated with agroecological farming (e.g., slash and burn and ploughing) are still used by some model farmers – confirming focus groups revelations. As such, there are overlaps between model and conventional farmers in terms of uptake of agroecological and conventional practices. It should be noted, however, that all the sampled farmers are members of peasant associations, and therefore even though they are not considered model farmers, they may have benefited from training directly or indirectly through other peasant association members. Moreover, some of the agroecological practices that PDL are promoting are inspired and inherited from ancestral practices. As noted above, transitions to agroecological farming are gradual and are affected by complex local factors.

4.3 Income from farming

Most farmers engage in intercropping. Since we cannot expect farmers to estimate the share of each crop on a given plot with precision, crop specific yields (in kg/ha) cannot be rigorously estimated. We estimate, therefore, the value of the harvest from the farmers' conventional and model gardens for one year prior to the interview, using standardised prices, notably the 2021 median farm gate prices for relevant units in which farmers reported their production values, as reported in Table 11. These prices were obtained from the household survey.

4.3.1 Main trees and crops

The main crops grown in the three communities are black beans, maize, pigeon peas, cassava, sugarcane, and banana. Sugarcane and black beans are considered the most important crops for respectively 55% and 30% of households, respectively. Maize and congo beans are the second and third most important crop for over 70% of households (figure 9). The most important tree species, include mangoes, bananas, whilst avocados, and cashew nuts are the second and third most important tree species, for more than 60% of households (figure 10).

BOX 1: INTERCROPPING AS EXPLAINED BY PDL

The term "Intercropping" in this study refers to the number of different crops that a farmer grows on a given plot of land for any one year. As such, intercropping captures the practice of diversification, based on the farmers' interests and the local contexts. The goals are usually to manage soil fertility (e.g., combination of legumes, cereals, root and tuber crops, and trees); to improve food and biomass production; and to extend the harvest period for different crops throughout the year, thus improving food access and security. The diversification strategy combines the elements of mixed intercropping (component crops are totally mixed in the available space) and temporal intercropping (the practice of sowing faster-growing and slower-growing crops that can be harvested at different times of the year), and agroforestry (integrating trees into farming systems). Figure 6 below provides an example of intercropping and diversification of a typical plot of land on a model farm for a whole year. *Most crops are grown at the same time, though not necessarily harvested at the same time*. It usually takes 3 to 5 years for trees (e.g., avocado, mango, coconut, etc.) to produce fruits or nuts. This may be compared to figure 7, illustrating what a conventional farmer typically grows on his main plot of land.

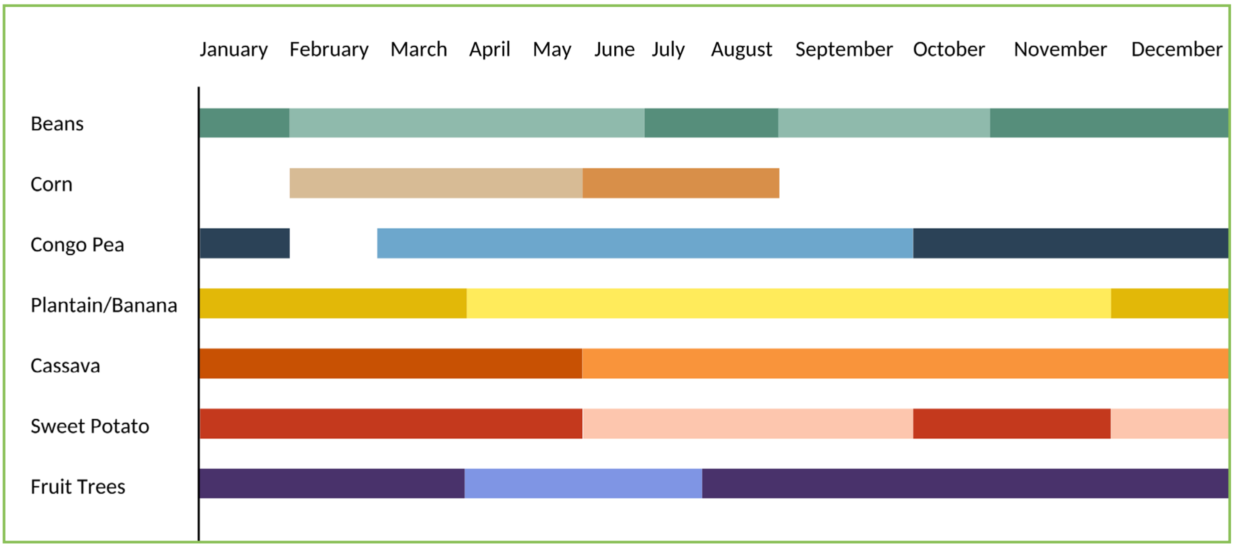


Figure 6: Typical crops found on a plot of land held by a model farmer (in bois neuf and sans souci). Light colors = production months, dark colors = harvest months. Credit: Ronel Lefranc

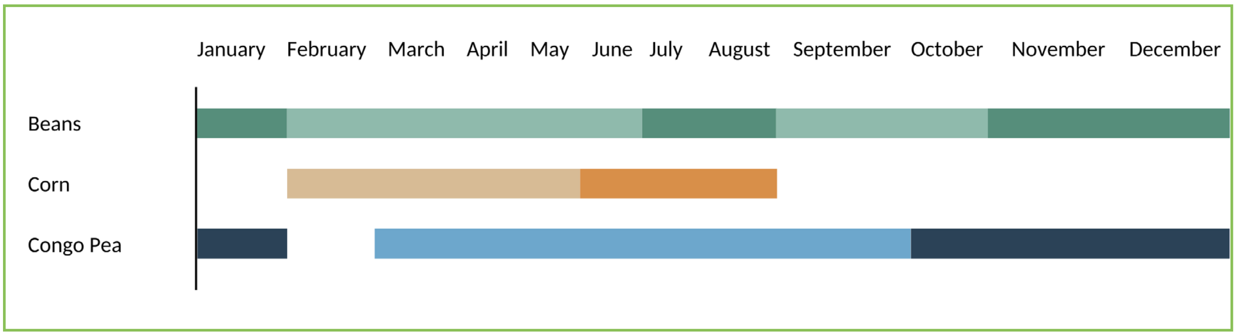


Figure 7: Typical crops found on a plot of land held by a traditional farmer in bois neuf. Credit: Ronel Lefranc

La Belle-Mère, Bois Neuf, and Sans Souci, differ in terms of crops that are grown. In La Belle-Mère farmers reap a large share of their income from the cultivation of sugarcane, whilst in Bois Neuf and Sans Souci, farmers main crops are black beans and pigeon peas. Figure 11 and 12 show the proportion of gross crop income (also called crop revenue) derived from the principal farmland under consideration (conventional and model farmland). Table 12 shows, furthermore, the average per hectare gross income from these crops.

4.3.2 Income from on-farm forest resources

Farmers have a range of trees on their farms from which they harvest fruits and nuts for their own consumption and sale. Main forest products include coconut, cashew nuts, lemon, orange, mango, avocado, soursoup and kachiman. Total gross income from the sale of the forest products grown within the farmers' main farming plots, range from an average of HTG 8,856 (124 USD) per ha[10] in Bois Neuf and Sans Souci to HTG 16,742 (233 USD) per ha in La Belle-Mère.

Table 8: Degree of intercropping - number of crops grown within the model and conventional garden plots, in the 12 months preceding the interview

Bois Neuf, Sans Souci and La Belle-Mère	Median* (sd)	min	max
Model farmers	5 (1.6)	2	9
Conventional farmers	3 (0.6)	1	4
Whole sample	4 (1.6)	1	9
Intercropping in La Belle-Mère	**Median(sd)**	**min**	**max**
Model farmers	6 (1.3)	3	8
Conventional farmers	3 (0.5)	1	3
Intercropping in Sans Souci and Bois Neuf	**Median (sd)**	**min**	**max**
Model farmers	5 (1.2)	2	9
Conventional farmers	3 (0.5)	2	4

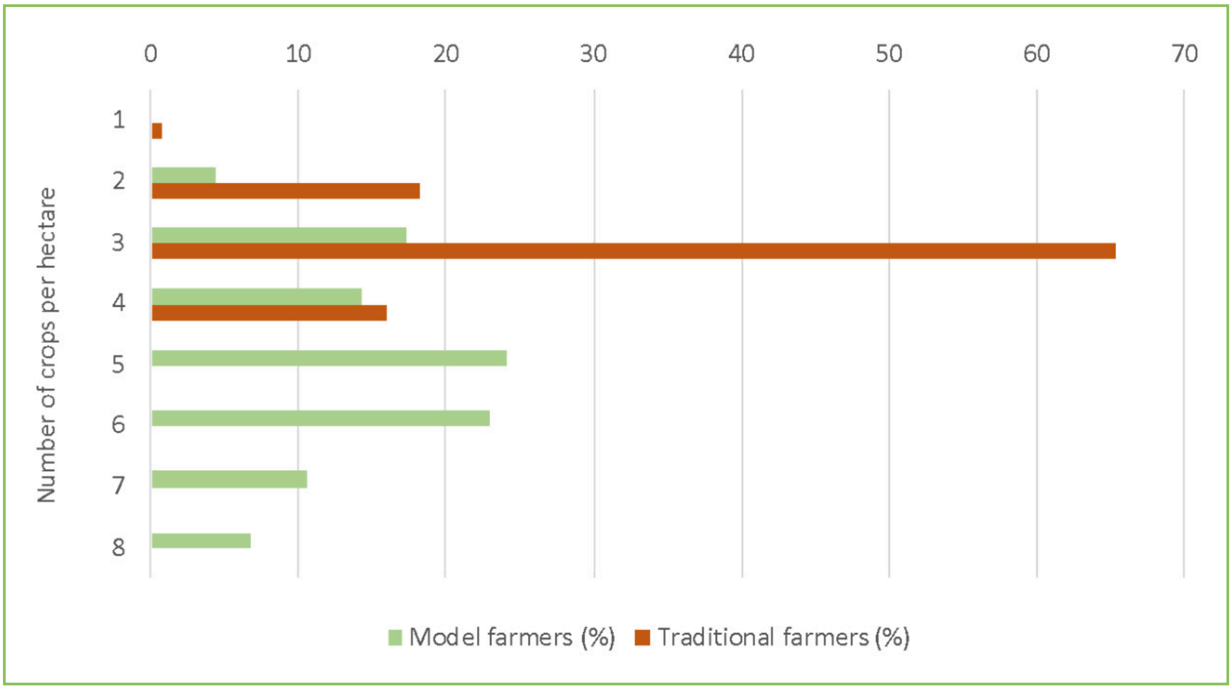


Figure 8: Degree of intercropping amongst model and conventional farmers

10 Based on: HTG 1 = 0.0139 USD, December 2020.

Table 9: Share of farmers having regenerated or planted trees within the last year

Have you planted or regenerated trees on your land the last 12 months?	Model farmer	Conventional farmer
	%	%
Yes	51	37

Table 10: What percentage of your farmland is occupied by trees?

Tree density	Model farmers	Conventional farmers
1-10%	31%	48 %
11-20%	57%	38%
21- 40%	12%	11.6%
41-60%	0.6%	2.1%

Number of different trees species on their main plot of land	Mean (sd)	median	min	max
Model	1.5 (1.4)	1	0	6
Conventional	1.4 (1.6)	1	0	6

Table 11: Median farm gate prices per unit for common crops in 2021

Crop	Unit	Median price per unit (HTG)	Crop	Unit	Median price per unit (HTG)
Maize	A pot	100	**Haricot**	A pot	700
Cassava	Set of 3	100	**Cassava**	A bag	1,000
Yam	Set of 3	50	**Yam**	A dozen	150
Yam	A bag	1,000	**Papaya**	A pot	1,000
Yam	Set of 3	100	**Pigeon Peas**	A pot	350
Yam	A bag	1,250	**Banana**	A bunch	400
Yam	A dozen	550	**Sugarcane**	A whole field	13,500
Sorghum	A pot	250			

The gross income for conventional farmers, range from an average of HTG 2,546 (USD 35) per ha in Bois Neuf and Sans Souci to HTG 9,176 (USD 128) per ha in La Belle-Mère (Table 13). It should be said that these are likely to be lower bound estimates of the true benefits from trees within croplands, as a large share of the produce is enjoyed by households (from 15% from oranges to 25% in the case of mangoes) for subsistence purposes. Moreover, fuelwood harvests for charcoal production and the value of timber are also left out of the analysis[11].

4.3.3 Production costs

The main expenditures that farmers incur are related to the purchase of seeds, rental of ploughing equipment, tree seedlings, family and hired labour costs of ploughing, planting, weeding, and harvesting and agroecological farming practices. Less than

11 Because this is considered an illegal activity, farmers estimates are not considered reliable.

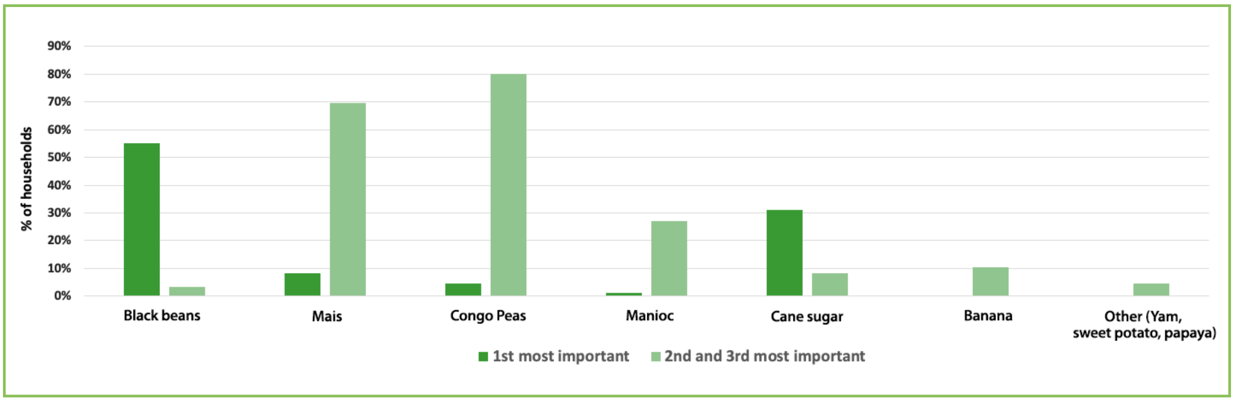


Figure 9: 1st, 2nd and 3rd most important crops by order of importance

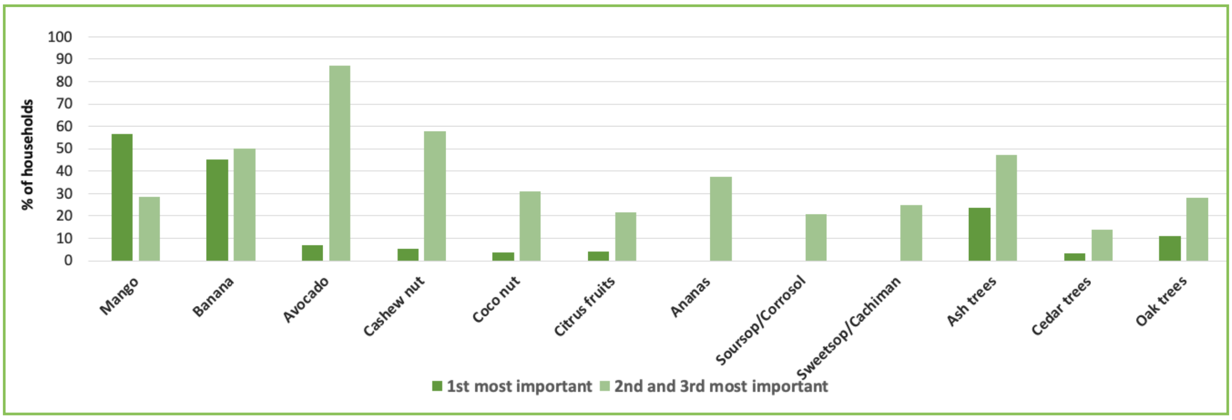


Figure 10: 1st , 2nd and 3rd most important tree crops

a handful of farmers (<0.5% of the sample) purchased fertilisers and pesticides, so these were not accounted for in the land use budgets for the average farmer. The cost for a day of labour was estimated based on what farmers had paid for a given service for any given day. As shown in Table 14, median labour costs are in the order of HTG 250 to 300 (approximately USD 4) per day.

Farmers, both conventional and model, were also asked how much they spent on agroecological practices in the 12 months preceding the interview – such as the planting of trees, pruning of trees and construction of conservation structures, such as contour barriers made of crop residues (*ramps*), rocks, live conservation barrier with food crops (*bande manje*), live hedges/fences. No labour costs are associated with these practices in La Belle-Mère. This is most likely because La Belle-Mère is a flat area and fewer labour-intensive soil conservation structures are built, in comparison to Sans-Souci and Bois-Neuf that are more mountainous (Ronel 2021, personal communication).

Table 15 summarises the average per hectare farming costs in La Belle-Mère, and Bois Neuf and Sans Souci, for both farmer groups. The highest expenditure is associated with the purchase of seeds amongst model farmers. While model farmers use less seeds, they are more careful in the selection of seeds, to help improve the quality of local seed varieties (Groundswell, 2017).

4.3.4 Other fixed costs associated with the uptake of agroecological practices

Farmers were also asked about other investment costs that they have incurred in relation to their agroecological farming practices. Average spending on fencing is in the order of 636 (USD 9) per ha, 295 (USD 4) per ha for drought resistant trees and HTG 600 (USD 8) per ha on chandelier cactus and for machetes. These investment costs were incurred on average 4 years ago (median). While these estimates are clearly in the lower bound, according to Lefranc (2021), the abandonment of agriculture as a means of livelihoods and the migration of labourers to the cities are also contributing to overall reduced

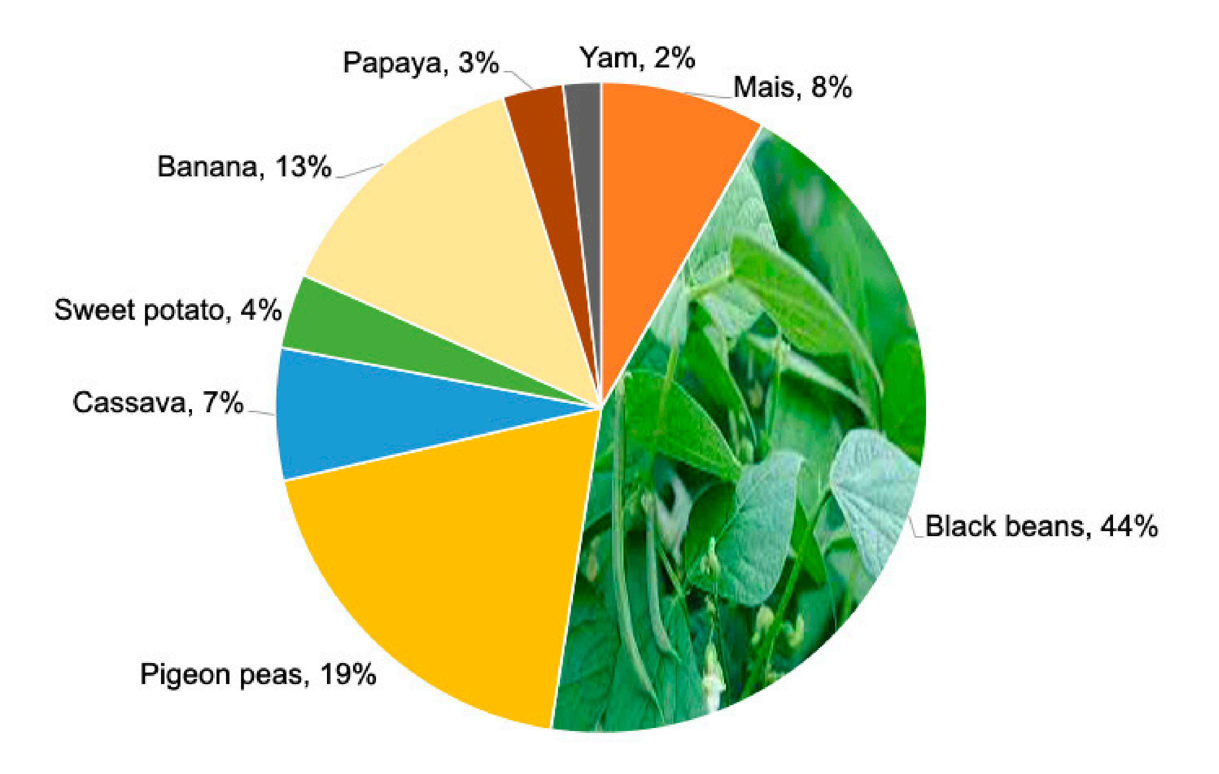


Figure 11: The composition of per hectare gross crop income in Bois Neuf and Sans Souci (all farmers)

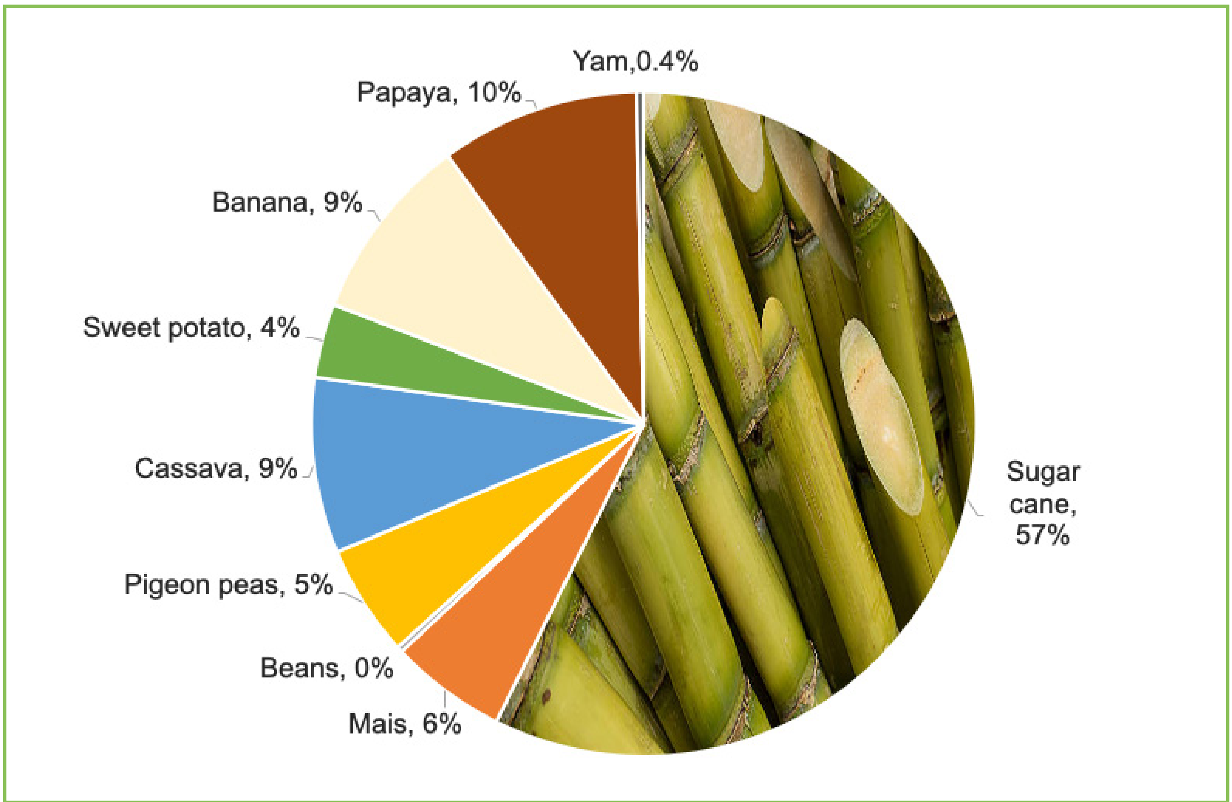


Figure 12: The composition of per hectare gross crop income in La Belle-Mère (all farmers)

investments in sustainable land management practices. Across the whole sample, however, the average expenditure is minimal, as seen in Table 16, and so not accounted for in the analysis.

4.3.5 Net crop and forest income

Based on above estimates on the benefits and costs, per hectare net incomes may be estimated for model and conventional farmers. The average per hectare estimate is shown in Table 19, demonstrating a significant difference between model and conventional farmers within Bois Neuf as well as La Belle-Mère. The average per hectare net income from model garden plots are almost double that which conventional farmers obtain.

Overall gross income, costs and net-income for model and conventional farmers in the two communities, are shown in figure 13 through to figure 16.

Table 12: Average annual per hectare gross crop income amongst conventional and model farmers

Whole sample (Model & conventional farmers confounded)	Bois Neuf & Sans Souci		La Belle-Mère	
	Gross income in HTG/ha	Share in gross crop income	Gross income in HTG/ha	Share in gross crop income
Sugarcane	0	0%	61,355	54%
Corn	7,469	7%	6,070	5%
Beans	40,115	37%	298	0%
Pigeon peas	5,958	6%	9,148	8%
Manioc	17,131	16%	5,816	5%
Sorghum	322	0%	394	0%
Sweet potato	3,368	3%	3,851	3%
Banana	12,165	11%	9,736	9%
Papaya	2,736	3%	10,364	9%
Yam	1,697	2%	390	0%
Total per hectare (HTG/ha)	**108,092**		**113,238**	
Total per hectare (USD/ha)	**$1,020**		**$1,069**	

Table 13: Income generated from the sale of on-farm forest resources in La Belle-Mère, Bois Neuf & Sans Souci

	La Belle-Mère		Bois Neuf & Sans Souci	
	Model farmers	Conventional farmers	Model farmers	Conventional farmers
Average gross forest income (HTG/ha)	16,742	9,176	8,856	2,546
Average gross forest income (USD/ha)	$233	$128	$124	$35

Table 14: The cost estimates for a given service paid for by farmers on any given day (HTG)

Cost for a day of labour (HTG)	Mean	Median	Sd	Min	Max
Ploughing	789	300	639	100	2,000
Weeding	299	250	271	0	4,000
Harvesting	269	250	191	100	2,000
Planting	249	250	116	20	1,500

4.4 Explaining the net-crop income differentials between model and agroecological farmers

As illustrated in figure 13 to 16 model farmers have net incomes that are approximately double that of conventional farmers. The challenge with simple bi-variate comparisons, however, is that income differentials may be due to other factors that we have not controlled for. For example, model farmers may be earning more because: their farming plots are located closer to their homestead; they are better educated; they have greater support networks; they use a more efficient level of conventional farming inputs in addition to adopting agroecological practices. To control

Table 15: The average per hectare farming costs for conventional and model farmers

	La Belle Mère		Bois Neuf & Sans Souci	
	Model farmers	Conventional farmers	Model farmers	Conventional farmers
Input costs (HTG/ha), including	**32,714**	**6,115**	**21,410**	**14,585**
Seeds	18,739	4,587	18,436	12,048
Tree seedlings	34	33	194	0
Rental of ploughs*	7,353	1,496	2,720	2,537
Total input costs in USD/ha	**$454**	**$85**	**$298**	**$203**
Total hired or family labour costs (HTG/ha): ploughing, weeding, harvesting, and planting	**8,187**	**2,318**	**7,912**	**5,884**
Labour costs associated with agroecology (HTG/ha)**	0	339	1,881	1,235
Total labour costs in USD/ha	**$113**	**$37**	**$136**	**$99**

* La Belle Mère is more flat land with higher demand for ploughing.

** Mainly for the planting and pruning of trees, construction of straw ramps, and fencing.

Table 16: One-off investment costs associated with uptake of agroecological practices in La Belle-Mère, Bois Neuf and San Soucis for model and conventional farmers (HTG/ha)

Bois Neuf & Sans Soucis	mean	min	max	N
Model	349	0	8750	108
Conventional	46	0	3000	89
La Belle-Mère				
Model	238	0	2000	54
Conventional	61	0	1500	49

Table 17: Cost of material bought for the main agroecological model farming land plot (HTG/ha)

Material	Average	Min	Max	N
Fencing	636	0	5000	44
Drought resilient trees	296	0	1500	35
Other investments (candelier cactus[1] and machetes)	600	0	2500	21

Years since the materials were purchased	Average	Min	Max	N
How many years ago were these investments undertaken?	9	1	60	44

1 For live fencing

for all the variables that may be driving the observed income differences, we have undertaken a production function model and included all variables that could be important in explaining actual land-use productivity. Land-use productivity here is measured with respect to gross crop income per ha since yield (kg/ha) are difficult to measure with precision when several crops are intercropped on the same piece of land.

4.4.1 Production function analysis

In the following production function analysis, we assess the drivers of agricultural performance with respect to per hectare gross crop income. The estimated coefficients of the production function provide an understanding of both the statistical significance of individual inputs and the magnitude of which of these variables affect outcomes. At first, gross crop income was regressed on all possible management practices, quantities of inputs and socio-demographic characteristics of relevance (canopy cover densities, major SLM practices, livestock holding, labour effort, education of household head, rental of ploughing equipment, etc.). Variables with insignificant coefficients were dropped from the final lin-log estimations. Two models were retained for further interpretation, specified as per equation 6 and equation 7.

Eq 6) $$G\_income\_ha_i = \alpha + ß_1(M)_I + ß_2 \ln(LW)_i + ß_3(L)_i + ß_4 \ln(S)_i + ß_5 \ln(C)_i + e_i$$

Eq 7) $$G\_income\_ha_i = \alpha + ß_1(T)_i + ß_2 \ln(LW)_i + ß_3(L)_i + ß_4 \ln(S)_i + ß_5 n(C)_i + e_i$$

Table 18: The average per hectare net income estimates for model and conventional farmers in Le Belle-Mère, Bois Neuf and San Souci

	La Belle-Mère		Bois Neuf & Sans Souci	
	Model farmers	Conventional farmers	Model farmers	Conventional farmers
Average gross forest income (THG/ha)	16,742	9,176	88,547	41,760
Average gross crop income (THG/ha)	138,949	57,557	110,894	63,463
Total average annual cost (THG/ha)	40,867	-8,740	-30,949	-21,704
Average net crop and forest income (HTG/ha)	114,790	57,961	89,561	44,306
Average net crop and forest income (USD/ha)	**\$1,670**	**\$806**	**\$1,246**	**\$615**

Where the outcome variable *G_income_ha* represents the gross crop income per hectare of each farmer *I,* on his main farming plot. The binary variable M equals one if the farmer is classified as a model farmer and zero if otherwise (in equation 6). The continuous variable T in Equation 7 represents the degree of intercropping (logged) and is included in model 2 below (Table 20). LW is a continuous variable to capture hired labour days for weeding (logged). L is a variable capturing all other hired labour, S captures spending on seeds (logged) and *C* is a community dummy variable that is equal to one if the farmer lives in La Belle-Mère and zero if otherwise. We control for location since bivariate comparisons above suggests that everything else being equal, farmers in La Belle-Mère where they are growing sugar, are enjoying higher per hectare incomes relative to Bois-neuf and Sans-souci[12]. Exact variable descriptions are included in Table 19.

4.4.2 Production function modelling results

The statistical regression model that is retained here, shows that spending on seeds, hired farm labour and model farming, as well as the community in which

12 This is arguably because farmers grow sugar cane in La Belle-Mère, a crop which requires processing after the harvest, bringing the actual income earned from sugar cane to similar levels for that of the crops grown in Sans Souci and Bois Neuf.

the farmer lives are significant drivers of gross crop income and farm productivity (table 20a). Specifically, the model farming coefficient shows that agroecological model farming – *holding everything else constant – increases gross crop income, by an average HTG 31,460 per hectare (USD 437 per hectare)*. This is a highly significant result as it demonstrates that higher incomes amongst model farmers are attributable to agroecological farming and not merely that they spend more on seeds, weeding and labour.

As model farming plots tend to be closer to household's than conventional plots, we also analysed

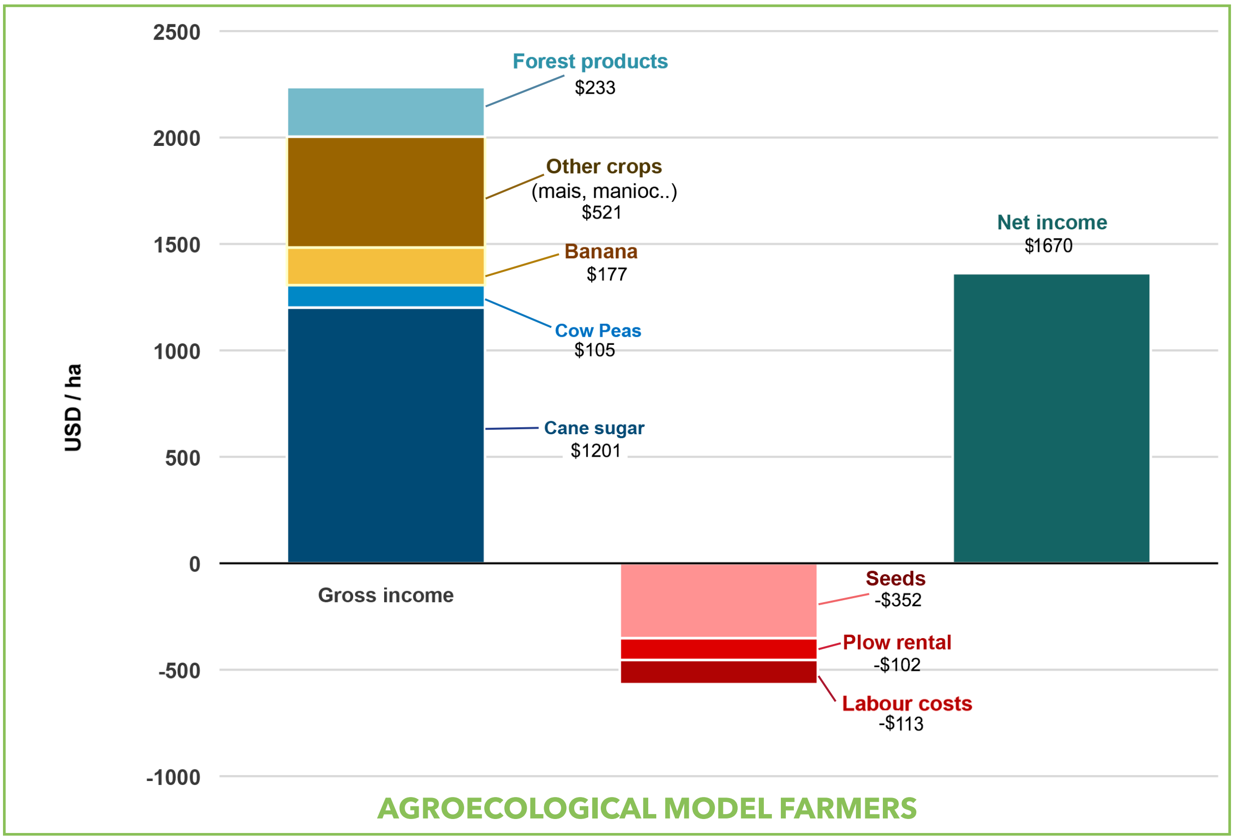


Figure 13: The composition of income and costs of an average agro-ecological model farmer in La Belle-Mère

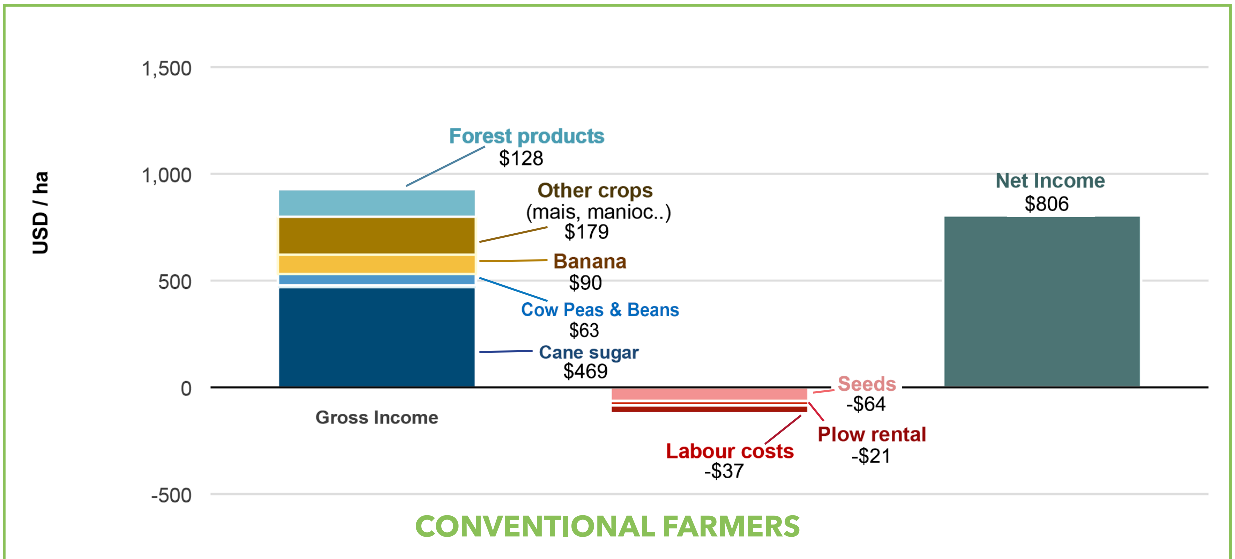


Figure 14: The composition of income and costs of an average conventional farmer in La Belle-Mère

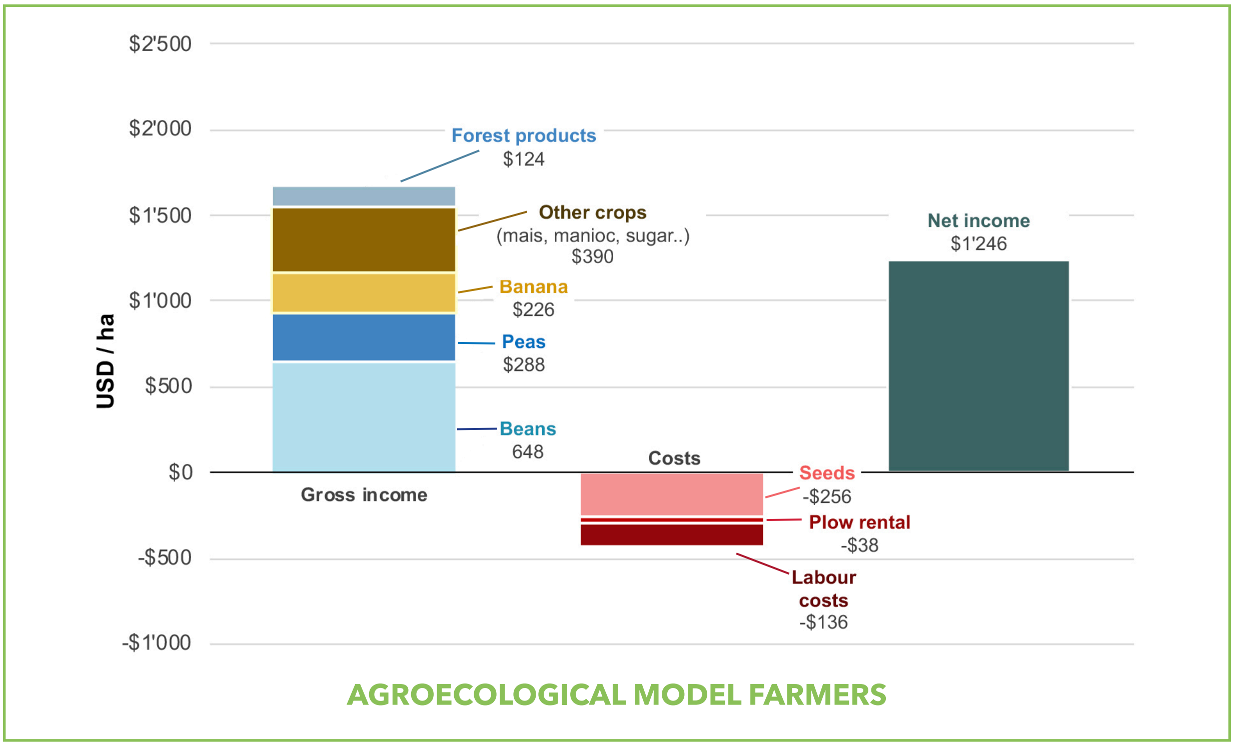


Figure 15: The composition of income and costs of an average agro-ecological model farmer in Bois Neuf & Sans Souci

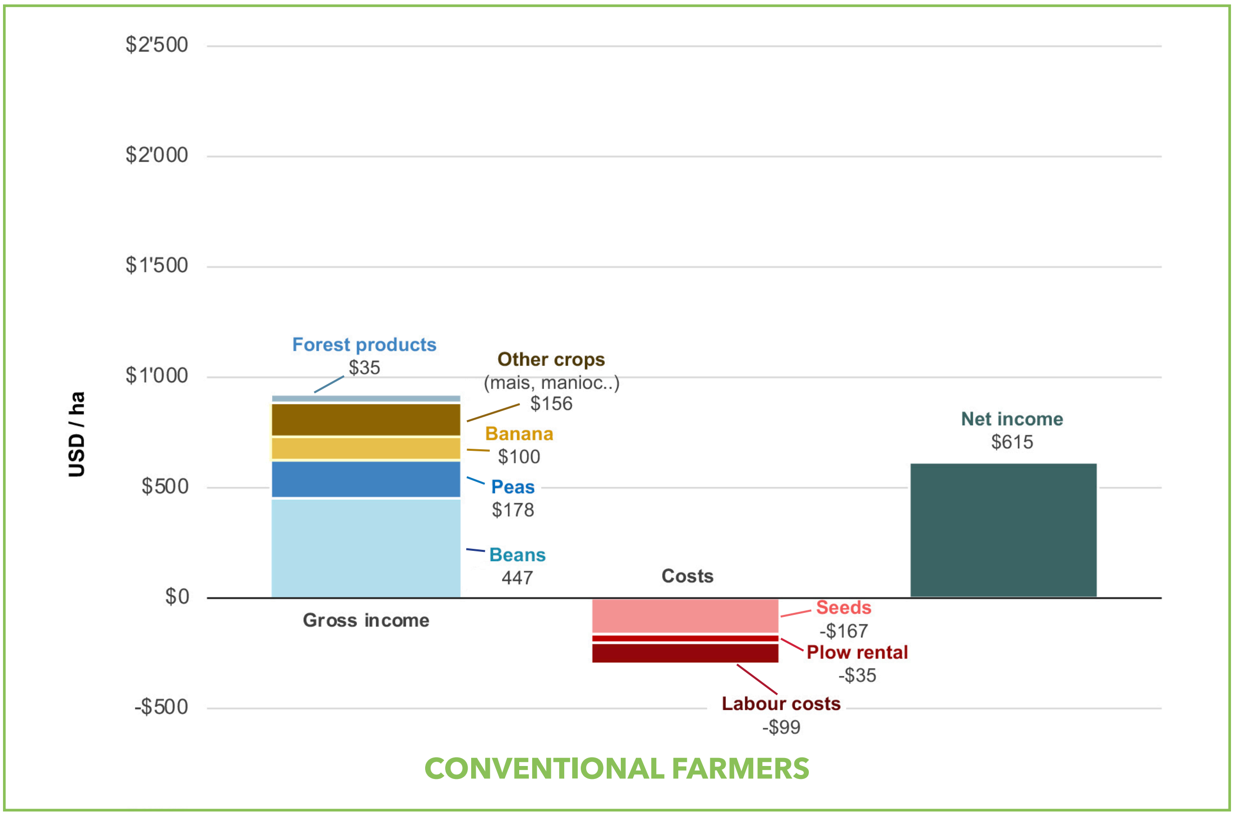


Figure 16: The composition of income and costs of an average conventional farmer in Bois Neuf & Sans Souci

if distance to the farm plots could explain higher productivity, but there was no statistically significant correlation. We also included the full range of agroecological practices in the production function modelling to see whether there were specific practices that were particularly important in driving land productivity. Except for intercropping, none of the agro-ecological practices displayed in Figure 5 were statistically significant determinants[13]. The degree of intercropping, however, i.e., number of crops grown per plot of land, is a strong determinant of productivity[14] and regression results are presented in model 2, table 20b. Interpreting the coefficient, a unit increase in the log of number of crops increases gross income by HTG 62,369 per ha. So, when the number of crops increase from two to three crops per hectare, for example, gross crop income increases by HTG 25,289 per ha (= 62,369*ln3 – 62,369 *ln2).

Agroecological model farmers have an average of 5 crops per hectare, against 3 crops per hectare for conventional farmers. When controlling for the degree of intercropping, the variable 'model farming' is no longer significant in the regression model (Model 3, appendix 1), due to a high correlation between intercropping and the likelihood of being a model farmer. As such, intercropping is a significant feature of model farming (See appendix 1 for explanation).

Amongst the different kinds of labour activities, including ploughing, weeding, harvesting, and sowing, weeding stood out as the most important driver of farm productivity. Weeding was therefore included as a separate variable, because of its importance in explaining gross crop income. The returns from all other hired labour activities are analysed together. Spending on seeds and days of weeding displays diminishing marginal returns, illustrating (consistent with economic theory) that adding more capital or more labour to the production process increases productivity, though at a diminishing rate[15].

When variables are logged, the coefficients measure the absolute change in gross crop income for a relative change in the explanatory variable. For example, with ß = 14,870, a unit increase in the log of seed expenditure increases gross income by HTG 14,870 per ha, or as farmers spend 1% more on seeds, gross crop incomes increase by HTG 148 (USD 2) per ha. By the same logic, as hired farm labour for weeding increases by e.g., 1%, gross crop income increases by HTG 170 per ha.

Table 19: Explanatory variables used in the final production functions

	mean	median	sd	min	max
Model =1 if the farmer is a model farmer	0.54	1	0.4992	0	1
Belle-Mère =1 if the farmer lives in La Belle-Mère and 0 otherwise	0.34	0	0.47	0	1
Spending on seeds in logs	14,334	9,766	15,474	0	97,550
Hired labour days for weeding in logs*	11	7	13	0	39
Hired labour days for all other work (except weeding)*	12	9	13	0	76
Degree of intercropping	4	3	2	1	8

* In the survey we asked how many days of labour (family and hired) had been dedicated to a specific task. But it appears that interviewers focused on hired labour, as in many cases they provided total expenditure on farm labour instead of "days" of farm labour. In the following results we therefor refer to hired labour.

13 This may be attributable to insufficient observations, or lack of information about the degree of uptake of these practices, and not because a given practice does not enhance farm productivity.

14 Indeed, when accounting for the degree of intercropping, the variable 'model farming' is no longer statistically significant.

15 The coefficient for all other hired labour does not display diminishing returns, possibly reflecting that it is a composite variable – covering many complementary farm related activities.

Table 20a: Regression analysis results wtih agro-ecological model farming

Production function model 1. Gross crop income per ha			
	Coef.	t	Significance P>t
Model farming	31,460	5.23	***
Spending on seeds (logged)	14,870	5.75	***
Hired labour days for weeding (logged)	17,021	5.73	***
Days for hired labour (all other)	889	3.09	***
Belle-mère	29,567	4.52	***
_cons	-111,921	-4.88	***

# of observation=300, F = 45.2; Prob > F = 0; R-squared = 0.4331; Root MSE = 48208

Table 20b: Regression analysis results with intercropping

Production function model 2. Gross crop income per ha			
	Coef.	t	Significance P>t
Intercropping (logged)	62,369	7.1	***
Spending on seeds (logged)	14,785	6.29	***
Hired labour days for weeding (logged)	12,749	4.52	***
Days for hired labour (all other)	731	2.76	***
Belle mère	27,201	4.07	***
_cons	-111,921	-4.88	***

# of observation = 300, F = 56.06; Prob > F = 0; R-squared = 0.5675; Root MSE = 0.61523. ***Significant at 99% level of confidence

The impact of intercropping and hired labour on gross crop incomes are plotted in Figure 17. In Table 21 we have used Model 1 to calculate gross crop income per hectare based on different stylized farmer characteristics. It allows us to show how average gross crop income changes, as various inputs within the farming system are increased[16].

Thus, an average farmer, who adopts model farming, lives in La Belle-Mère, has hired 10 days of labour for weeding, and 10 days for all other activities, spending an average of HTG 10,000 per ha on seeds, has an average annual gross crop income of HTG 134,154 (USD 1865) per ha. It should of course be recalled that the model depicts the *average* impact of increasing hired labour, weeding, uptake of model farming, etc. The individual farm, however, is conditioned by many other factors such as the local climate, the soils, the slope, the land tenure regime, and financing opportunities, etc., that we have not been able to account for in this study. Despite this, our statistical model confirms that agroecological model farming is a significant determinant of higher gross crop incomes, providing the average farmer with about HTG 30,000 more per ha, with everything else held constant.

4.4.3 Validating findings with earth observations

Interviews for the household were undertaken within the main plots of the model and conventional farmers. This has allowed us to assess whether satellite imagery tells the same story, as the empirical household data. As shown in box 2, agroecological model farmers have statistically higher land productivity, as measured by Normalized difference vegetation index (NDVI), further confirming our results.

16 The agro ecological model farmer remains a model farmer, but he is conditioned by land tenure, the ecosystem, and his economic situation (financial). All model farms are not similar. There can be some similarities between model farms within the same ecosystem, but not everyone within that ecosystem has the same characteristics (land tenure, incomes, access to finance etc.,). (LeFranc, 2022)

Table 21: Changes in gross crop income with changing inputs levels

Spending on seeds	5,000 HTG	10,000 HTG	10,000 HTG	10,000 HTG	10,000 HTG	10,000 HTG
Hired labour days for weeding	5 days	5 days	10 days	10 days	10 days	10 days
Hired labour days, all other tasks	5 days	5 days	5 days	10 days	10 days	10 days
Agroecological model farming	No	No	No	No	Yes	Yes
Farm located in la Belle-Mère	No	No	No	No	No	Yes
Gross crop income per hectare (HTG per ha)	46,600	56,900	68,700	73,100	104,600	134,154
Gross crop income per hectare (USD per ha)	648	791	955	1,016	1,454	1,865

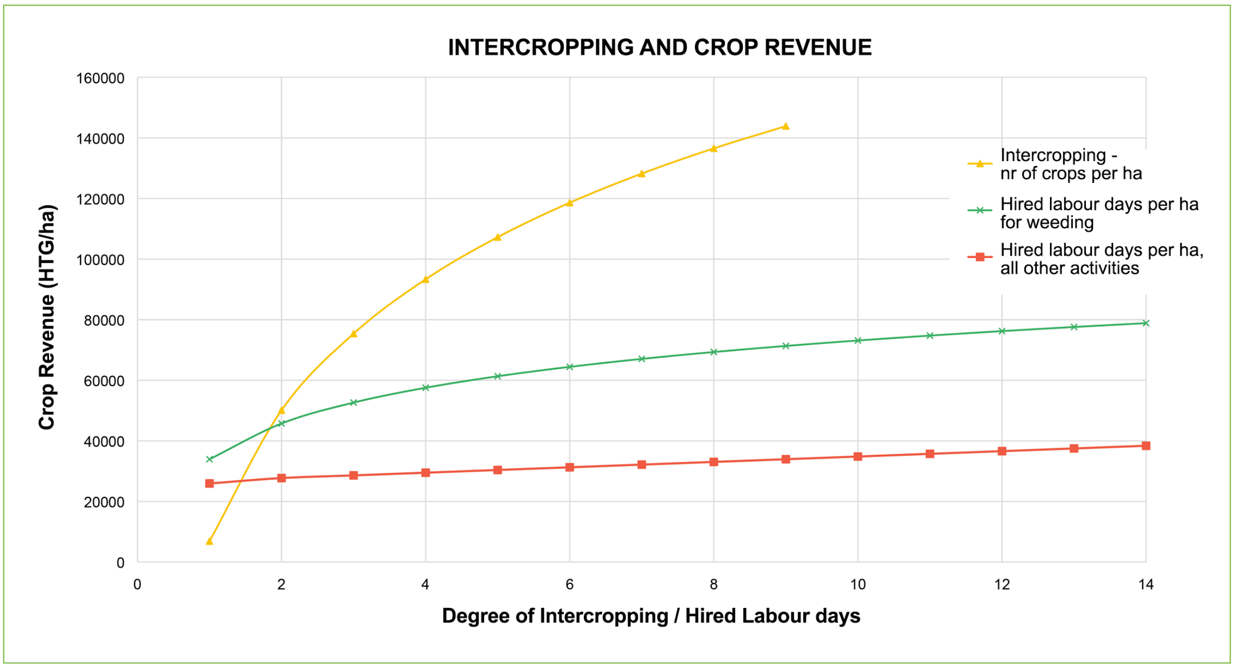
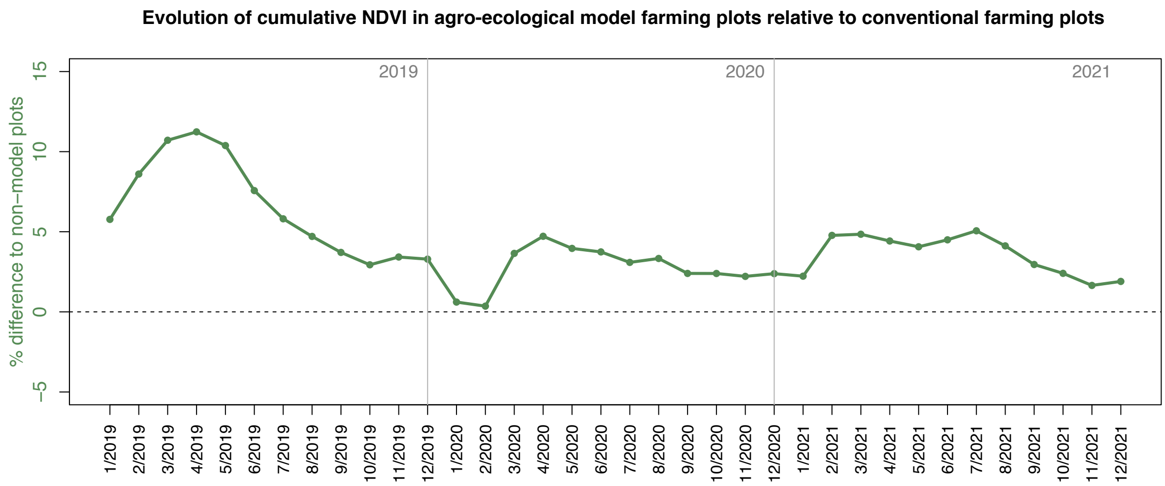


Figure 17: Correlation between the degree of intercropping and hired labour days with gross crop income

BOX 2: NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) OF NET CROP INCOME BETWEEN MODEL AND AGROECOLOGICAL FARMERS

To assess whether observed differences in net crop income amongst model and agro-ecological farmers can validated with remote sensing data, we compared values of NDVI (Copernicus Sentinel 2021) and precipitation (ERA5 2021) for the years 2019-2021. Over that time period monthly values of NDVI were on average 4.3% higher than in traditional plots (indicating higher fractions of vegetation) - this was consistent over the entire time frame (see green line). Because precipitation strongly influences vegetation development, we evaluated if the higher values on NDVI were related to higher precipitation occurring in model farms. We found that not to be the case. Agroecological model farms received on average 3.5mm less precipitation per month than traditional ones over the investigated time frame.

Interestingly therefore, agroecological model plots have higher NDVI values, despite lower precipitation levels. This suggests that agroecological farming plots are characterized by higher land productivity and climate resilience, which is in line with ground-sourced survey findings of higher net crop incomes. It also gives testimony to the use of remote sensing as tool to monitor farm level resilience, but it should be acknowledged that NDVI is a broad measure of vegetation state and should be supplemented with metrics such as water storage, carbon content, fire occurrence and input use, for a more complete picture of vegetation health. This is a subject of future research.



Sources:

Copernicus Sentinel data (2021). Retrieved and processed from GEE.

ERA5 (2021) Fifth generation of ECMWF atmospheric reanalyses of the global climate. Copernicus Climate Change Service (C3S), Climate Data Store (CDS), https://cds.climate.copernicus.eu/cdsapp#!/home

Success of model farming – as perceived by farmers and other repercussions

The above analysis of the farmers' production costs, outputs, and incomes, clearly demonstrates that model farmers can reap higher net-income per hectare of land dedicated to agroecological model farming, relative to conventional farmers. It is of relevance to put such results in perspective with respect to farmers' own appreciation of model farming.

In this regard, Table 22 shows that the overwhelming majority (98%) state that they will continue to undertake agroecological farming, and 98% also plan to expand the area they have dedicated to model farming. All the model farmers also report experiencing some increase in agricultural production because they have adopted agroecological practices (figure 18). Those that report a large increase, started on average 5 years ago. In terms of estimates regarding production outputs, Table 24 shows that one third of all agroecological farmers say they have experienced at least a 33% increase in agricultural production volume, half of all agroecological farmers have experienced a 50% increase and 10% report that they have been able to double their production (figure 19). These figures provide even further confidence to the quantitative assessment of farming incomes, based on land use budgets.

Table 22: Responses to survey regarding model farming continuation and expansion

	Yes	No	Don't know
Will you continue to undertake model farming?	98 %	0.53 %	1.6 %
Do you foresee expanding the area of your agroecological model farm over your conventional farming area?	98 %	2 %	0 %

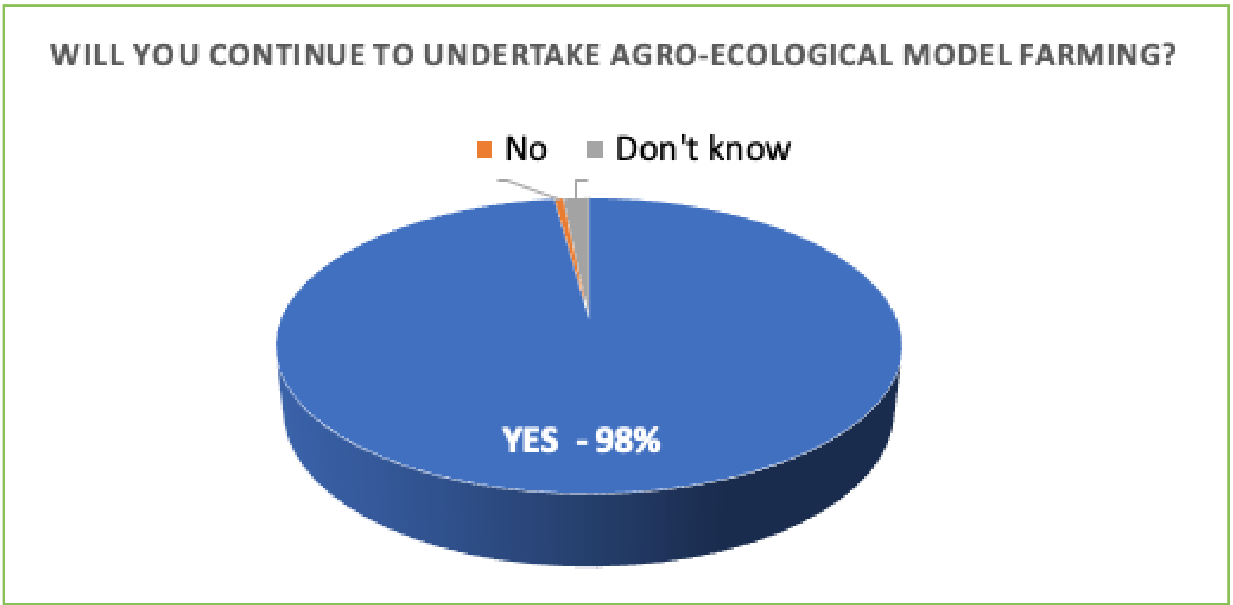


Figure 18: Response to survey regarding model farming continuation

Table 23: Perceived increase in agricultural production since adopting model farming and years since SLM practices were adopted

Has your agricultural production changed after adopting agroecological farming?	%	Years since the SLM practices were adopted by the household?
1=Decrease in production	0 %	
2=No change	0 %	Average
3=Small increase in the production	84 %	4 years
4=Big increase in the production	16 %	5 years

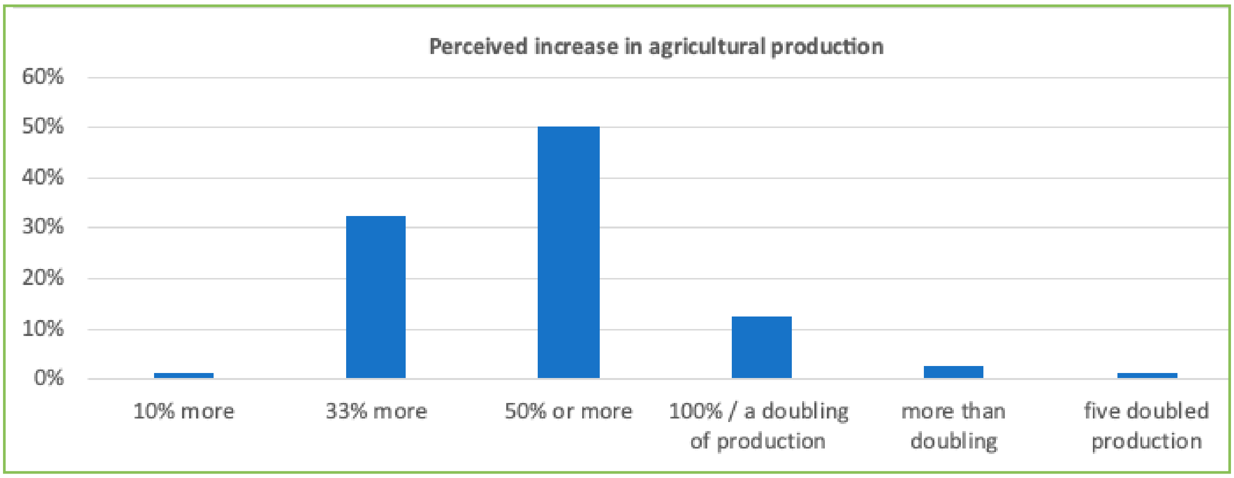


Figure 19: Perceived increase in agricultural production since adopting model farming

Table 24: Perceived success of model farms since adopting agroecological methods

What is your impression of how successful your garden design is (in terms of being able to provide food all year round, improving soil fertility, improving your income)?	Percent
Highly successful	11
Rather successful	58
Little success	32
No success	0

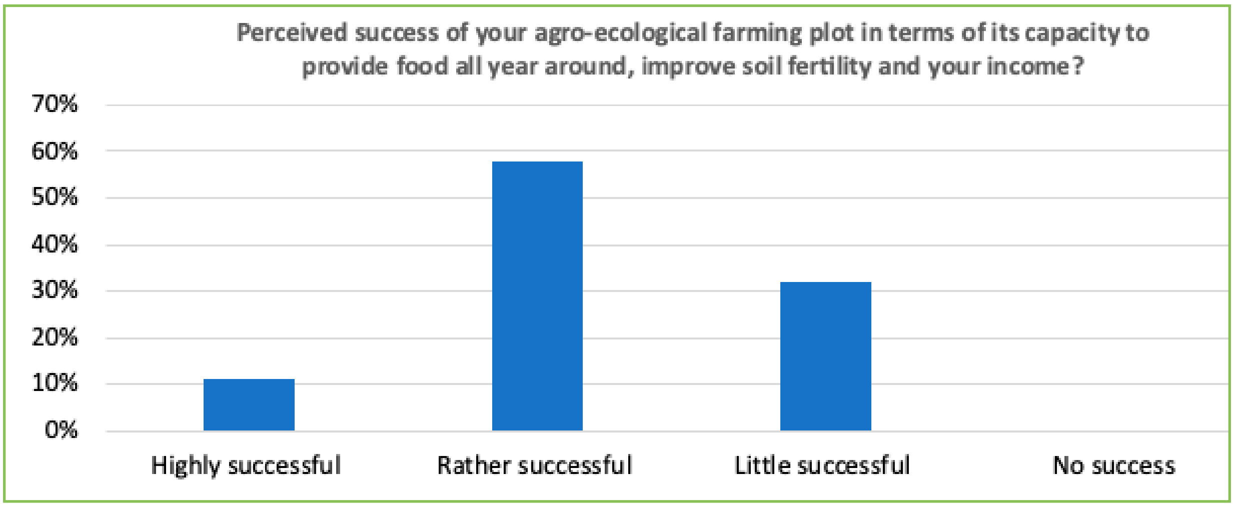


Figure 20: Perceived success of agroecological farming plot in terms of capacity to provide food all year round, improve soil fertility and household income

5.1 Other visible implications of model farming

Finally, in this section we consider whether there are other distinguishing differences between agro-ecological model and conventional farmers, notably with respect to food security, loss of food and access to markets.

As shown in Table 25, overall agroecological farmers have experienced less food loss and less problems with accessing markets for their produce. It is not clear if this is due to the kind of products they produce (more diversified) or potentially because they receive better support from their peasant associations to store their produce and bring it to markets. In terms of food security, at the time of the interview, agroecological farming households had an average dry food stock of 50 kg against, 35 kg for conventional farmers. In other words, agroecological farming households had a 42% higher food stock relative to conventional farmers.

Table 25: Losses of agricultural product and market access in conventional and model farmers

Have you lost agricultural products in the last 12 months, due to improper storage and transport?	Conventional farmers	Model farmers
Yes, a lot	31%	8%
Yes, a bit	57%	61%
No	11%	28%
Did you lose access to markets for your agricultural products in 2020?	**Conventional farmers**	**Model farmers**
Yes, a lot	12%	2%
Yes, a bit	77%	64%
No	11%	32%
In this moment, what is the level of your dry food stock in kg?	**Conventional farmers**	**Model farmers**
Kg per household (median)*	35*	50
Min & Max	0 to 150 kg	0 to 150 kg
Kg per person	5.7	7.0

*Ttest and Krystal Kwalist tests confirms statistically different means between model and conventional farmers

We also used the selected questions from FAO FIES food security scale, which focuses on self-reported food-related behaviours and experiences associated with difficulties in accessing food due to resource constraints. The scales allow for measuring different degrees of food insecurity as shown below.

When using selected questions from the FAO FIES food security scale, we see no statistically significant differences in the level of food security amongst model and conventional farmers, except for experiencing the running out of food. The difference (42.5% for model farmers versus 48.5%) is small.

Figure 21: Food insecurity based on FAO FIES: What does it mean? Credit: FAO (www.fao.org/hunger/en)

Overall, the level of food security may also be deemed significant in that at least 40% of households, whether model or conventional, have experienced running out of food in the 12 months prior to the interview and the majority of the households felt they ate less than they should have (table 26).

There is an apparent discrepancy between the higher net incomes and food stocks amongst model farmers compared to conventional farmers, and the farmers' self-reported perceptions of food insecurity from the FAO FIES food security scale. This latter source shows little difference between model and conventional farmers. One possible explanation is that, given the level of extreme poverty for peasant households in Haiti, and the lack of functional government supports and policies, even those farmers who are able to generate significant positive benefits through agroecology still have difficulty achieving food security. This is consistent with reports of Haiti having one of the highest levels of food insecurity in the world, with 4.4 million needing immediate food assistance and amongst these 1.2 million suffer from severe hunger (UN WFP 2022). Complementary interventions and policies are required to achieve food security.

Table 26: Food security of households

During the last 12 months, was there a time when, you or other members of your household… because of lack of money or other resources	Conventional farmers	Model farmers
Were unable to eat healthy and nutritious food? (=yes)	94%	91%
Ate less than you thought you should? (=yes)	94%	89%
Ran out of food? (=yes)	49%	43%
Still thinking about the past 12 months, have there been moments when you or someone in your household went without eating for a whole day? (=yes)	16%	15%

Table 27: Other sources of income, cash or in kind

Does your household receive other types of income, in cash or in kind, for example (q36.6)	Conventional farmers	Model farmers
Remittances	55%	64%
Inheritances	16%	19%
Pension	1%	1%
NGO support	11%	11%
Government support	0%	1%
Community business dividends	1%	0%

5.2 Limitations

The study presented here has compared agroecological and conventional farmers, that are all members of peasant associations. Had we been able to also assess the performance of agroecological farmers against farming households who are not members of peasant associations (that account for almost 90% of the population), it is likely we would observe even more pronounced differences in the productivity of farming systems. This remains an area for future research.

Other limitations are that some conventional farmers also adopt some agroecological practices, although at more limited levels, so the analysis is not 'pure' agroecological versus 'pure' conventional farming, but rather a question of degrees of adoption and transition in challenging, real-world conditions. In addition, the data was collected over one year (2020), and data collected over a longer time horizon would allow for analysing the variability between years, but is cost prohibitive and burdensome on farmers.

In designing any valuation assessment, it is important to consider how impact may be attributed to the agroecological model farming itself, as opposed to observable and non-observable factors, farmer characteristics and other external factors. The challenge is to precisely estimate a counterfactual, a situation which would prevail for agroecological farmers had there been no intervention by peasant associations. This situation is of course not observable, because of those interventions. This non-random allocation of 'control and intervention' may lead to biased results (Damgaard, 2019; Larsen, Meng and Kendall, 2019). Had control and model farmers been randomly allocated to 'model and non-model farming', e.g., using Randomized Controlled Trials, differences in observed impacts between control and model farmers may be attributed to actual project impact, if enough beneficiary households are sampled[17]. For obvious reasons model farmers are not randomly chosen by peasant associations. They have features (e.g., they tend to be female headed, have greater support networks, have chosen to join peasant associations, and other non-observable factors, etc.) that make them more likely to adopt model farming. It may be these features (in-part), that are leading to improved productivity and not agroecological model farming practices in particular. To mitigate this bias, we introduced and controlled for all the various factors that could be driving productivity improvements - including gender, distance to the farm plot, education - within the production functioning analysis presented in section 4.4.2. All those that were not significant were dropped. Propensity score matching was also undertaken (not reported on in this study), which confirmed that that higher net-crop incomes could be attributed to agroecological model farming amongst matching model and conventional farmers. Both methods, however, fail to account for non-observable factors that could also have influence outcomes, such as differentials in micro-climate within model and conventional farm plots, or personal characteristics of farmers. The satellite based NDVI analysis in box 3, shows that higher productivity persists within agroecological farming plots, even when they have less favourable climatic conditions. Whilst there may be other unknown non-observables that may be driving observed outcomes, we believe there is ample evidence of pronounced positive impact from the adoption of agroecological farming in the study above.

17 See as an example 'Innovation for Poverty Action' for evaluations that uses RCTs for designing poverty actions. https://www.poverty-action.org/about/randomized-control-trials.

06 Recommendations, management, and policy implications

6.1. What can be done to scale agroecology - Survey findings

Chapter 5 has shown that spending on (more expensive) local seed varieties, dedicated labour for weeding, increased intercropping, and diversity of crops on a given farm plot, lead to increases in land productivity and crop incomes. Moreover, agroecological model farming, which is associated with intercropping and other sustainable land management practices, results in impressive economic returns to farmers even when we hold the level of input use constant. Our results show that model farmers earn HTG 31,000 per ha higher gross crop income per hectare per year, relative to conventional farmers. Additionally, accounting for forest produce, their average gross income is HTG 38,000 (+7000 per ha) higher relative to conventional farmers. At the end of 2020, when the survey was undertaken, this would have equated to approximately USD 530 of additional net income per ha per year per household. This is significant where many people are living on less than USD 1.25 per day (or USD 456.3 per year). Assuming such results from adopting agroecological farming could be extended to Haiti's approximately 1 million smallholder farmers, this could allow Haitian farmers living in extreme poverty to generate an additional USD 0.53 billions of additional net income per hectare per year for their families[18] and more importantly, create resilience in the face of international price hikes on basic food staples.

Given this result, it may be questioned why adoption levels are not higher and why agroecological farmers do not extend this model of farming to all their land plots? In this regard, household survey responses point to several factors. The most important reason according to both conventional and agroecological model farmers, is the lack of labour (Table 28). An increase in migration away farmlands and abandonment of agricultural activities due to extended drought and/or climate catastrophes has left farmers with fewer labourers. There has been continued urbanisation and migration of the rural population due to poor long-term investment and development plans to revive the agriculture sector, that have been aggravated by severe droughts, natural disasters, and slow economic growth. As a result, Haitians move to the cities in search of better economic prospects especially within the informal economy or nascent service industry, or migrate to other countries[19]. Moreover, poorly directed economic assistance programs, including export subsidies on food to Haiti, amongst other reforms, has created an over-reliance on imported food, which has in term harmed and undermined agricultural sector development in Haiti (Wisner 2022).

Suitable financing opportunities are also a major obstacle for almost 60% of all the farmers. This lack of credit is linked to the labour issues as without sufficient funds, farmers are unable to hire labourers to work their lands. Initial PDL supported model farmers looked to soil and water conservation structures such as rock walls and contour canals, both requiring a strong labour force, sometimes mobilized through *konbit*, or traditional solidarity work groups. With rural depopulation and many young as well as adult farmers leaving to urban areas, farming practices have had to adapt, accounting for less labour-intensive practices such as intercropping and increased diversification of croplands.

Farming households' economic constraints go beyond being unable to pay for labour. Over the

18 Ignoring any general equilibrium effects on prices.

19 https://country.eiu.com/article.aspx?articleid=866651470&Country=Haiti&topic=Economy

course of the 12 months prior to the interviews, 91% of all conventional and 77% of all model farmers stated that their households did not earn enough to cover their basic household needs (i.e., food, housing, clothing etc.) (Table 29), and more than half of all households have unpaid debt whilst less than one third of households have savings.

These findings are not unique to this study. In Molnar (2015), banana and maize farmers from Haut du Cap, Grand-Riviere du Nord, and Trou-du-Nord in Northern Haiti, typically resort to selling their livestock to finance their agricultural operating activities. With interest rates in the conventional banks such as 'Caisse Populaire', being too high, farmers are calling for agricultural banks (Molnar 2015)[20]. Fonkoze – Haiti's largest microfinance institution serving the poor and ultra-poor (primarily rural women) – also considers agriculture risky, and works to minimize risk by providing loans to groups of rural women for income generating activities, and to create a built-in system of accountability and support. It is for these reasons that PDL supports *gwoupman* and peasant associations to establish savings & credit cooperative funds, with interest rates significantly below those of moneylenders, banks or even microfinance institutions, to allow lending for members economic and agricultural activities. (Brescia 2022). Yet clearly more access to credit at reasonable interest rates is needed.

Focus group discussions organised in connection to this study (chapter 2) also emphasised the importance of being able to access finance. When farm-

Table 28: Constraints to the adoption of improved agriculture and model gardens. What are the three main constraints for creating improved farms?

	Conventional		Model	
1st most important, 2nd most important, etc.	Most important	2nd most important	Most important	2nd most important
No time to go to an association	26%	5%	18%	1%
Wild animal incursions/free roaming and escaped livestock	6%	7%	3%	2%
Lack of labour	49%	38%	54%	32%
Lack of appropriate credit	18%	39%	18%	45%
Lack of other agricultural inputs e.g., pruning knives, fencing etc.	1%	4%	1%	9%
Lack of land security (e.g., I don't own land)	0%	0%	0%	2%

Table 29: General level of wellbeing and income security

	Conventional farmers	Model farmers
Does your household have saving in the banks, credit or saving clubs and credit associations (> 3000 HTG? = yes)	17%	28%
Did the household have a loan? (q36.10)	34%	26%
Does the household have unpaid debts (> 1000 HTG)? (q36.9)	55%	59%
Has your household income been sufficient to cover household needs in terms of food, shelter, and clothing during the past year? (q36.16)	Yes=0% Almost=9% No=91%	Yes=1% Almost=21% No=77%

20 Financial issue was raised as the main constraint to be solved to help farmers clear and weed their land. The funds are needed to hire labor. They believe with improved access to inputs, such as *machetes, pickaxes, hoes, and tractors* - they can increase their production (Molnar 2015)

ers were asked what their main recommendations to PDL would be, they called for *"financial support for soil conservation"* arguing, that "*what famers are able to do on their own is not sufficient to fight against erosion"*. They talked about a neighbouring community as an example, where Agro-Action Allemande (AAA) is paying hired workers to undertake soil regeneration with semi-bunds, contour channels, dry stone wall hedges and reforestation on farmers' land. Previous studies have also shown that the introduction of permanent soil and water conservation structures such as terracing, semi-bunds and stone hedges require significant upfront investment costs and often need to be subsidised (WOCAT, 2007; Sanz *et al.*, 2017). On the other hand, sustainable land management (SLM) interventions such as integrated soil fertility management measures[21], and changes in crop types (WOCAT, 2007) have lower upfront costs and may therefore be more promising for the adoption on a wider scale (Reichhuber *et al.*, 2019). Farmers will sequence the adoption of agroecological practices based on the perceived costs and benefits at each stage, as they gradually improve their farming systems over time (Bruil and Gubbels, 2019).

From a societal perspective, permanent soil and water conservation structures provide significant off-site benefits, for example in terms of reducing erosion and landslides. Yet these are costly to implement. As such, there is an overarching need for some combination of subsidies and financing, as well as for institutional and regulatory reforms to help landowners reap some of those benefits. Government policies should be designed to better align farmer's incentives with wider societal interests, hereby helping overcome barriers to adoption (World Bank, 2021). Possible pathways for doing so are discussed in section 6.4 and forward.

6.2 How are barriers to agroecological farming overcome – survey findings

In terms of how farmers have overcome the various constraints to improving farming techniques, Table 30 shows that participants report that the support of families and neighbours is the single most important factor (for 64% – 77% of farmers). Amongst model farmers, the support of peasant associations also ranks high. These factors are related, as solidarity within and between neighboring households are the initial building blocks of peasant associations. According to Cantave Jean-Baptiste, Director of PDL (2022), the approach taken by PDL requires strengthened capacity and agency of community and peasant organisations, and cannot be sustainably put into practice through individuals alone. Farmer organisation is a necessary social construct that creates the space for decentralised, agroecological technical innovation, where much can be learnt through farmer-to-farmer training and agriculture volunteer promoters organize to extend effective practices to other farmers. Farmers who have received training and support to test, adopt and master agroecological farming practices can then support other farmers to do the same. This social infrastructure is important for capacity building, promotion of model farming techniques, complementary activities such as savings and credit cooperatives, and the sustainable implementation of agroecological practices.

In the next section, we discuss the recommendations stemming from this study, in relation to recent research and initiatives, that are of relevance to communities, farmers, NGOs, lenders and policy makers.

Table 30: Constraints to the adoption of improved agriculture and model gardens. How have you overcome these constraints?

	Conventional farmers	Model farmers
I have not overcome these constraints	12%	2%
Support from family/neighbours	77%	64%
Other (support from the peasant association, financial support, etc.)	11%	32%

21 Seeking to optimize soil nutrient and water for crop growth, achieved by combining the application of chemical and organic soil additives (e.g., livestock manure, compost, green manure)

Farmers preparing tree nursery seedlings. Photo by Ronel LeFranc.

6.3 Lessons of relevance to communities, farmers, and NGOs

Land degradation is affecting more than 3.2 billion people worldwide (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), 2018), highlighting the need for large-scale adoption of sustainable land management practices (Cherlet *et al.*, 2018). A myriad of factors influences the farmers' likelihood of adopting agroecological practices, including: their underlying asset base, ambitions, education level, agronomic, financial, market, land tenure situation, agricultural policies, farmland characteristics, knowledge and access to information on agroecological farming and social networks (Westerberg, Costa and Ghambashidze, 2016; Schoonhoven and Runhaar, 2018; Westerberg and Damnyag, 2020). Mounting evidence and research also suggest that large-scale adoption, is only possible when farmers' engagement is at the heart of such initiatives (Bouma, 2019; Albaladejo, Díaz-Pereira and de Vente, 2021).

This is in alignment with PDL's perspective, which bases its approach on strengthening the agency and capacity of rural communities and farmer organisations to lead in the co-creation of knowledge and agroecological transition processes. These initiatives must allow for autonomy in deciding which practices are suitable, at what time, and where. Farming approaches need to be developed by farmers - not selected, transferred or copied - depending on the situation, the people involved, objectives, possible solutions and resources available (Liniger *et al.*, 2011; Bruil and Gubbels, 2019). For this purpose, farmer organisations need to be supported to experiment and test best farming practices, adapt these to local contexts, and disseminate the results to other farmers and communities. Agreocology is more than just practices, but emphasizes social innovation, placing farmers at the center of co-creation of knowledge, and integration with wider transitions to sustainable food systems.

Dissemination is supported through agroecological volunteers (AV) that are selected from successful model farmers and promote farmer-to-farmer learning (Jean-Baptiste, 2009; Bruil and Gubbels, 2019). As similarly recognised in other research, the creation of tight collaborative networks that enhance farmers acquisition and sharing of knowledge is a key factor for successful SLM adoption (Kristjanson *et al.*, 2014; Ensor and Harvey, 2015; Soto *et al.*, 2021). For example, Dessie, Wurzinger and Hauser, (2012) also found that participatory research involving farmers and researcher enabled social learning,

Farmers using A-frame level to build soil conservation contour barriers. Photo by Cantave Jean-Baptiste.

translated into higher farmer adoption of soil terraces compared to farmers who did not participate in the research. Social learning through knowledge exchange between farmers, researchers, and other stakeholders to address issues of common interest foster relations of support and trust among participants (Scholz, Dewulf and Pahl-Wostl, 2014) that expedite SLM adoption (Harvey *et al.*, 2013)

NGO's have an important role to play here, notably supporting experimentation and the testing and validation of the farming techniques across various locations. They can also help facilitate the dialogue between farming communities in various geographical areas and spread effective and localised agroecological methods to other farmers and communities once they are validated. It has been shown that an area supported by an NGO actor with strong relationships with communities and local government and deep contextual knowledge, the transition to a transformative level of resilience can be undertaken quicker than an area without (Mentz-Lagrange and Gubbels, 2019). NGO's may also be integral in the documentation of findings and the dissemination of the results, as well strengthening community-managed, complementary support activities. In support of the Agricultural Volunteers, NGOs can provide basic and practical education on agroecological principles and practices. The fostering of new knowledge and collective understanding is particularly relevant to overcome barriers to SLM addition because farmers beliefs about farm management practices are often grounded in tradition and long-term practice, which support path dependency (Darnhofer, 2020).

It is logical to assume that lowering costs, increasing benefits, reducing constraints and providing appropriate supports will encourage the spread and wider adoption of agroecological strategies. PDL, as well as other organizations, have developed program support strategies related to many of these needs and opportunities, some explored in more detail in this report than others, that could be built upon, continuously improved, and adapted by other farmers organizations and NGOs, and supported by local government and ministries.

Key specific recommendations include:

Agroecological innovation by farmer organizations: Strengthen the agency and capacity of farmer organizations to assess agricultural challenges, identify and test relevant agroecological practices, validate results, and spread effective alternatives through farmer-led extension and support.

Women's empowerment: Women have heavy responsibilities for agricultural production, reproduction, maintaining families, and marketing. They play a leading role in Haiti in adopting agroecological farming. They can be supported through women's solidarity and savings and credit groups, improving their access to land, livestock and other productive resources, and appropriate training tailored to their needs and time management.

Seeds: Accessing seeds is one of the highest costs identified for farmers seeking to implement agroecological practices. Support could be provided to allow farmers' organizations to better select, produce, store and distribute seeds, for example through participatory plant breeding and community-managed seed banks, to ensure they are best adapted to local conditions. Supplies of seeds adapted to local conditions, controlled by farmers, and accessible to them when they need them given unpredictable rainfall patterns and climate conditions, are vital.

Labor: A second high cost in adopting agroecological practices is for labor, in particular for preparation of soil and water conservation structures. This could be addressed by subsidizing employment for creation of these structures on more land. Increasing farmers access to labor saving tools, for example through community-managed tool banks, access to appropriate technologies for preparing land or seeding, or support for cooperatively managed animal traction plowing systems. Finally, solidarity work groups such as traditional *kombit* can be incentivized where feasible.

Credit: Access to credit at reasonable interest rates is a clear need. Strengthening community savings and credit cooperatives, through training, capacity building and matching funds, can improve farmers access to credit at affordable interest rates for labour and other needs.

Diversification of farming systems: Much research and practice confirms 'that agriculture can provide concrete solutions to the challenge posed by climate change while meeting the challenge of food security through the implementation of agricultural practices adapted to local conditions: agroecology, agroforestry, conservation agriculture, landscape management, etc.'[22] As detailed in this report, the term 'intercropping' goes beyond the limited definition of cropping one type of plant between rows of another crop, but rather refers to diversification of crops and trees on farms, that provide different benefits and synergies, and that can be harvested at different times throughout the year to enhance food security. Peasant farmers adapt diversification principles on their farms based on their local contexts and interests. As also detailed in this report, farmers adopt these practices due to the intrinsic benefits they experience, including increased food production and net incomes, improved soil fertility, and resilience to droughts and heavy storms exacerbated by climate change. Through the dynamics of healthier farming systems, the results of sequestering carbon in soils and plants contribute importantly to these intrinsic benefits that farmers experience. If these practices were expanded in Haiti and beyond, the carbon sequestration benefits would have profound wider extrinsic social benefits at national and global levels in mitigating and reversing climate change. The challenge then is to define the most effective strategies to achieve that. This report highlights the importance of promoting the intrinsic benefits to farmers of agroecological strategies, as a means to promote their adoption and potential scaling across the wide platform of smallholder, as well as larger scale, farmers. This can be supported through farmer-centered agroecological innovation and extension (e.g., soil and water conservation, cover crops/green manures, diversified farming systems, etc.) and complementary supports such as community-managed tree and plant nurseries, seed banks, savings and credit cooperatives, and other strategies.

Water: Support farmer experimentation with and funding to allow farmers to invest in rainwater harvesting, cisterns, and wells. Foster experimentation to improve soil and water conservation, soil organic matter, and water holding capacity. Support community protection and management of natural water sources.

Local markets: Strengthen farmers' linkages to local markets to improve incomes from and incentives for agroecological production, for example through guaranteed institutional markets (e.g., school feeding programs), food aggregation and marketing centers, and cooperative farmer enterprises for value added processing and sale of agricultural produce.

22 https://4p1000.org; https://drawdown.org/; https://www.evergreening.org/

6.4 Recommendations for decision makers

6.4.1 Blended finance solutions to up-scaling agroecology

Besides social learning and technical support, smallholders also need financial and material incentives to implement agroecological practices, when costs are beyond their means. The greater the labour and financial needs for maintenance, the less likely the resource users or local community will adopt the technology (Studer and Liniger, 2013).

As noted earlier, despite their socio-economic importance to smallholders and the societal benefits of agroecological practices, smallholders have little or no access to formal credit, which limits their capacity to invest in the technologies, practices and inputs needed to increase their yields and incomes. The challenges to increasing access to finance are numerous. Financial institutions interested in serving smallholders in Haiti face a myriad risks and challenges associated with agricultural production and lending, including seasonality and the associated irregular cash flows, high transaction costs, and systemic risks such as floods, droughts, and plant diseases. While these challenges apply to agricultural lending in general, they impinge on smallholder lending in particular, given the relatively higher transaction costs of provision and smallholders' limited ability to mitigate risks (International Finance Corporation, 2018). The challenge is greater when trying to provide financing to semi-commercial smallholder farmers (like those in our case-study area) that do not have strong relationships with other value chain actors, and selling is more opportunistic rather than based on longer-term relationships with buyers.

To meet this challenge, blended finance is emerging as one solution by using public support – development aid, government funding and NGO expertise - to mobilise commercial finance. The logic behind the approach is simple. Whilst agroecological farming has important public good dimensions and leads positive projected returns, as demonstrated in this paper, the associated risk and uncertainty deter commercial investors from providing financing. Cofinancing or credit guarantees governments and technical assistance by NGOs, in blended finance solutions, are increasingly used to address these issues by improving the risk-return profile of investments. These strategies can also be linked to supporting community-led savings and credit cooperatives, as mentioned above. This allows for attracting commercial financing (see for example USAID'S Haiti's reforestation project and application of blended finance to support the conversion to clean cooking (Jacob, 2021). There is ample scope for scaling-up further deployment of blended finance approaches in Haiti and to make use of other economic and regulatory instruments as discussed below.

6.4.2 Institutional and policy frameworks that create enabling environments for agroecology

Constraints to scaling agricultural investments should also be addressed through careful policy design and complementary policy interventions. Policy instruments applied in land use sector typically include regulatory approaches (management plans, sustainability standards, land governance and tenure arrangements), information and voluntary instruments (disclosure requirements and sustainability certifications, extension service provisions), and economic instruments like payments for ecosystem services (PES), results-based expenditures, subsidies for agricultural inputs and environmental taxation. Land use sector fiscal policies in Haiti, as elsewhere, have not been evaluated in terms of their impact on incentives for deforestation and other environmental damages. For example, fiscal incentives are commonly provided to landowners depending on the area being used for agriculture, irrespective of tree canopy cover within the farmland. In many cases, fiscal incentives for agriculture therefore prioritise forestland clearing outside and inside farmland. It is well beyond the scope of this report to analyse how the policy reforms in Haiti can support the uptake of agroecology and landscape restoration, and the significant institutional challenges facing the Haitian government, but some areas of strategic interest are discussed below.

Different to conventional agricultural policy programmes focusing on subsidising conventional farming inputs (fertilisers and seeds) there is a need for strategic support and investments into community-led agroecological innovations (as argued above), including soil conservation and terraces; water harvesting and storage; seed banks and tree nurseries; savings and credit funds and rotating livestock schemes; post-harvest storage, and local market access and linkages. Peasant associations can be better linked with knowledge hubs, researchers, and scientists, who can support experiments and research on seed varieties, monitoring and improving soil biology and fertility, and rainwater harvesting techniques etc.

6.4.2.1 Local supply chains

There is also a need to enhance the ability of farmers to market their products in local, regional, and national markets. Local supply chains can be built by linking peasant agroecological production to: school feeding programs; hospitals and other institutional markets; food aggregation and distribution hubs; and cooperative enterprises for value added processing of food. National education campaigns that celebrate the local Haitian cuisine and health benefits of consuming a diverse diet of local produce could help provide stimulus for investments into the marketing of local and regenerative produce.

6.4.2.2 Trade policies

There is also evidence that the international aid regime that pushed to liberalize Haiti's economy has undercut the country's domestic production and fostered an over reliance on (subsidized) food imports, such as subsidized rice and poultry from the United States (Gros 2010, Wisner 2022). It is beyond the scope of this study to make recommendations regarding potential reform to international trade policies, but any serious effort to address food insecurity in Haiti will require review and appropriate redress of policies that undermine Haiti's capacity to address food security.

6.4.2.3 PES Schemes and fiscal transfers

With regards to the introduction of economic instruments, expenditure policies, such as PES, can also provide strong incentives for smallholders and community-based groups to invest in sustainable land management and ecosystem services (typically, carbon sequestration, biodiversity, and watershed services). PES projects are generally designed to reduce poverty through their contributions to building alternative livelihoods that replace land degrading activities. By improving the economic situation of participants, either directly or through benefit-sharing arrangements, PES provide an incentive to fully commit to the programs. If local users actively participate, this has the added benefit of reducing the need for extensive monitoring, which reduces associated transaction costs and improves environmental outcomes (Vander Velde, 2014). PES in conjunction with access to research and conservation technologies can help to alleviate the upfront costs of adopting a regenerative model farm. PES has been shown to be successful in supporting the adoption and scaling of regenerative farming methods in the Andes and Nepal for example (Piñeiro *et al.*, 2020).

While Haiti faces significant historical and institutional challenges in consolidating effective governance at local and national levels, it is worth highlighting potential policy directions for the present and future, based on experiences in other contexts. For example, intergovernmental fiscal transfers between central and local governments could be designed to improve the incentives of local governments to invest in landscape restoration by including environmental criteria in the formula used for calculating the size of transfers. Different landscape restoration criteria are possible, for example, tree canopy cover within and outside cropland, quality of area designated as protected area, forest carbon stocks (for example, aboveground biomass), or area certified under third-party sustainability certification. The environmental indicator(s) chosen should be determined based on governance capacity, as some indicators are relatively more complicated to use (World Bank, 2021). India has used such Ecological Fiscal Transfers since 2014, to determine how much tax revenue India's central government should distribute annually to each of its 29 states (Government of India, 2014; Busch, 2018). In India, the only condition for receiving payment is the level of forest cover, with no additional requirements about how the outcome is produced or where funds are spent. This allows for low administrative costs in additional revenue neutrality (in government spending), whilst achieving significant financial scale.

6.4.2.4 Land tenure

Finally, the success of all above mentioned reforms hinge on improving land tenure so that farmers can have collateral and reap the rewards from their investments in soil and water conservation, in seeds and other vegetal materials. In Haiti, the transmission of property titles from parents to children in rural areas does not legally guarantee a land title to the inhabitants (Lefranc, 2022). While this study found that land tenure was not a significant concern for the model farmers, it has the potential to be a significant determinant when model agroecological farming is scaled in a manner that increases farming incomes and land values.

Overall, the adoption and scaling of agroecological production by peasant associations will require significant support and public-private-NGO partnerships at both national and local level. Specific reforms and economic instruments of interest to scaling agroecology in Haiti should be evaluated, designed, and implemented in the context of the overall fiscal, economic, political, and administrative systems in Haiti.

07 Conclusion

The ambitious 2030 Agenda[23] and the Paris Agreement will require significant investment as well as new forms of partnerships to increase investment and stimulate collaboration on sustainable development. Agroecological farming practices go a long way in supporting the UN Sustainable Development Goals, including no poverty (SDG 1), no hunger (SDG 2), gender equality (SDG 5), decent work and economic growth (SDG 8), reduced inequalities (SDG 10), responsible production and consumption (SDG 12), climate action (SDG 13) and life on land (SDG 15).

Specifically, this study has shown that the scaling-up of agroecological model farming in the Northern plateau of Haiti would have major implications for the income and rural economies. Whilst model farmers currently apply agroecological practices on a third of their land (0.6 ha), the quasi-totality (98%) would like to scale these practices. Should they have the resources to do so, and convert the remaining two thirds to model farms, this would result in approximately HTG 60,800 of additional income per household per year.[24] This currently equates to USD 555[25]. If extrapolated to the entire peasant farmer population this would result in a significant infusion into rural economies on top of the individual level benefits.

Such scaling will require significant investment as well as new forms of partnerships. To increase investment and stimulate collaboration, one must mobilise additional financing from the private sector domestically and externally and from other actors not currently investing in developing countries. NGOs, when rooted in the context of the community, can support the strategic use of development finance, government investments or guarantees, and can help with the mobilisation of additional finance. Also key to both de-risking farming and providing sufficient incentives for sustainable land management investments, is through enabling government and agricultural programmes, or fiscal transfers, performance-based payment systems.

Coupled with this, NGOs such as PDL are serving critical complementary roles, by strengthening peasant organizations from the bottom-up to create democratic participation in spreading agroecological farming and sustainable livelihoods. In a political context, this contributes to the creation of decentralized agricultural innovation, extension and development, and the regeneration of degraded land and rural livelihoods.

Momentum is sustained and gained, by involving the organisations in the planning, implementation, and monitoring of the processes and practices. The study presented here, will likewise be shared within the municipalities of Saint Raphael, Mombun-crochu and Pignon, to further stimulate social learning, co-innovation, and co-creation of solutions to help the transition toward sustainable food systems, improved health, and well-being in the Northern Plateau of Haiti.

23 https://sdgs.un.org/goals
24 Ignoring any potential general equilibrium effects.
25 where 1 gourde is USD 0.0091

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Appendix

Appendix 1: Degree of intercropping as a driver of productivity amongst model agro-ecological farmers farmers

Production function model 3, table A2.1 includes a binary *model farming* variable, to capture whether a farmer is classified as a model (model=1) or conventional farmer (model=0). When the degree of intercropping (number of crops grown per hectare over 1 year) is introduced, the coefficient for the model farming variable is no longer significant. The high correlation between the two variables (degree of intercropping and undertaking model farming) implies that higher productivity and gross crop incomes amongst model farmers, are driven essentially by their degree of intercropping. The model fit also improves from R2 to 0.43 to 0.51, suggesting that intercropping is a stronger indicator of land us productivity relative to being a model agro-ecological farmer or not.

Production function model 3. Gross crop income per ha			
	Coef.	**t**	**Significance**
Intercropping (logged)	56,749	5.88	***
Spending on seeds (logged)	14,371	6.3	***
Hired labour days for weeding (logged)	12,767	4.42	***
Days for hired labour (all other)	728	2.75	***
Belle mère	27,064	4.36	***
Model farming	7,288	1.06	
_constant	-158,663	-7.18	***

# of observation = 300, F = 51.06; Prob > F = 0; R-squared = 0.52; Root MSE = 45540

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