



SHADE-GROWN COFFEE

Double dividend for biodiversity and small-scale farmers in Peru

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PREFACE

Biodiversity is the cornerstone of our very existence. Also in agricultural systems, biodiversity plays an important role in providing important goods and services to farmers, for example in crop pollination and maintenance of soil fertility. In coffee cultivation systems, layers of shade trees used to be very common. Shade trees play a key role in providing timber and fruits, storing carbon, maintaining a favourable microclimate, and harbouring biodiversity. Nevertheless, coffee farmers across the tropics have often removed these shade trees, in search of higher coffee productivity. The question is however, whether this presumed higher productivity of full-sun coffee cultivation, has also brought farmers the desired economic advantages and benefits.

End of 2013 Hivos requested the Copernicus Institute of Sustainable Development of the Utrecht University to focus on biodiversity-friendly coffee cultivation, an area of interest to both Hivos and the Copernicus Institute. Coffee is an important product in the world economy and for smallholder farmers throughout the tropics. We wanted to gain insights in the contributions of agroforestry systems to farmers' livelihoods on the one hand and biodiversity conservation on the other hand. Shade-grown organic coffee, value-added agroforestry products and the carbon-offset market are examples of commercial activities that seem to have the potential to provide substantial biodiversity and socio-economic benefits in addition to financial returns.

The research was building on earlier research commissioned by Hivos and conducted by the Copernicus Institute on biodiversity-friendly value chains and the role of small and medium-sized enterprises in biodiversity management. This research already concluded that these businesses not only deliver in conventional economic terms but also in ecological and social terms but lacked access to suitable finance. Since then, Hivos has created several financial products: A green inclusive finance programme (MFIs), the pioneer accelerator programme and Procif, a graduation programme for sustainable producer organisations. In collaboration with Triodos Bank, it has also revisited the focus of the Hivos-Triodos Fund since 2011 to invest more in sustainable small-medium enterprises.

This second research develops the business case for biodiverse coffee production in a more profound manner. The results of the work of the authors Rosalien Jezeer and Pita Verweij are loud and clear. It dispels myths on loss of productivity due to biodiversity conservation. Based on its results, we can now confidently say that shaded organic systems have great potential to combine the twin challenges of local socio-economic development and biodiversity conservation. Shaded coffee provides a viable business case to coffee smallholders and supports biodiversity and ecosystem services.

This report will be shared and highlighted at the Global Landscapes Forum in Paris, on 5 and 6 December 2015 where Hivos has organised a dialogue on innovative and viable adaptation strategies in coffee landscapes. The Global Landscapes Forum is the largest side event to the climate negotiations in the framework of UNFCCC. We hope that this report will inspire people and organizations to contribute to the further development of environmental friendly and economically viable coffee production, because it not only serves people and planet, but it also makes business sense.

Carol Gribnau
Director Green Society Program, Hivos



Photo 1

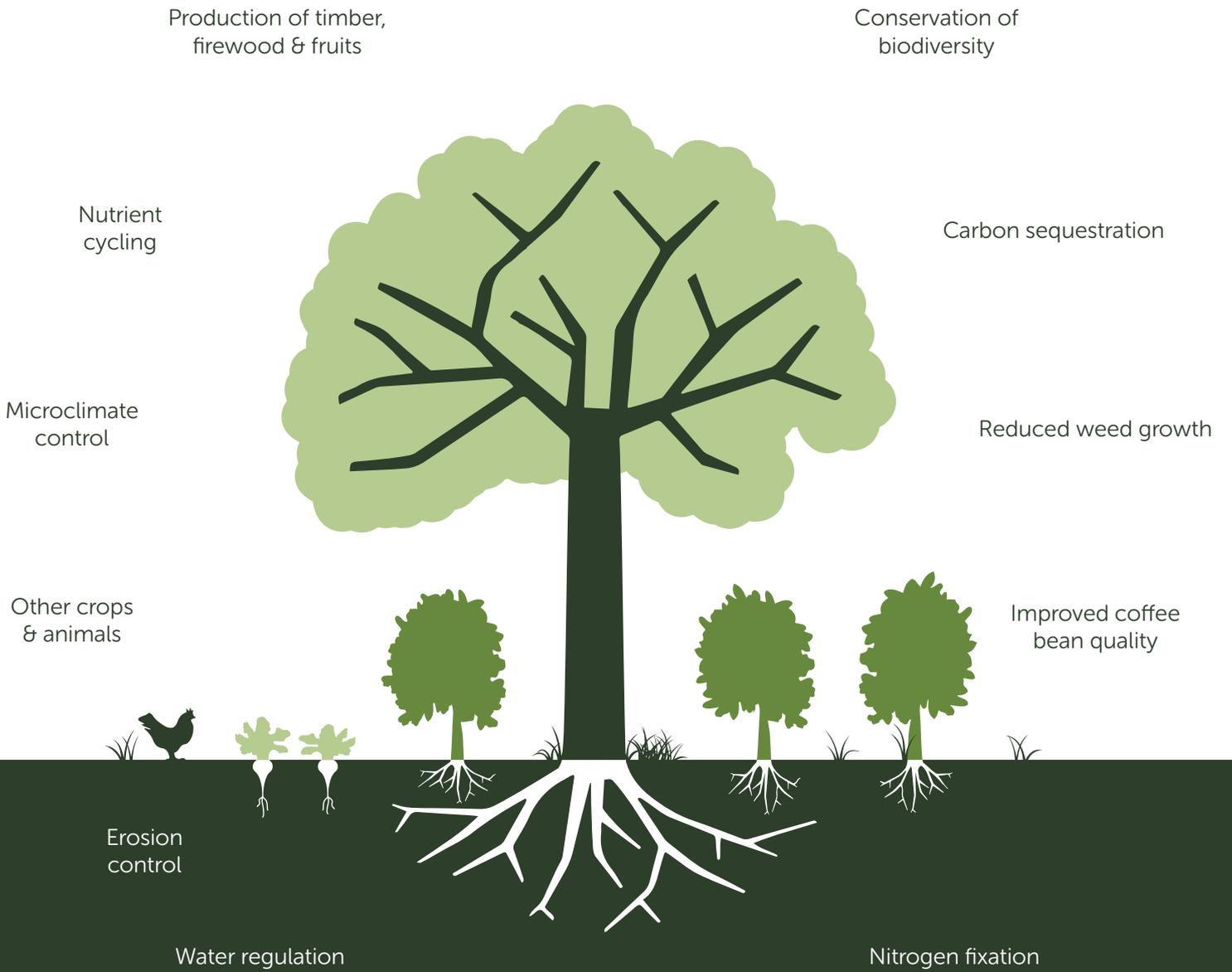
This photo shows a berry collecting station in Chinchiná.

Colombia, where ripe coffee berries of more than fifty hectares of coffee plantation are collected

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Figure 1
Benefits derived from
shade trees



1 INTRODUCTION

Coffee is produced by millions of farmers in the Global South. The great majority of the world's coffee producers- some 25 million- are family farmers engaged in small-scale farming (Eakin et al., 2009). Consequently, the production of coffee is economically very important in Latin America. In Peru, coffee even represents the most important export crop (MINAGRI, 2013). The growing global demand for coffee and the economic importance, both for small-scale farmers and trade worldwide, emphasise the influence of coffee production worldwide. However, small-scale coffee producers worldwide are experiencing economic challenges as coffee prices have strongly fluctuated over the last decade, while access to markets and capital can be limited.

Besides the economic challenges, environmental problems are posing additional challenges for small-scale coffee producers, such as the depletion of natural resources, an increase in the frequency of droughts and other disasters as a result of climate change, an increased incidence of pests and diseases, and seasonal fluctuations in food production (Caswell et al., 2012). On the other hand, the expansion and intensification of coffee plantations are also contributing to tropical deforestation and environmental degradation, resulting in a loss of biodiversity and associated ecosystem services (Philpott et al., 2008).

Coffee is shade tolerant and traditionally grown under shade trees in complex agroforestry systems, thereby providing a refuge for biodiversity and sustaining other ecosystem services. The ecological and economic importance of coffee worldwide presents a good opportunity to develop programs for sustainable development that combine conservation and economic goals. Therefore, shade grown coffee is increasingly promoted as a promising approach to deal with the twin challenges of biodiversity conservation and local development. Biodiversity benefits associated with shaded coffee practices are well researched and it is clear that these systems hold considerable potential to conserve biodiversity (Bhagwat et al., 2008). Unfortunately, despite the growing attention, the business case for shaded systems for small-scale farmers is less clear as the effectiveness and lessons learned from creating biodiversity-friendly coffee plantations have not been well documented.

THE INTENSIFICATION OF COFFEE SYSTEMS

In spite of its ecological benefits, recent decades have seen a transformation of coffee farming worldwide to more intensified systems by eliminating shade trees, increasing agro-chemical inputs and selecting genotypes - all to increase short-term income. This has resulted in a broad spectrum of coffee plantation management, ranging from low input, to shaded plantations to high-input sun plantations. It is widely assumed that shaded plantations are less profitable, but this assumption is often based on incomplete cost-benefit calculations. First of all, coffee productivity is often used as an indicator for profitability, which is assumed to be lower for shaded systems. Furthermore, the costs associated with producing coffee are usually not taken into account. Finally, the direct and indirect benefits derived from shade trees are often not included in the equation. Although the business case for conventional plantations may be straightforward, the calculation of the costs and benefits for shade plantations can be more complex. In order to be able to compare both types of business cases in a more comprehensive and realistic way, it is therefore important to include all costs and benefits in the calculations.

COFFEE AND BIODIVERSITY

Agroforestry systems are often applauded for their biodiversity conservation value, yet these systems are actually designed to improve farmers' livelihoods by increasing overall productivity, profitability and sustainability (Atangana et al., 2014). According to the World Bank (2008), the improvement of these three aspects of smallholder farming is a key pathway out of poverty, emphasising the potential of agroforestry practices to alleviate poverty. Within coffee systems, shade trees can provide multiple benefits (Tscharntke et al., 2011). First of all, not only is the overall biodiversity enhanced, but also functional biodiversity, which can increase productivity and ecological resilience. For example, cross-pollination can increase coffee yield by up to 50% compared with self-pollination (Tscharntke et al., 2011) and biological control can reduce pest or herbivore outbreaks (Kellerman et al., 2008; Perfecto et al., 2004; Philpott and Armbrecht, 2006). The effects of biological control are particularly important, as the damage caused by pests and diseases pose great risks to small-scale coffee farmers. Second, shade trees play an important role in erosion control and the maintenance of soil productivity by stimulating litter decomposition. Third, shade trees can generate additional products such as timber, firewood and fruits, providing important contributions to farmers' livelihoods, especially in times of low coffee prices or low coffee productivity. Fourth, shaded coffee systems can provide nutrient safety nets as they can retrieve part of the nutrients moving down the soil profile beyond the effective root zone of coffee. Lastly, shade trees in coffee systems can mitigate the effects of climate change by enhancing a favourable micro-climate and increased carbon storage. As is becoming clear, shade trees provide both direct and indirect benefits, making it difficult to fully quantify the total benefits. Nevertheless, these benefits are expected to improve farmers' livelihoods by stabilising their income and increasing their overall resilience (Atangana et al., 2014).

BUSINESS AND BIODIVERSITY CASE

Although biodiversity friendly businesses such as shaded coffee plantations are seen as a promising approach to reconciling local development and biodiversity conservation, evidence is lacking. This report provides insights into trade-offs between biodiversity and the economic performance of shaded coffee systems, demonstrates the business case for biodiversity-friendly businesses, and identifies key success factors and challenges.

In order to gain more insight into the business case of shaded systems and its relation with biodiversity performance, an extensive case study of small-scale coffee farmers in Peru was conducted. The relationships between management practices and their biodiversity and economic performance can take multiple forms. Two variables that have a large impacts on the productivity and biodiversity of coffee plantation are management intensity and vegetation structure (Hernández-Martínez et al., 2009). Management intensity refers to management practices such as the frequency of weeding and pruning, but also the use of agro-chemicals. Vegetation structure refers to the structural complexity of the plantations, for example the density and type of shade trees, coffee tree density and canopy closure. In order to cover the full spectrum of variation in management practices, we included high-input sun coffee systems as a reference system. In collaboration with 154 small-scale coffee growers in Peru, data were collected, representing a broad range of coffee management from low-input shaded plantations to high-input sun plantations (see box 1, methods). For these plantations, data on management intensity, vegetation structure, biodiversity and economic performance were collected, both on a farm and landscape level.

REPORT OUTLINE

Here we will present the results of this study, discuss the implications for coffee farmers and other local stakeholders, and make recommendation for further research. Chapter 2 outlines the current state of the coffee business in Peru, both on a farmer and sector level. Additionally, chapter 2 presents the socio-economic background of the small-scale coffee farmers in the field work region and describes four different small-scale management systems that were identified. In chapter 3, the results from the business case of the four different management systems are presented and discussed, focussing on productivity, coffee price, costs and income from other products. In chapter 4, the results from the potential of the four systems to conserve biodiversity and provide ecosystems services are presented and discussed. In chapter 5 the main opportunities and challenges for the biodiversity-friendly production of coffee are discussed, and implications for coffee farmers and other local stakeholders are addressed. Chapter 6 presents the main results and conclusion and provides recommendations for different stakeholders and further research.

BOX 1: DATA COLLECTION FRAMEWORK

Data collection

The data were collected by local expert workshops, interviews with local experts, farmer surveys and field work on coffee plantations and natural forests. In total, 154 farmer surveys were conducted in the district of San Martín from April 2014 until July 2015 (fig. 3), addressing the issues presented in the data analyses framework (table 1). Farmers and plantations were carefully chosen to represent a broad range in both management intensity and vegetation structure. Importantly, all the farmers were smallholders and the plantations were at least three years old, but preferably older than five. To assess the vegetation structure, biodiversity and ecosystem services on the coffee plantations, the field data were collected on 46 plantations and natural forest (box 7).

TABLE 1: DATA COLLECTION FRAMEWORK

GLOBAL THEME	CORE ELEMENT	INDICATOR
Key characteristics	Household demographics	Producer characteristics (age, gender, education)
		Migrant or native
		Household composition
	Farm characteristics	Farm characteristics
		Farm location
		Land tenure
Living conditions	Acces to basic needs	Acces to water and electricity
	Housing conditions	Quality of housing
	Food security	Months of less food security
Resource management	Resource/ input management	Pesticides use (insecticides, herbicide, fungicide)
		Fertilizer use
Biodiversity	Plantation structure	Coffee plant density
		Genetic variation of coffee plants
		Tree density and diversity
		Level of shade
	Biodiversity of butterflies	Butterfly species diversity
		Potential for conservation of forest species
Other ecosystem services	Sequestration and mitigation	Carbon stock
		Land use change
	Microclimate	Humidity
		Temperature
	Nutrients	Soil condition

TABLE 1: DATA COLLECTION FRAMEWORK

GLOBAL THEME	CORE ELEMENT	INDICATOR
Producer livelihoods	Revenue	Productivity of coffee
		Coffee price
		Other farm revenues (other crops, livestock, timber, firewood)
		Household revenue, off-farm
	Costs- capital	Land costs
		Initial equipment costs
	Costs - products	Fertilizer costs
		Pesticide costs
	Costs - labor	Family labor days
		Paid worker labor days
Risk (economic resilience)	Diversification	Revenue from other crops
		Number of other crops or animal products
		Other off-farm revenue
	Vulnerability to pests and diseases	Pest and disease incidence and effect
Competitiveness	Differentiation	Current standards and certifications
		Price premium
	Efficiency	Production/labor efficiency
		Cost efficiency
Producer organization	Governance	Member of producer association

2 THE COFFEE SECTOR OF PERU

In recent decades, the production of Peruvian coffee has increased substantially and coffee has become the main agricultural export product. Currently, coffee generates more revenue than any other crop. Exports have increased from 2 million bags in the '90s to about a 5 million bags this year with a total export value of approximately USD 700 million (figure 2). About 223.000 families are involved in coffee production and the supply chain involves more than 1 million people (CENAGRO, 2012a). This emphasises the great economic and social importance of the coffee sector in Peru.

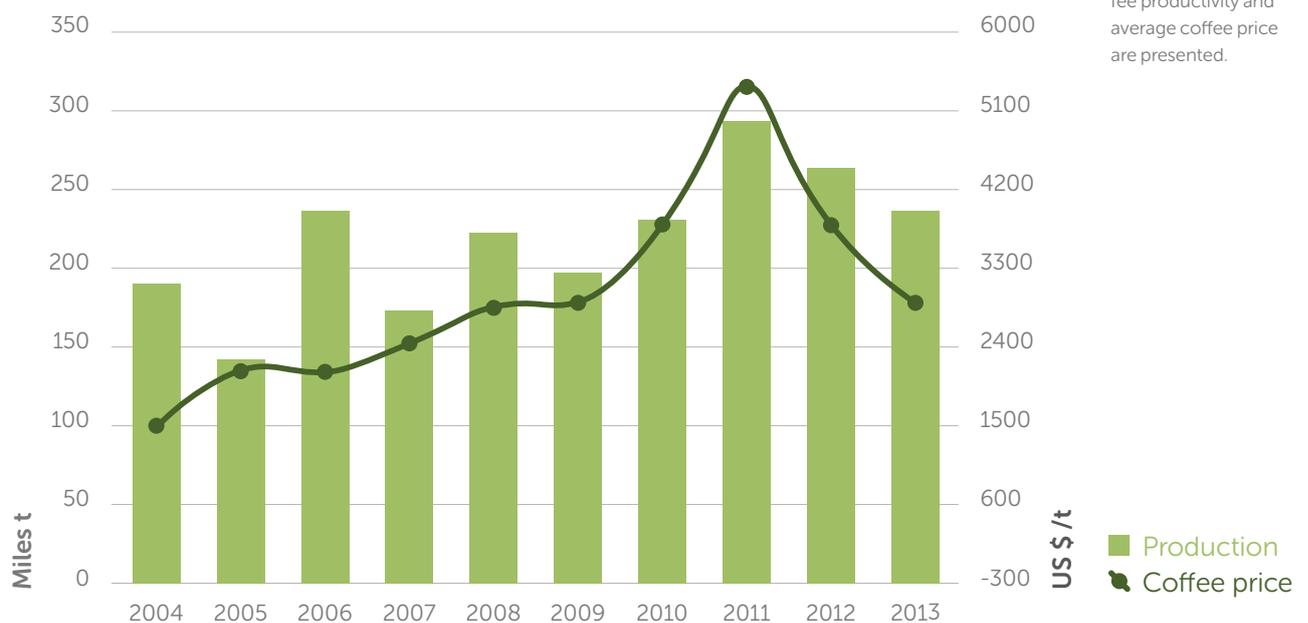
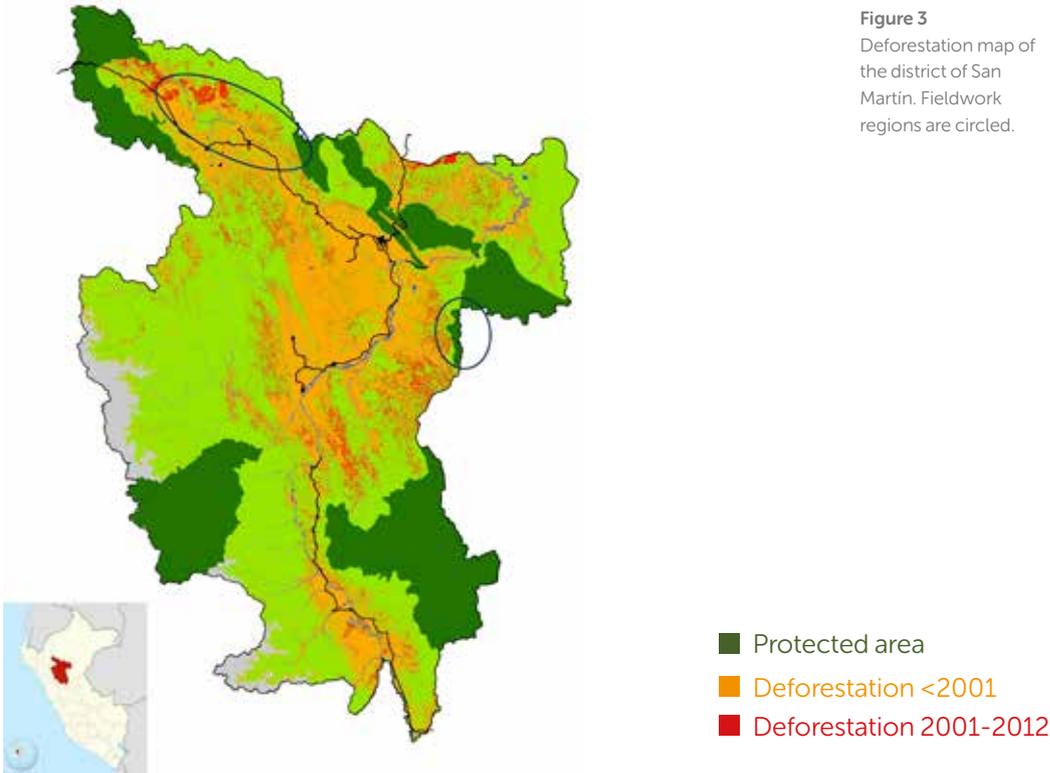


Figure 2
The development of the Peruvian coffee sector from '04-'13. The total national coffee productivity and average coffee price are presented.

2.1 THE ENVIRONMENTAL IMPACT OF COFFEE PRODUCTION

Unfortunately, the expanding coffee production has left its mark on the landscape as increased production is realised through the establishment of new plantations often in previously forested areas. This is reflected in high deforestation rates throughout Peru, but in particular in the department of San Martín. In this department 25-30% of all Peruvian coffee is produced by about 35,000 families on 90 thousand hectares. This region is located in the northeast of Peru (figure 3) and most of its original land cover consisted of tropical forests and wetlands. However, by the end of the 20th century, the region started to see a rapid increase in deforestation rates. It currently holds the highest deforestation rate in Peru of more than 10 thousand hectares per year, and it is estimated that 30 percent of the total primary forest area- which comprises 1.6 million hectares- has already been converted into agriculture (Rodriguez, 2010). This rapid conversion was caused mainly by government efforts to connect the region with the rest of the country through the construction of roads as well as changing legislation and capacity building programs. Thus, many farmers switched from growing coca to coffee and cocoa. Furthermore, it accelerated the influx of migrants from economically depressed rural areas in the Andean highlands of San Martín as the number of migrants more than doubled in 10 years. As a result, migrants represented more than 30 percent of the total population in San Martín at the beginning of the '90s. If the current deforestation trend continues, San Martín could lose most of its forest by 2050 and along with it the natural capital needed to improve the human well-being of its inhabitants. Due to the environmental and economic impacts of coffee production in San Martín, it is important to seek opportunities to reconcile conservation practices and local development, especially since the effects of environmental degradation are becoming more visible.





BOX 2: SOCIO-ECONOMIC BACKGROUND OF THE COFFEE FARMERS

Over 90 percent of the interviewed farmers were male, indicating gender inequality in the coffee business in San Martín. Most of the farmers had finished primary school, but only 20 percent had finished secondary education. The income derived from the coffee plantations supports on average five persons. The living conditions of these families leaves room for improvement, as their houses are predominantly made from wood and soil. The majority of them are however connected to the electricity and water network. Based on farmer interviews, we estimate the average net income of the coffee farmers to be almost S/. 5000,- per year, which corresponds to roughly € 1300,-. The largest share of the farmers indicated that they experience months of resource scarcity of on average four months throughout the year.

Photo 2
House of a coffee farmer in San Martín, situated in a mixed agricultural landscape

2.2 WHO ARE THE COFFEE FARMERS IN SAN MARTÍN?

The largest share of the coffee from San Martín is produced by smallholders, on lands ranging from lower-lying, flat areas in close proximity to cities, to elevated, hilly regions bordering forests and far from urban centres. Although this scenery can differ, the conditions and risks faced by many of these small-scale Peruvian coffee farmers are similar. Here we first outline the context of Peruvian small-scale farmers and their socio-economic background based on the data we collected through interviews with 154 farmers in San Martín (box 1). Thereafter, we focus on the differences between coffee management practices and the implications for the coffee farmers and their management.

THE REALITY FOR COFFEE FARMERS IN SAN MARTÍN

In the relatively young coffee sector of San Martín, the largest share of the coffee is produced by smallholders. This was confirmed by our survey, as the average coffee plantation size of all 154 farmers is 2.75 hectares, corresponding to the average size of coffee plantations in all of San Martín (CENAGRO, 2012). The income derived from coffee provides the main source of income for these farmers (76 percent). More than 90 percent of the interviewed farmers are migrants who moved to San Martín in the last twenty years. This recent and ongoing migration reflects the recent increase in coffee production and the associated pressure on the natural forests in San Martín. Almost three quarters of the farmers indicated that their farm and coffee plantations are established on previously forested land, confirming the relation between increased coffee production and increased deforestation in San Martín (figure 3). On the one hand, it will become more difficult to obtain farming land, and on the other hand, deforestation is expected to coincide with the degradation of the ecosystem’s health causing increased risks of pests and diseases, especially for small-scale farmers.

In contrast to many other coffee producing countries and despite the large influx of migrants to San Martín, we saw that insecurity of land ownership does not pose a major threat as the majority of farmers in Peru hold some type of land title. The majority of the interviewed farmers hold a document of purchase of sale (63 percent, ‘contrato de compra y venta’), while there are also farmers who rent their land (12 percent). Only 5 percent of all the farmers indicated having occupied the land without any legal kind of document for their land (posesionario).

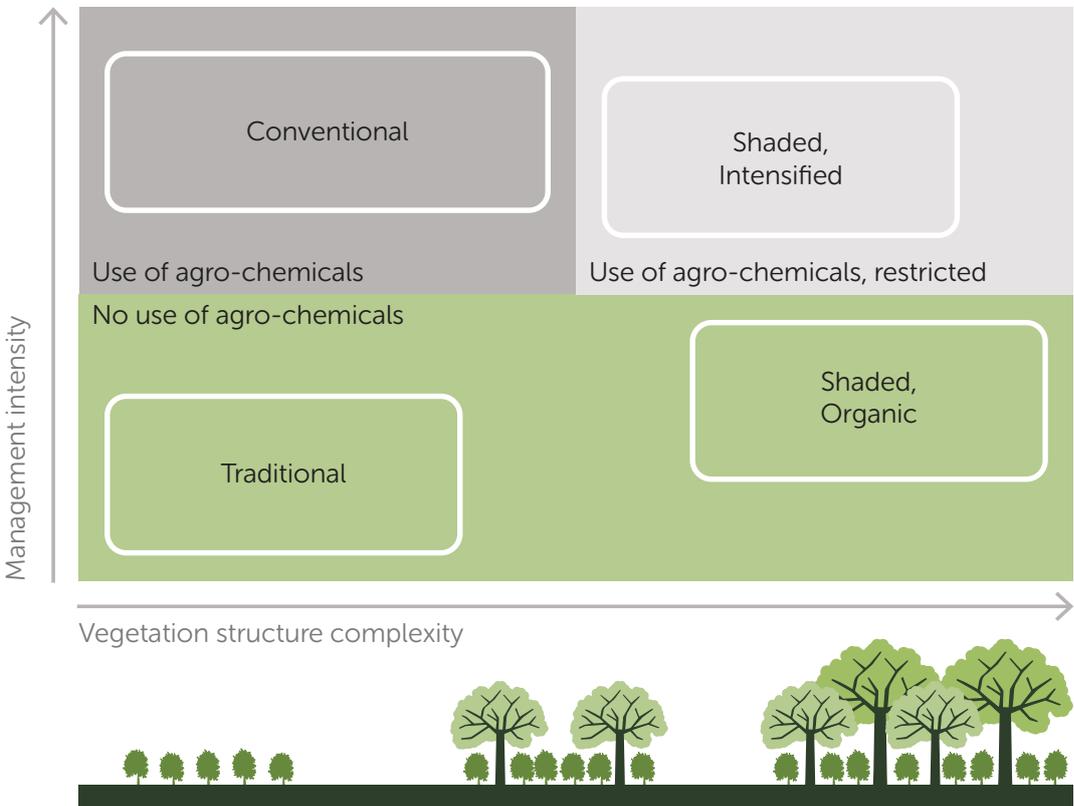


Figure 4
Schematic overview of the four coffee management groups, according to vegetation structure complexity and management intensity

Photo 3
Mixed agroecological
landscape, San Martin,
Peru





Recent migration and the conversion and degradation of land form the major challenges faced by coffee farmers in the region as pressure on the natural forests has increased and the ecosystem services provided have been reduced.

FOUR SMALL-SCALE COFFEE SYSTEMS

Even though most coffee producers in San Martín are smallholders, they apply a variety of management practices, as some have low-input agroforestry practices and others high-input sun plantations. All the interviewed farmers were carefully chosen so that their plantations represent a broad variety along the intensification gradient. Based on management intensity (low, medium, high) and type of input (organic or agro-chemical) and vegetation structure complexity (number and type of shade trees per ha, timber shade trees), four different management classes were distinguished (figure 4). In San Martín, these management practices are characterised by farmers with different socio-economic backgrounds, geographical spreads and organisational structures, yet they are all smallholders. Here a brief description of the main management systems and the corresponding groups of farmers is presented, and (figure 5) shows the vegetation structure complexity per management group.

1. Conventional (n=32):

The group of conventional farmers represents farmers who have intensified their plantation, both by eliminating shade trees and increasing agro-chemical input. As a result, these plantations have little to no shade, a low diversity of shade trees and high coffee tree density. The level of input is generally high, both of organic and chemical products. Only a minority of the farmers are organised in associations and few produce certified coffee. This group is presumed to be the least biodiversity-friendly of all four groups and functions as a reference group.

2. Traditional (n=29):

Traditionally managed plantations are characterised by their low management intensity and low vegetation complexity, since there is little to no shade, a low diversity of shade trees and a low density of coffee trees. Input is very limited, often because these farmers live further away from urban areas where they can gain access to input, finance and knowledge on coffee farming. Their livelihoods often depend on their farms, both in terms of income derived from coffee and the production of other crops for their own consumption. As input is scarce, these farms often produce organic coffee by default, although only a minority of them have acquired certification. An important point is that this group actually represents the largest share of coffee farmers in San Martín.

3. Shaded Intensified (n=38):

The group of shaded intensified plantations is positioned in between conventional and shaded organic plantations regarding management intensity and structural complexity. Overall, these plantations are characterised by their high vegetation complexity, due to the high density of shade trees, caused by both high and low value tree species, and the high density of coffee trees. Management intensity is generally medium to high and both organic and chemical-based products are applied, yet the use of some agro-chemicals is restricted on some of these plantations. The majority of the farmers in this group are members of an association and produce certified coffee.

4. Shaded Organic (n=55)

The group of shaded organic plantations represents the highest vegetation structure complexity. The management intensity is medium and only organic input is used. The majority of these farmers produce certified coffee and are members of farmer associations.



CONVENTIONAL PLANTATION

This photo shows the spraying with herbicides on the plantation of Señor Adelicio Pardo Camacho. His coffee plantation lies close to the city of Nueva Cajamarca at a relatively low altitude of 891 metres. The coffee trees were planted seven years ago at high density, and intercropped with plantain. Similar to other coffee farmer who grow coffee in this area, he has more financial resources than average and relatively easy access to materials and input due to the proximity to the city. This enables him to hire this relatively expensive land and invest a bit more in management and equipment. His plantation has few shade trees and is managed intensively, with a high level of agro-chemical input. Herbicides are used to control weeds (as can be seen in the picture) and once a year he sprays insecticides to minimise yield losses due to insects. Chemical fertilizer is applied a few times per year and fungicide is sprayed to control the impact of coffee rust disease. Most of the work is done by hired labourers, and he owns a motor cycle to facilitate the transport of coffee to the middlemen.

Photo 4
Intensified sun plantation of señor Adelicio Pardo



SHADED ORGANIC

Señor Martin Felix Rojas Delgado lives in Nuevo Lambayeque, a small village at an altitude of 1500 metres. Here he owns 4.5 hectares of land, of which 4 are planted with coffee trees. He recently became president of the farmer association 'Aproeco', which is one of the first organic farmer associations in Alto Mayo, the research area. Being the president, during weekdays he now lives in Moyobamba, about three hours from his home. However, he prefers life on the plantation, as he is passionate about farming and nature and runs his plantation as environmentally friendly as possible to conserve nature and its biodiversity. He has sustained and planted different tree species, some of them especially for fruits provided for birds. He prunes the trees carefully to avoid large and dense canopies, maintaining an intermediate level of shade. In the picture he shows one of the many orchid species that grow on his plantation, which he tries to foster carefully by not removing all the weeds and maintaining shade. These orchids could provide an extra income, as he says that they are often stolen from his plantation and sold in the city for large sums of money. Besides carefully managing the shade trees, he applies different fertilizers, all organic. He does not actively apply pest management. The infrastructure of the village is poor: it takes two hours to transport two bags of coffee by mule to a village accessible to cars. This situation will however change soon, as a road is currently being constructed to make the village accessible to cars and motor vehicles.

Photo 5

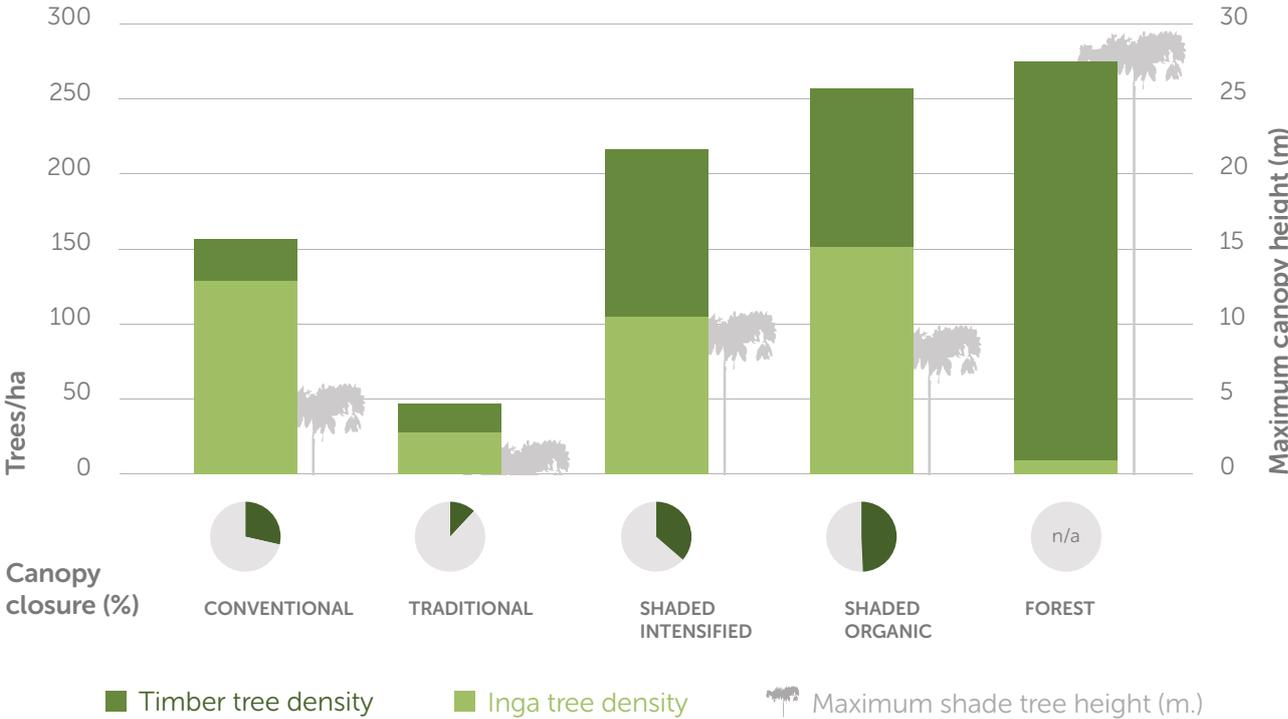
Señor Martin Felix Rojas Delgado showing one of the many orchid species that grow on his plantation.

VEGETATION STRUCTURE OF THE FOUR COFFEE SYSTEMS

Probably one of the most widely discussed management options -both from an ecological and economic perspective- is the presence of shade trees within a coffee plantation and the related plantation structure. In figure 5, the plantation structure of the four management systems is presented based on data collected from 46 of the 154 plantations. This graph shows how management systems are characterised by the number of trees per hectare, canopy closure and maximum tree height, which are all indicators of vegetation structure complexity. A forest group is included as a reference.

Apart from natural forest, vegetation complexity is highest for shaded organic plantations, followed by shaded intensified management systems. The shade on conventional plantations is predominantly caused by Inga trees and the vegetation structure complexity is therefore low. Traditional plantations have a very low density of shade trees and consequently the lowest vegetation structure complexity.

Figure 5
Plantation structure of the four management systems





A



B



C

Photo 6
Coffee plantations with different vegetation structures:
a) without shade;
b) simplified shade, predominantly Inga;
c) diversified shade, multi-strato

3 THE BUSINESS CASE FOR GROWING COFFEE IN PERU

Different types of coffee plantation management in San Martín were identified, implying that there are differences in management in terms of labour intensity, costs and benefits. Here, we consider the costs and benefits of the four different management systems by evaluating coffee productivity, coffee prices and the costs of labour and input that are associated with coffee production. Additional benefits associated with coffee plantation are included, such as the income derived from firewood and other crops.

3.1. COFFEE PRODUCTIVITY

LEVEL OF SHADE

Many small-scale farmers worldwide have intensified their management by eliminating shade trees and increasing their agrochemical input to increase coffee productivity. At first sight, the results seem to confirm these expectations as the coffee yields of the intensified conventional plantations were higher than the other three systems. However, the differences were not significant (figure 6). Underlying these intensification practices is the relation between shade and coffee productivity, for which it is generally assumed that shade decreases coffee productivity (Foley et al., 2011; Seufert et al., 2012).

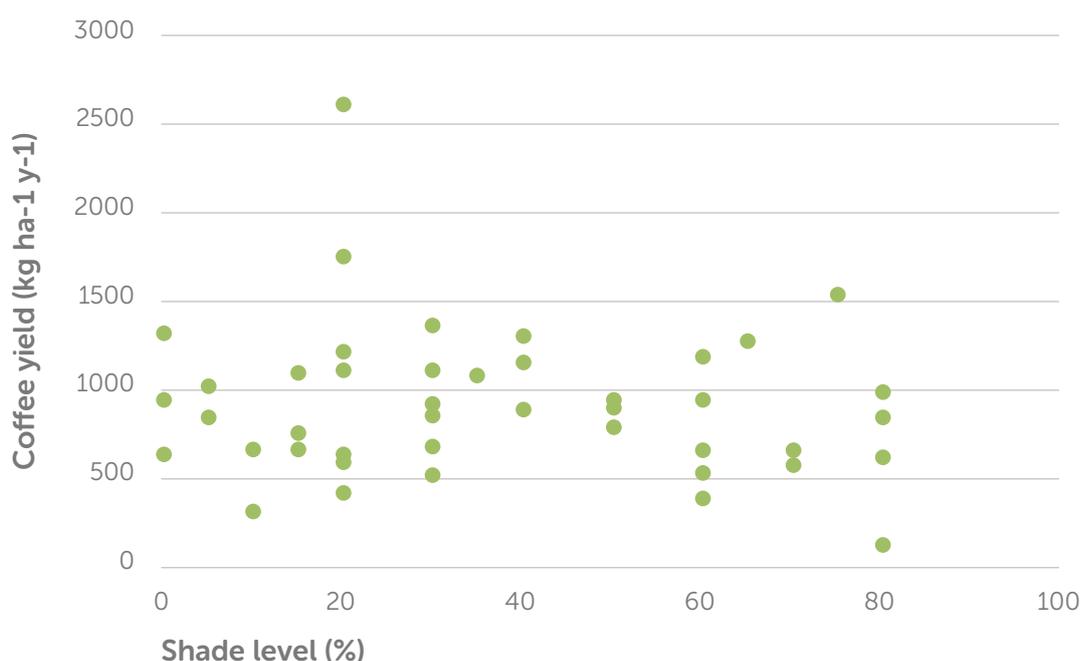


Figure 6
Relation between level
of shade and producti-
vity of 46 plantations

However, we found no relation between coffee productivity and shade cover (figure 6), which is in line with an increasing number of studies showing that moderate shade levels have little effect on coffee yields (Perfecto et al., 2005; Soto-Pinto et al., 2000). Overall, the coffee yields of the farmers we visited were about 10 percent higher compared to the productivity data of the local government, which estimated the average production at 600 to 700 kg per hectare per year (CENAGRO, 2012).

BOX 3: METHODS- PLANTATION MANAGEMENT AND THE ASSOCIATED COSTS AND BENEFITS

Management and costs

Each farmer was asked about: i) their current yield and coffee price, and that of the previous four years from 2010 to 2014. Gross coffee revenue was calculated by multiplying the coffee yield and price; ii) their costs for land, equipment and input, and they were asked to specify the type of input and purpose (fertilizer, pest control, herbicide); iii) the benefits derived from firewood, livestock, other crops; iv) an estimation of the type and number of shade trees on their coffee farms; v) an estimation of the labour days spent on preparing the land and planting coffee trees; vi) an estimation of family labour days per year and hired labour days per year and the frequency of weeding, fertilizing, pruning, pest control, harvest and post-harvest.

All the costs and benefits were calculated for one hectare of coffee plantation in euros per hectare per year. One quintal of dried coffee beans was therefore converted to 56 kg, and one Peruvian sol to € 0,26. The costs and benefits spanning more than one year such as land costs and equipment but also income from timber were calculated according to a 20-year coffee cycle and the use of a 5 percent discount.

Other products and timber

Most of the additional products such as livestock and firewood do not provide a direct income as a large share is used for their own consumption. However, as these farmers would otherwise have to buy these products, the monetary benefits are included in terms of the gate prices indicated by the farmers.

Timber income is derived from the 46 plantations for which the field data were collected (box 7). DBH and height are used to calculate the current standing timber volume using a 70 percent conversion factor on the total trunk volume. Current local prices of separate tree species were used to calculate the current value of standing trees. Costs for producing timber are not taken into account (seedlings, planting, pruning), resulting in an overestimation of the income derived. However, this is the value from the current standing stock, with an average age of 9 years and the timber value is expected to be significantly higher after 20 years. In that sense, timber values are now underestimated.

COFFEE LEAF RUST

Coffee is a fragile crop that is vulnerable to insect pests and diseases and changes in weather, leading to fluctuations in productivity. Pests and diseases are responsible for losses of approximately 30 percent to 40 percent of the total coffee production (Lin, 2010; Perfecto, 2007). Intensified management such as the application of fungicides and insecticides are aimed at decreasing such losses and maximising productivity. Just like other Latin American countries (Avelino et al., 2006), Peru has been hit by the devastating fungi coffee leaf rust (*Hemileia vastatrix*) and national coffee production has declined by 30- 40 percent over the last few years (fig 2, Larrea et al., 2014). This is reflected in the productivity of the farmers in San Martín, which was reduced by approximately 50 percent from 2010 to 2014 (figure 7a). The impact was highest for shaded organic systems (-66 percent) and lowest for traditional farmers (-18 percent). As a result of the high impact of coffee leaf rust, many farmers either abandoned their plantations or have started renovation, meaning that new coffee trees are being planted. Instead of the Arabica variety Caturra, which is widespread because of its high productivity, but sensitive to coffee leaf rust, less susceptible varieties are being planted. For example, farmers are planting the Arabica variety Catimor, which is less productive but not susceptible to the fungus.

Photo 7

This photo shows local women selling coffee seedlings along the road. Besides the ongoing expansion of coffee area in San Martín and associated demand for coffee seedlings, many farmers are renovating their plantations by planting new coffee trees to recover from the damage of the coffee leaf rust.



3.2 GROSS COFFEE INCOME

COFFEE PRICE: FLUCTUATION, QUALITY AND CERTIFICATION

The price farmers receive for their coffee is very important for the net revenues farmers derive from their plantation, yet these prices can fluctuate from year to year and differ between management systems (figure 3; figure 7b). Although these fluctuations follow the same pattern as the world coffee price for mild Arabica's, the changes are less pronounced and the price received by farmers in San Martín lies far below the average world coffee price.

In San Martín, we saw that coffee prices were highest for shaded organic systems with a difference of up to 10 percent compared to traditional farmers. Based on interviews with farmers and members of coffee associations, we presume that this price difference is mainly caused by two related aspects: differences in bean quality and a price premium as a result of certification. We indeed saw that of all 154 farmers, the 53 percent which produced certified coffee received a price that was 11 percent higher than non-certified coffee farmers. As a larger share of the shaded organic plantations were certified (69 percent), in contrast to traditional farmers, this could indeed explain differences found in coffee price. Although coffee quality is not part of this study, shaded systems are known to produce higher quality coffee beans (Muschler, 2001; Vaast et al., 2006), increasing the suitability of shaded grown coffee for specialty markets. Since the specialty coffee market has doubled over the last decade and is expected to keep growing (Jha et al., 2014), price premiums received by small-scale farmers as a result of environmental certification can play an important role in raising farmers' incomes (Lyngbæk et al., 2001).

Overall, traditional farmers receive the lowest gross coffee revenue. On top of the low coffee production, these traditional farmers also receive the lowest coffee price per kilogram, which is probably related to difficult market access and lower bean quality due to their limited knowledge on management. Since conventional plantations produce higher yields, the related gross coffee income was highest, which is in accordance with other studies. However, hereafter we also look into the associated costs as well as income from other sources.

SITE-SPECIFIC CONDITIONS

The relation between coffee productivity and bean quality is not only influenced by shade, but also depends on site-specific environmental conditions such as temperature and solar radiation. At higher altitudes a negative effect of shade on productivity and bean quality was observed (Bosselmann et al., 2009). Shade appears to bring the greatest benefits in productivity and quality for coffee plants which grow in suboptimal and heat-stressed growing regions, where shade can bring environmental conditions closer to being ideal. This has implications for the certification of plantations at different altitudes, and the potential benefits of shade trees. If farmers at higher altitudes are to consider switching to a shaded system, the presumed decrease in coffee yield and quality needs to be compensated by a price premium. In this regard, research on the combined effects of environmental conditions and management practices on coffee productivity and quality is recommended.

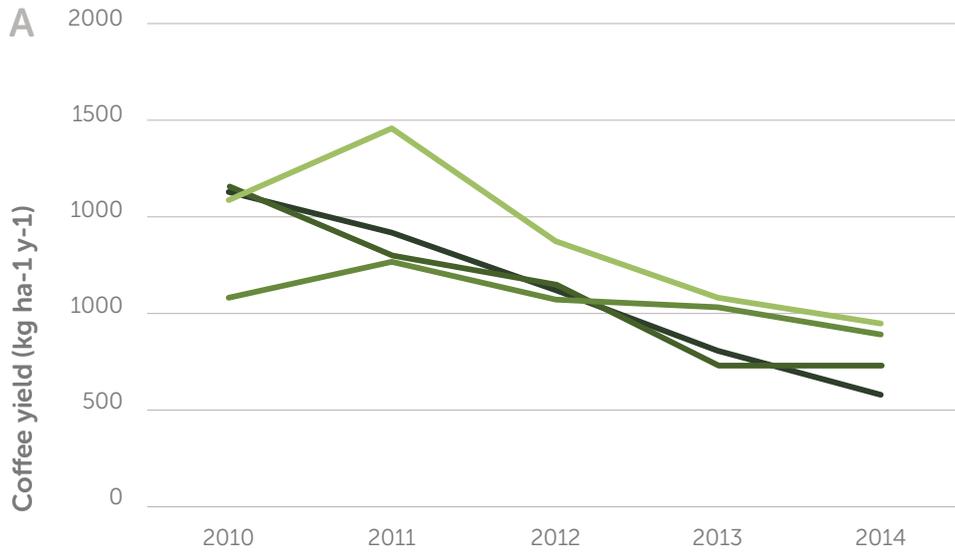
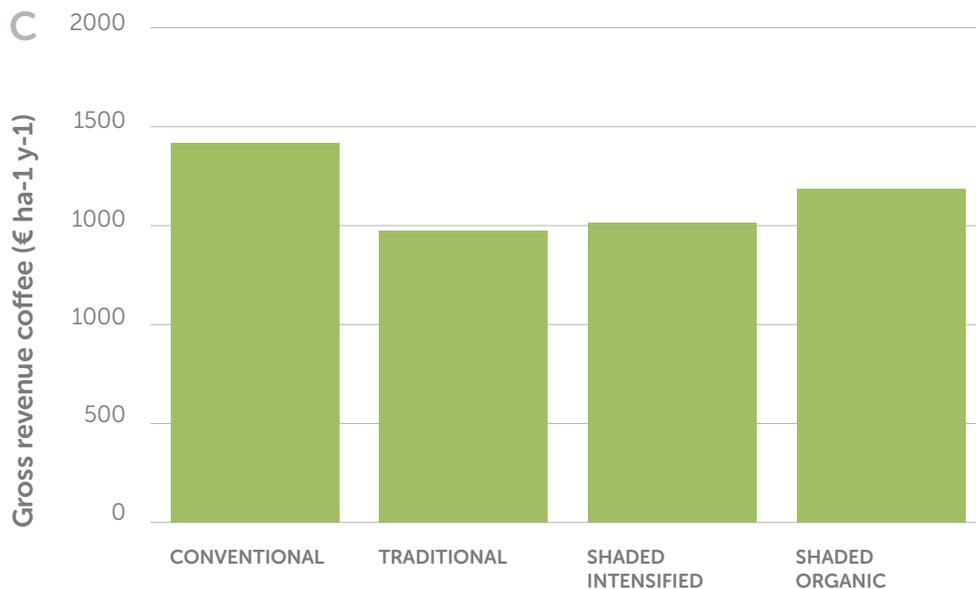
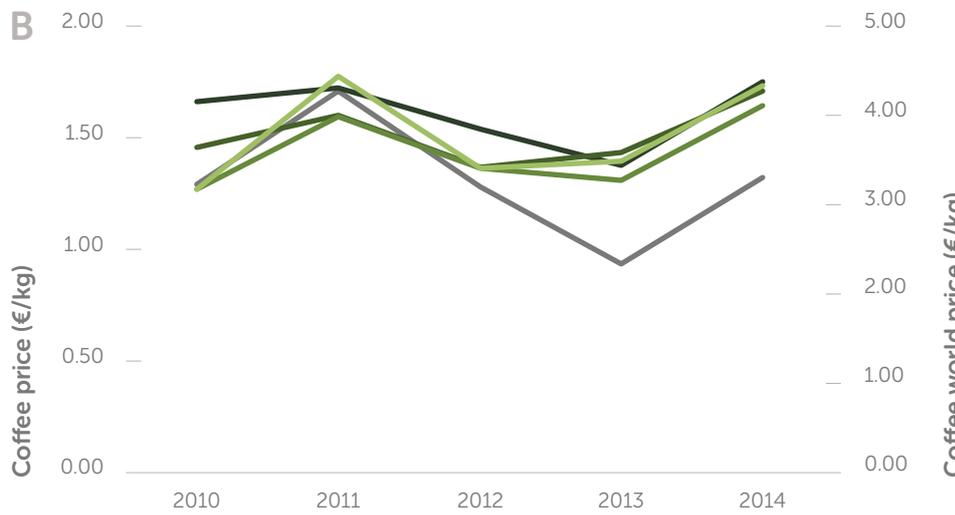


Figure 7:
 a) productivity,
 b) coffee price and
 c) gross revenue, from
 2010-2014





BOX 4: THE RHYTHM OF COFFEE FARMING: FROM PLANTING TO HARVESTING

After the establishment of a plantation by clearing the land and planting the coffee seedlings, coffee trees start producing in the second or third year and reach optimum production by the fourth or fifth year. In general this production can be sustained until 20 to 30 years, but the majority of the interviewed farmers indicated that they would plant new trees after 20 years. Therefore, the calculations in this study are based on a 20-year coffee cycle, after which new coffee plants will be planted. In between, the coffee shrubs may be cut back to their trunks in cycles of about seven to ten years to increase productivity. Besides this radical procedure, the trees are pruned mostly every year to sustain one stem and to select productive branches. To bridge the gap between planting and the first substantial income from coffee, young coffee plants are often intercropped with maize or beans (photo 9). Especially during the initial years, removing weeds is a labour intensive but important task to stimulate the growth of the coffee shrubs (figure 8). Later on, either the coffee trees themselves or shade trees provide shade, which reduces the growth of weeds and shrubs. In Peru, there is usually one major harvest per year, approximately from March until June. Ripe fruits are manually picked, which is a very labour intensive job for which farmers often hire pickers (figure 8). At the same time, many of these coffee farmers work on their neighbours' plantations to pick fruits, exchanging services.

After harvesting the fruits, the coffee cherries are further processed by the farmers themselves. The harvested cherries are poured into water-filled basins to soften the outer husk and pulp. When softened, the cherries are run through a pulping machine to remove the husk. Then the beans, which are still covered by a silver skin, are left in water tanks for 12 to 48 hours for natural fermentation. The fermented beans are laid out on black mats in the sun to dry (photo 13). After drying, the farmers sell their coffee per bags of 56 kilos as 'café pergamino': dried, unroasted beans, preferably with a moisture content of 11 percent

Photo 8
Ronald Mori Pezo is measuring butterfly diversity in a shaded coffee system

Photo 9
Intercropping of young coffee plants with maize and beans.

3.3 WHAT ARE THE FARMERS' EXPENSES?

Coffee is a labour intensive crop, of which most of the labour is done by the farmers and their families (Eakin et al., 2009). Here we discuss the costs associated with growing coffee according to the different systems in terms of labour, land, equipment and input.

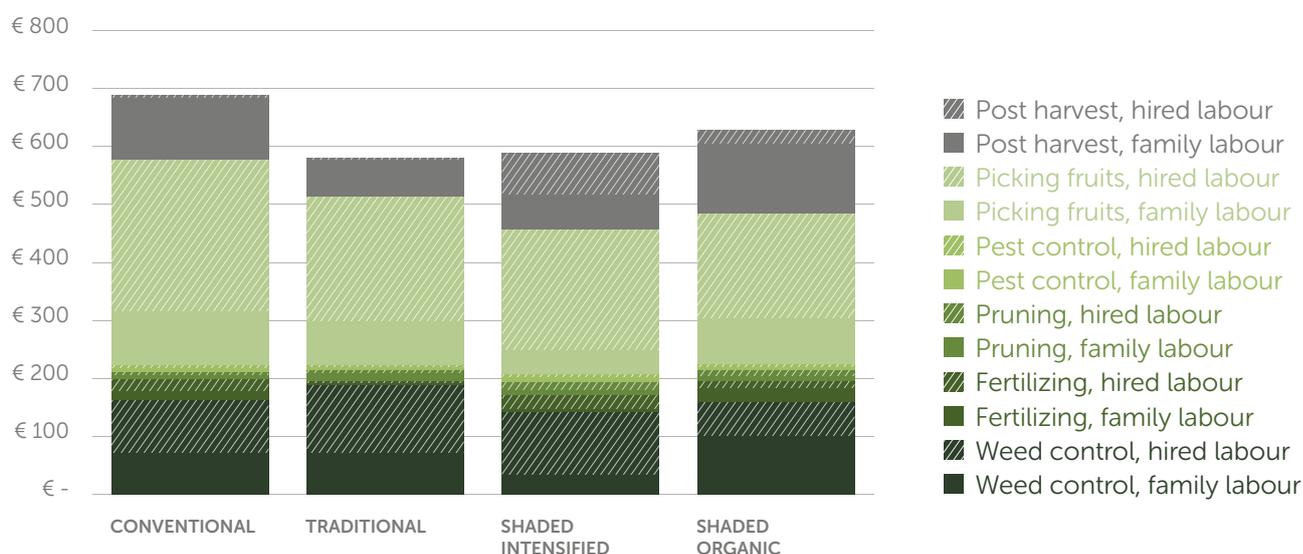
LABOUR COSTS

When looking at the four different systems and management applied, the total labour costs of conventional plantations were 18 percent higher than the labour costs of the traditional plantations, reflecting the management intensity of both systems. Yet the overall difference between the total labour costs was small, and the main observed difference between the systems is the amount of labour that is conducted by the farmers' family or by hired labour. Shaded intensified systems hire the most labour (73 percent), as opposed to shaded organic systems, of which the majority of work is done by the farmers and their families (53 percent). Both costs are included in the analysis, but family labour is not an actual incurred costs cost as it can be seen as an opportunity for income generation. In this regard it is excluded from some of the subsequent analyses, which decreases the average labour costs of the systems but increases the labour cost differences between the systems. When family labour is excluded, labour costs are 45 percent higher for shaded intensified systems when compared to shaded organic systems.

COSTS OF LAND, EQUIPMENT AND INPUT

Although we found that labour covers the largest share of the costs of the farmers in San Martín, investment in land, equipment and input should not be underestimated and varies between the four management systems. Improved management practices such as fertilizing and pest and disease control are particular costly and account for 28 percent of the total incurred costs (figure 9). As expected, the costs for conventional plantations are highest, mostly due to high fertilizer input. This is similar for shaded intensified plantations.

Figure 8
Costs associated with labour, both family and hired, in € per hectare per year.



The two plantations with less intensive management (traditional and shaded organic) show lower fertilizer costs and lower overall costs. Traditional farmers hardly apply any pest management and very little fertilizer, and are therefore often organic by default. These differences in costs reflect the management intensity and are important to take into account when looking at the profitability of a system.

COMPARING COSTS BETWEEN THE FOUR COFFEE SYSTEMS

Overall, conventional systems invest most in their plantation management, followed by shaded intensified systems, and the costs for traditional and shaded organic plantations are lower. When family labour is not taken into account as these are not actual incurred costs, shaded organic systems have the lowest overall costs since the share of family labour is high. As small-scale farmers often have limited access to resources and finance, the lower costs associated with shaded organic systems are in that light a more attractive option for many coffee farmers. These dynamics are not just seen in Peru but also in other coffee producing countries. In El Salvador, Gobbi (2000) demonstrates that the capital requirements for organic shaded coffee systems are low and that these requirements increase with a reduction in shade cover. This reflects the general idea that the intensification of coffee management systems is associated with higher costs, due to an increase in management intensity and agrochemical inputs, especially fertilizer input. We found similar dynamics, as the difference in costs between the four systems can be largely assigned to fertilizer input.

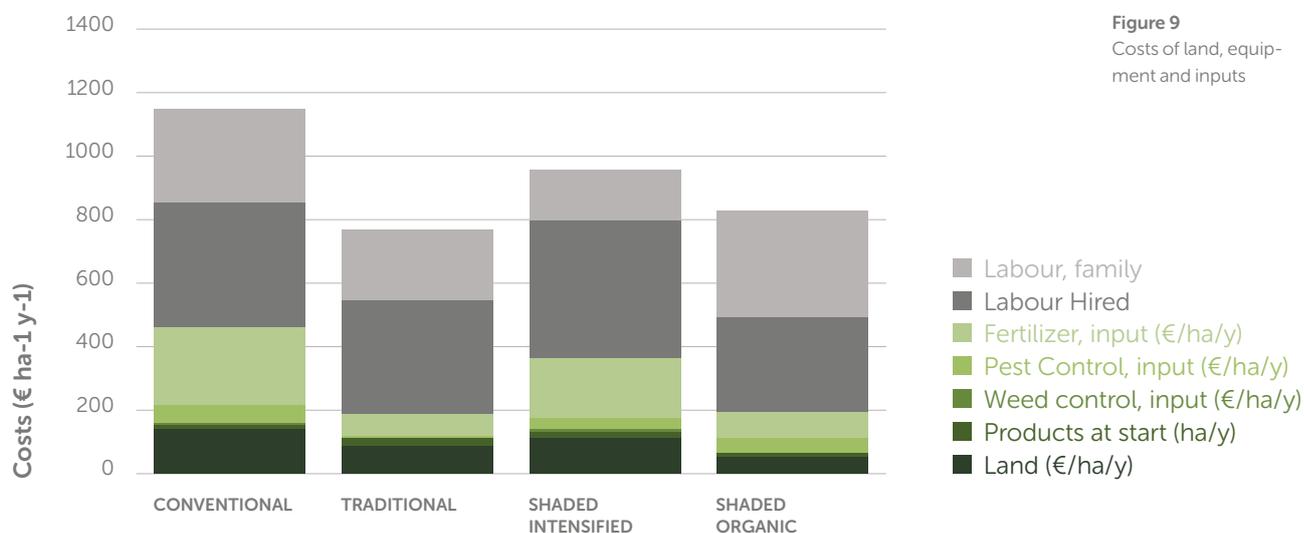


Figure 9
Costs of land, equipment and inputs

3.4 BENEFITS FROM OTHER PRODUCTS

An important motivation for farmers to adopt agroforestry management practices is to improve their livelihoods by increasing their overall productivity and diversifying their income to increase their resilience. In this regard, it is important to identify other products generated on the coffee plantations and quantify these benefits. To this purpose, data on income from other crops (mainly plantain and cassava), livestock, firewood and timber were taken into account (box 2.). When these monetary benefits are taken into account, potential revenues from shaded plantations increase substantially, mostly due to the revenues derived from timber (figure 11). Gross revenues from other products are highest for shaded organic systems followed by shaded intensified systems, mainly due to the value of the current standing timber volume. If revenues from timber are not taken into account, shaded intensified systems have the highest combined revenues, largely explained by the higher income from livestock. Conventional systems provide the lowest income per hectare, even when timber is left out of the equation.

DIVERSIFICATION

Income derived from other products can contribute greatly to the income of small-scale farmers (Rice, 2008). In our case, income from other products accounted for 9-24 percent of total farm income, excluding potential income from timber and was lowest for conventional systems. If we were, however, to include the potential income from timber, the total yearly income can increase by an estimated 35 percent in shaded organic plantations and, logically, the potential increase is close to zero (1-2 percent) in the conventional and traditional systems as these plantations have little to no shade. Souza et al. (2010) found similar results, as income derived from other products added more than a third to the income derived from coffee. The same results were found in Costa Rica and Guatemala, where income from timber and firewood accounts for more than 70 percent of the income derived from shaded coffee plantations (Martínez Acosta, 2005; Mehta and Leuschner, 1997). Overall, it is clear that income from fruit trees, timber or firewood is significant and may result in a better financial performance than would occur in plantations without shade trees or with low diversity Inga trees (Beer et al., 1998).

FORESTRY PRACTICES

Although income from shade trees in terms of timber looks promising, we saw that the commercialisation of timber faces both ecological and economic challenges. Ecological interactions such as competition for nutrients or water and canopy size make some tree species more suited to being intercropped with coffee than others. It became clear from local expert workshops that there is a need for a short list of suitable tree species that meet these ecological criteria. However, besides the selection of suitable species, the proper management of the shade trees is key. Access to knowledge on management and technical assistance is therefore essential to obtain high quality timber and to control the canopy size to maintain moderate levels of shade and therefore productivity. If these ecological challenges are overcome, economic challenges such as market accessibility, transport and timber value should not be overlooked. Coffee plantations are often located in remote areas with little infrastructure (photo 10), limiting the possibility to market timber. Commercial timber value and market accessibility should therefore be taken into consideration when valuing the economic potential of tree species and forestry practices on coffee plantations. If these barriers are however overcome, the benefits derived from shade trees can provide important contributions to farmers' livelihoods, especially in times of low coffee prices or low coffee productivity, thereby increasing their economic resilience.



BOX 5: SOCIO-ECONOMIC RESILIENCE THROUGH DIVERSIFICATION

Small-scale farmers are very sensitive to changes in coffee prices and declining coffee yields as coffee often provides their main source of income. The farmers in San Martín are no exception, as we saw that coffee provides more than 50 percent of the income of farmers, thereby excluding potential timber revenues. By diversifying their income, fluctuations in coffee prices will have a lower impact on their total income. This effect of diversification on income is illustrated by a study on shaded coffee plantations in Mexico (Gordon et al., 2007). This study showed that a recent coffee price crash on the international market had a much greater impact on the net revenue of conventional coffee plantations (a 30-fold decrease relative to the pre-crisis prices) than on the net revenue of the extensive agroforestry sites (2.9-fold decrease) and other shaded plantations (6.7-fold decrease). Timber trees in particular can be addressed in times of low prices or failure of the coffee production and can therefore be considered a 'saving account'.

Photo 10
Construction of the new road, that will connect Nuevo Lambayeque with the nearest village accessible by car

3.5 HOW COST-EFFECTIVE AND PROFITABLE ARE THE FOUR COFFEE SYSTEMS?

COST-EFFECTIVENESS

As many small-scale farmers have only limited access to resources to invest in their plantation, cost-effectiveness is an important indicator. To gain insight into the cost-effectiveness, all gross income (coffee and income from other products associated with the coffee area) is divided by the costs associated with coffee production. Since family labour contributes a great deal to the costs, the benefit-costs ratio (BCR) is presented for both options (Figure 10). All systems are profitable as the average BCR values are higher than 1.0 (y-axis = 1.0). However, there are large differences in the cost-effectiveness of the systems. It can be immediately seen that shaded organic systems show the highest cost-efficiency, with or without family labour included as costs. The intensified systems (conventional and shaded intensified) on the other hand show the lowest cost-efficiency, also with family labour included as a cost. Shaded organic systems are twice as cost-effective as conventional systems when family labour is excluded. This is in contrast with the coffee productivity of these conventional systems. Since the intensified systems include the lowest share of family labour, the cost-efficiency is not as high as the other systems, especially when compared to shaded organic systems, which involve a larger share of family labour.

PROFITABILITY

Although BCR is a good indicator for cost-efficiency, at the end of the day, net revenue is very important as this represents the profitability of the farmer's plantation. When we correct the gross coffee revenue for its costs and add benefits from other sources, the difference between the systems becomes clear: conventional and shaded organic plantations are the most profitable (figure 11). When income from timber is included, shaded organic plantations have by far the highest profitability, which is 43 percent higher than conventional systems.

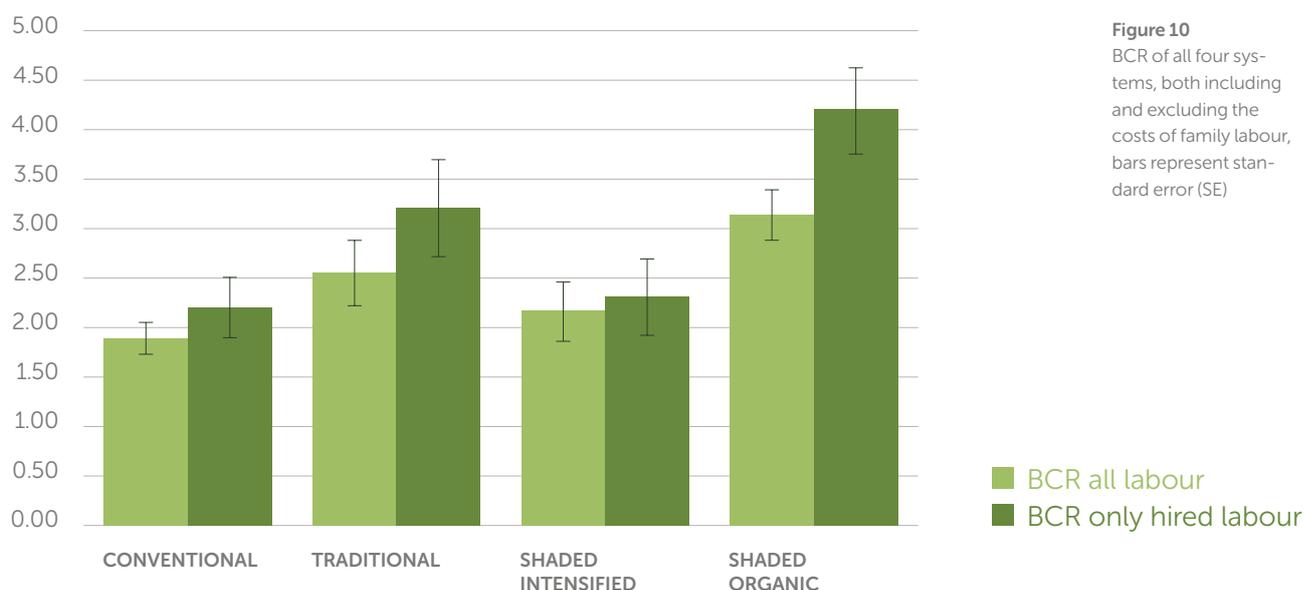


Figure 10
BCR of all four systems, both including and excluding the costs of family labour, bars represent standard error (SE)

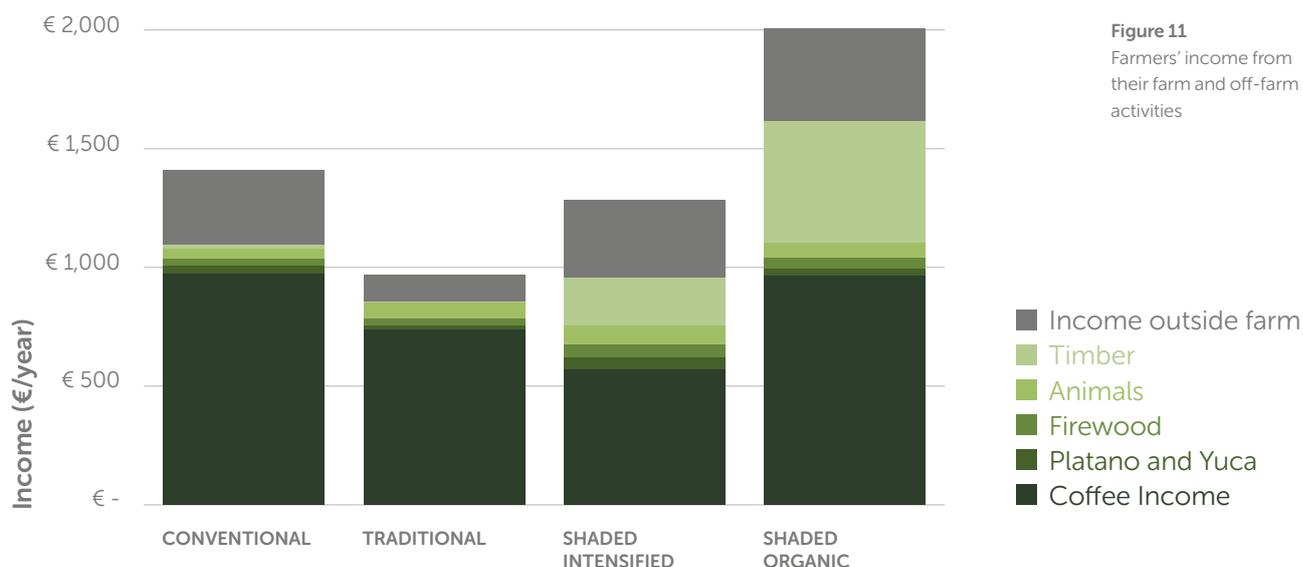


Figure 11
Farmers' income from their farm and off-farm activities

Although traditional plantations have low productivity and coffee prices, the profitability is higher than that of shaded intensified systems when looking at coffee income alone. This can be explained by the low costs of traditional systems and the high costs of intensified shade systems. Traditional farmers depend most strongly on income from farming, since off-farm activities, such as taxi driving, only account for 12 percent of their total income. Since this group represent the majority of farmers in San Martín, this was no surprise, as we see that many small scale coffee farmers in Latin America depend mostly on their income derived from coffee (Eakin et al., 2006).

BOX 6:

This business case for shaded coffee plantations illustrates that farmers who grow their coffee in diversified systems and farm organically have the strongest business case for smallholder coffee farmers in Peru, San Martín. This can be explained by the lower input, higher coffee prices and income derived from other products. Thus, in assessing the suitability of a system for smallholders, it is important to take both costs and benefits into account. Productivity is certainly not equivalent to profitability

4 BIODIVERSITY AND ECOSYSTEM SERVICES

Coffee is grown in areas that coincide with high biodiversity levels and where livelihoods depend on the forest and its services (De Beenhouwer et al., 2013). At the same time, these coffee growers have a significant effect on shaping the landscape as coffee plantations are often established on previously forested land, resulting in deforestation and degradation. The loss of associated ecosystem services such as natural pest or erosion control is expected to increase the vulnerability of the farmers. More complex systems such as agroforestry systems and the associated biodiversity are known to supply environmental services, but the extent of these (often indirect) benefits is not clear, especially compared to intensified systems. In this chapter, we discuss the influence of management intensity and vegetation structure on biodiversity conservation potential and the associated ecosystem services, as well as the direct and indirect benefits for smallholder farmers.

Photo 11
Butterfly on a coffee shrub

Photo 12
Frog encounter on a coffee plantation



BOX 7: METHODS FOR VEGETATION STRUCTURE, BIODIVERSITY AND ECOSYSTEM SERVICES

To quantify the conservation value and ecosystem services of the coffee plantations in Peru, we visited 49 out of the 150 plantations, representing all four management systems. On all the plantations we collected data on vegetation structure, biodiversity and micro-climate.

Vegetation structure

To examine the vegetation complexity on the plantations, different vegetation characteristics were measured. On each plantation the location for a plot 25 x 25 metres was selected by eye for a representative vegetation structure for the whole plantation. Shade trees with a diameter at breast height (DBH; 1.30 m) larger than 10cm within the plot were identified for genus and their height was measured. All the data were converted to hectares. The shade level was estimated by eye and by analyses of five hemispherical photographs made of the canopy on each plot.

Biodiversity

Butterfly diversity and abundance was measured according to the transect walk method, which means that all butterflies were recorded along a 300-metre transect throughout the plantation (Walpole & Sheldon, 1999; Schulze et al., 2004; Ghazoul, 2002). For further analysis the butterfly data were used to create the species richness. The butterflies were classified into two groups: a forest habitat group with species related to natural forests, and an open habitat group with species related to open areas or described as pioneers in disturbed land. To quantify the potential of the coffee systems to conserve forest biodiversity, we also collected butterfly data on four forest sites as a reference.

Ecosystem services

Above ground (ABG) carbon stock was calculated according to Brown et al. (1989). Micro-climates in terms of temperature and air humidity were measured when the plantation was visited. Soil samples were collected on each plantation and analysed for i.e. nutrient and moisture content

WHY IS BIODIVERSITY IMPORTANT FOR COFFEE FARMERS?

More complex shaded systems are known to provide habitats for different animal groups and therefore support a more diverse wildlife community than systems managed without shade (Bhagwat et al., 2008). This greater biodiversity and more complex vegetation structure have been associated with different ecosystem services. The potential effect of natural pest control is particularly important, as damage caused by pests and diseases pose great risks for small-scale coffee farmers. Empirical evidence from several studies suggests that, for example, birds can play an important role in minimising the effects of pests. Perfecto et al. (2004) found that more diverse shaded coffee systems supported a more diverse bird community, which increased predation on caterpillars, thus reducing plant and fruit damage. A bird exclusion study by Kellerman et al. (2008) showed that birds supplied ecologically and economically valuable services to Jamaican coffee farmers by reducing damage of the

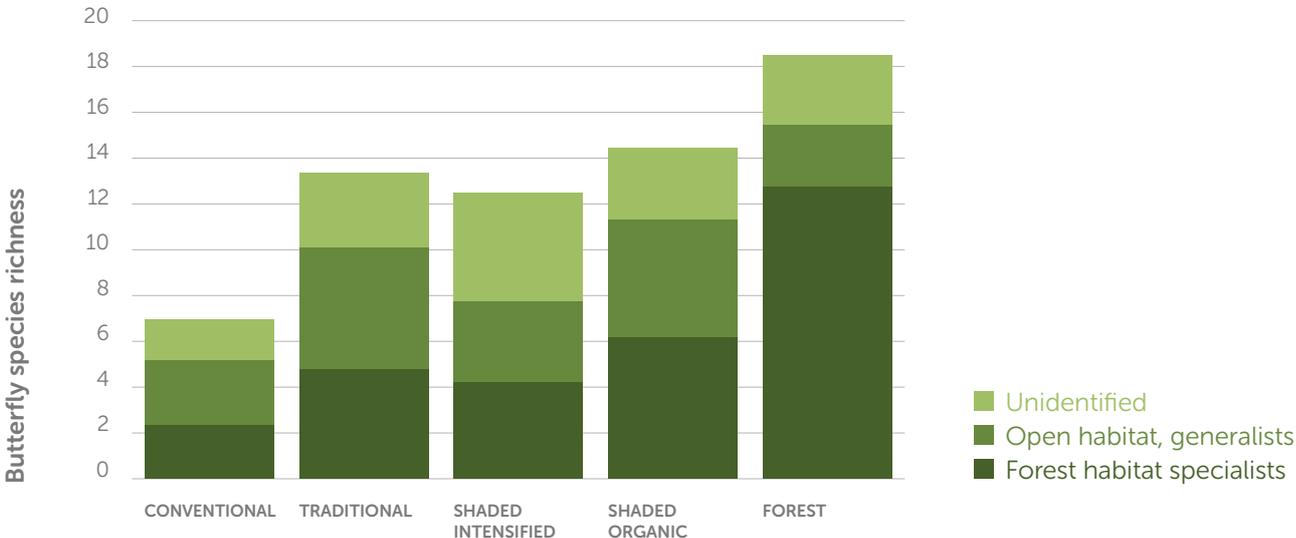
coffee berry borer. The difference in the proportion of damaged coffee berries was translated into an average benefit of € 70,- per hectare, excluding other direct benefits such as reduced pesticide use. Ecosystem services provided by biodiversity are therefore expected to positively contribute to farmers' livelihoods and increase pest and disease resilience. Additionally, shaded coffee systems therefore help maintain landscapes that would otherwise be much poorer in biodiversity.

4.1 HOW BIODIVERSITY FRIENDLY ARE THE FOUR COFFEE SYSTEMS?

One of the most studied aspects of agroforestry systems is the potential to conserve biodiversity. As measuring biodiversity is a time-consuming and costly activity, we used butterfly diversity and abundance as an indicator for plantation biodiversity (box x). Butterflies (Lepidoptera) can function as a proxy for biodiversity due to their sensitivity to micro-climatic changes in e.g. temperature, air movement, moisture and insolation (Bobo et al., 2006), thereby reflecting short-term land-use changes. Due to this sensitivity, butterfly abundance and diversity were reported to be related to plantation characteristics, such as shade cover, shade tree diversity and also pesticide use (Dolia et al., 2008; Kessler et al., 2009). In line with our expectations, these relations were also found in the plantations we visited. Butterfly species richness was highest in the forest sites, followed by shaded organic plantations, and lowest for the conventional systems (figure 12).

Besides the overall butterfly diversity, it is also important to look at the types of butterflies in the different systems. Most butterfly species have specific habitat preferences, roughly dividing the species we encountered into two groups; a forest habitat group with species related to natural forests, and an open habitat group with species related to open areas or described as pioneers in disturbed land. Since the coffee plantations in San Martín often replace natural forests, we

Figure 12
Butterfly species richness



are particularly interested in the forest specialists to provide insight into the potential of these coffee plantations to act as a refuge for the conservation of forest biodiversity. After the forest sites, forest specialist richness was highest in the shaded organic plantations, and lowest for the conventional plantations (figure 12). Looking only at forest butterfly species diversity, the forest reference group differed significantly from the two intensified management systems (conventional and shaded intensified). However, the forest butterfly species diversity of traditional and shaded organic systems did not differ significantly from the forest reference group. The data show a shift towards more generalist species when forest habitat is converted into coffee plantations, especially when it concerns intensified systems.

Butterfly diversity itself is not of direct importance to coffee farmers, but as explained, these indicators serve as a proxy for habitat quality and the impact of land-use change. The phenomenon of a shift towards generalist species due to disturbance is seen in communities around the world, such as for butterflies (Warren et al., 2001), aphids (Rand and Tscharnke, 2007) and pollinators (Potts et al., 2010). The ecological effects of losing an important share of the habitat specialists in an ecosystem are not exactly known. Nevertheless, butterfly abundance and diversity are related to the abundance and diversity of other animal groups, such as birds (Fleishman et al., 2005; Schulze et al., 2004), bumblebees (Vessby et al., 2002), bees (Davis et al., 2008) and other insects (Hymenoptera in general; Carroll and Pearson, 1998; Kerr et al., 2000). Although butterflies do not provide direct benefits to coffee farmers, some of the above mentioned animal groups such as ants and birds are known for their positive relation with coffee productivity as we discussed before. The higher butterfly biodiversity measured in shaded systems is therefore an important indicator for the potential services provided by biodiversity, such as natural pest control and pollination, which are directly beneficial for small-scale coffee farmers. Currently there is, however, little empirical evidence from San Martín that these biodiversity-related ecosystem services play a role in pest control, and research to disentangle ecological processes is recommended.

BOX 8: THE ROLE OF TECHNICAL KNOWLEDGE AND LOCAL REGULATIONS

The reduction of shade or increased agrochemical input results in the loss of biodiversity and the associated benefits to farmers, such as natural pest control and the regulation of micro-climates. It is therefore important that local regulations favour shade and organic input. Unfortunately this is not yet the case in San Martín. Although it became clear from interviews with farmers and expert workshops that ecosystem services are a hot topic and of interest to different stakeholders, the local government in San Martín distributes fungicides to minimise the risk of coffee leaf rust. Despite the great interest in ecosystem services expressed during local expert workshops, it was remarkable that natural pest control was not recognised as an ecosystem service. Farmers consider pests and diseases a nasty problem that should be rather controlled by applying pesticides and fungicides. Technical assistance frequently discourages the use of shade trees. Access to proper technical assistance and awareness raising amongst local stakeholders are in that sense crucial to promoting the proper use of shade trees, organic input and biological pest control methods.

4.2 MORE ECOSYSTEM SERVICES

Besides the direct benefits to small-scale coffee farmers, further opportunities to increase the attractiveness of shaded plantations may lie in ecosystem services related to shade trees. With this research we quantified carbon storage and micro-climate control (box 1). Overall, we saw that ecosystem services provided by shaded systems were higher than those of their conventional unshaded counterparts. This provides important direct and indirect benefits for small-scale coffee farmers which we are discussing here.

CARBON STORAGE

The high potential of agroforestry systems to sequester carbon is widely accepted (Nair et al., 2009). Following expectations, above ground carbon sequestration in coffee plantations was higher with increasing vegetation structure complexity (figure 13a). Compared to forests, however, the carbon stock is low (42 percent for shaded organic plantations). It should be noted that carbon stored in coffee plants is not taken into account, therefore underestimating the total above ground carbon stock in all plantations. More importantly, the potential carbon stock is expected to increase with the maturing of shade trees, taking into account that carbon stocks were measured at an average plantation age of only 9 years.

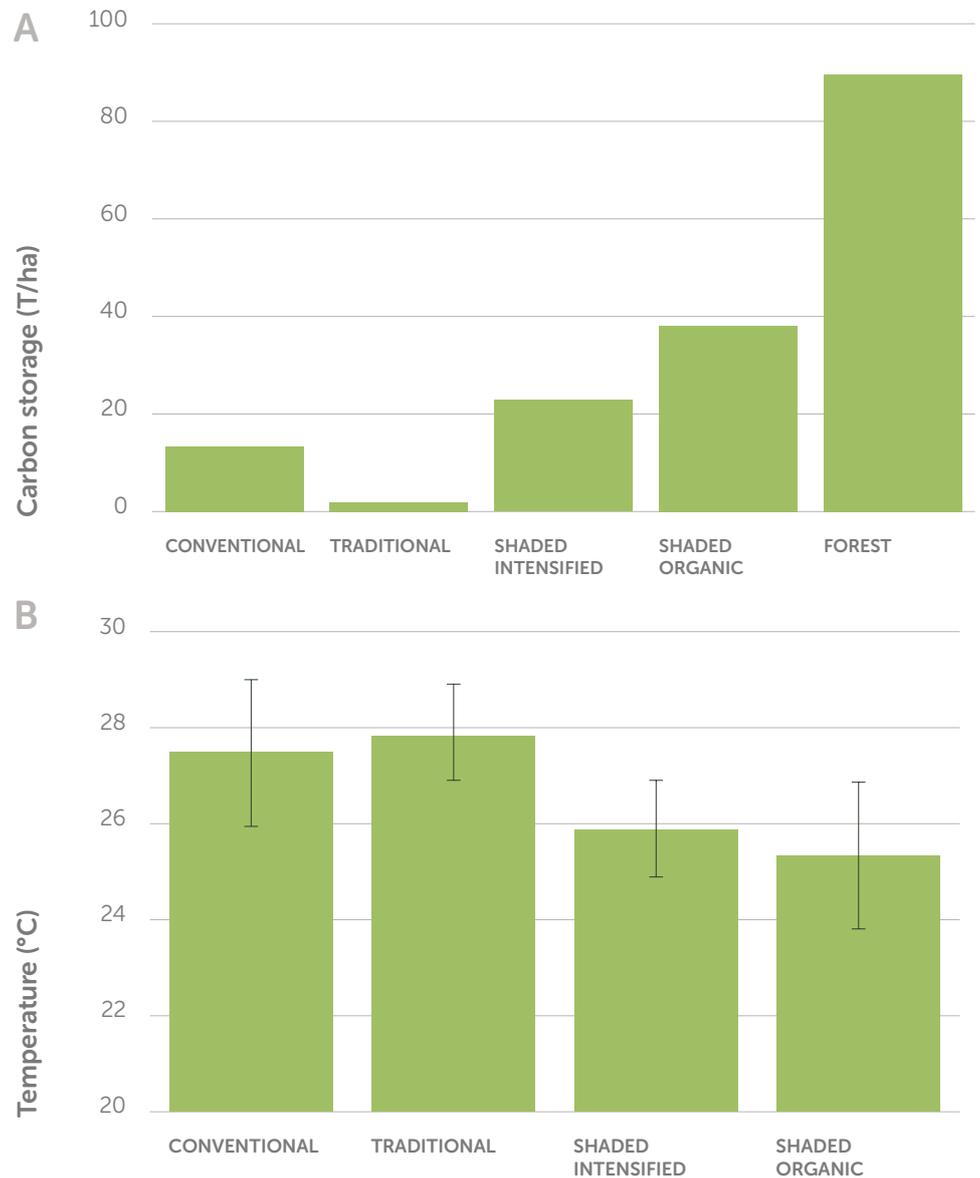
Although these are indirect benefits for coffee farmers, payment for ecosystem services is proposed as economic instruments to incentivise the provision of ecosystem services. In the case of carbon, opportunities do arise, such as price premiums received by farmers as a result of environmental certification or projects based on the concept of Reducing Emissions from Deforestation and forest Degradation (REDD; Clough et al., 2009). A recent reforestation project in coffee plantations in Piura (Peru) yielded successful results and provided the farmers with additional income (Porrás et al., 2015). Although fluctuating carbon prices and market access remain challenging, they conclude that carbon revenues can offer important incentives for small-scale coffee farmers.

MICRO-CLIMATE CONTROL

Shade trees can also provide more direct benefits to small-scale coffee farmers. The threat of climate change has caused concern for coffee farmers as key climate variables for the production of coffee such as temperature and rainfall are changing (Lin, 2007). Coffee plants are sensitive to changes in micro-climate and climate variability is therefore expected to play a key role in the productivity of coffee plants. We therefore looked at the daily temperature and humidity of the plantations in San Martín in relation to vegetation structure complexity. We indeed saw that daytime temperature decreases and air humidity increases with increasing levels of shade (figure 13b). This effect could not be attributed to differences in altitude. Shade trees in this sense help to keep coffee shrubs cooler during the day and warmer at night, which is essential for the productivity and quality of coffee (Lin, 2010). Overall, the climate buffering function of shade trees will become increasingly important, as climate variability is only expected to increase. By increasing resilience to climatic variability and stabilising productivity and income, shade trees can therefore improve farmers' livelihoods.

NUTRIENT CYCLING

Soil samples showed us that the level of shade was positively related to the nitrogen level in the soil (figure 13d). In this way, shade trees can reduce and also limit the amount of fertilizer needed by planting nitrogen fixing trees, such as the widely planted leguminous Inga trees in San Martín. Since the price of chemical fertilizers has increased over the last decade and is



expected to keep increasing (Weber et al., 2014), thereby increasing the benefit of planting shade trees with respect to the availability of nutrients. Additional agronomic research on the effects of fertilizer on productivity under different environmental conditions is recommended, in particular the trade-off between nutrient input and coffee productivity, with respect to associated costs and benefits.

4.3 SHADE, BIODIVERSITY AND NATURAL PEST CONTROL

Pests and diseases pose one of the greatest risks to farmers' livelihoods, and this is only expected to increase with the changing climate. It is therefore important to understand the effects of shade trees and agroforestry measures on the incidence of pests and diseases. Farmers in San Martín estimated a production loss of 50 percent due to the current coffee leaf

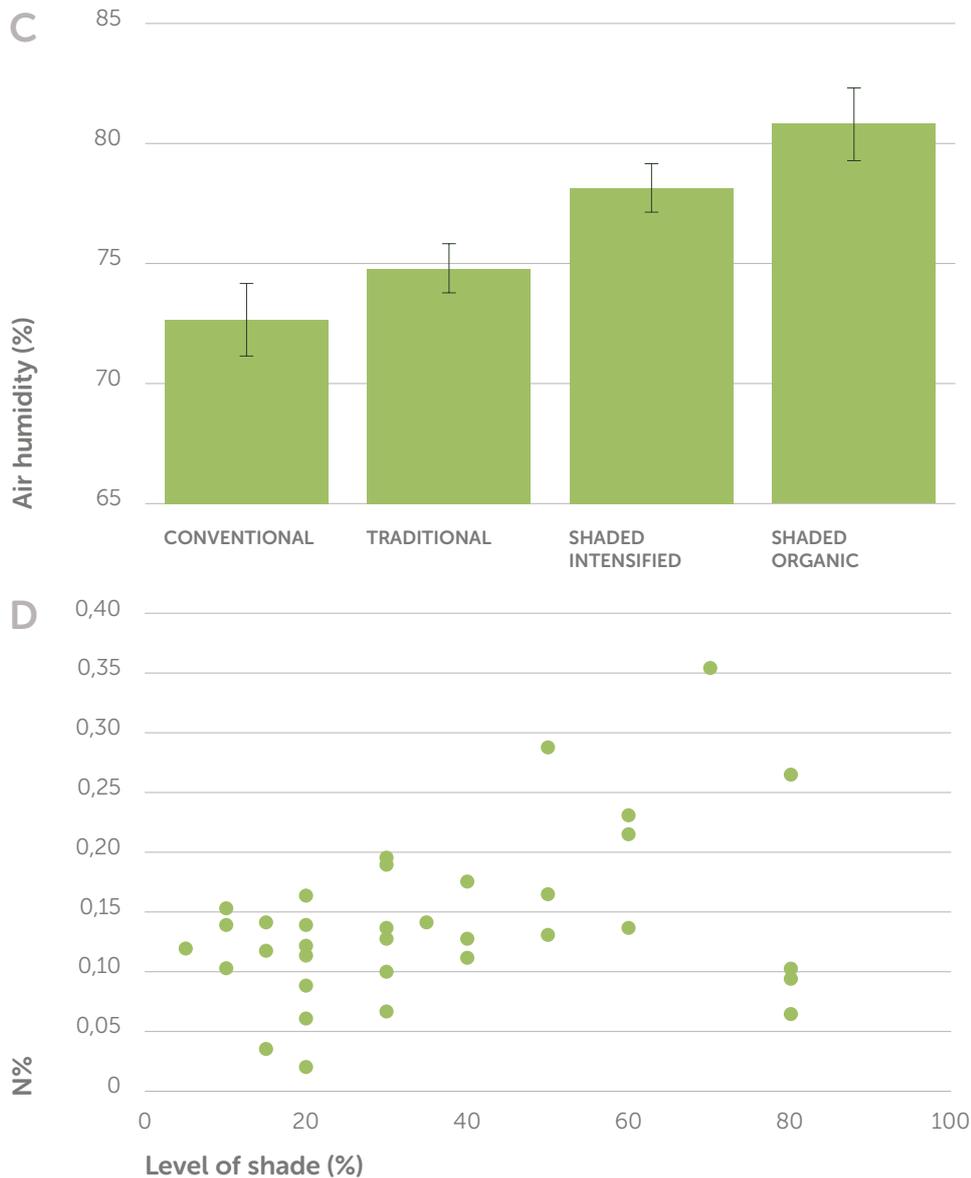


Figure 13
 a) Carbon sequestration in Above ground Biomass (ABG) in tonnes per hectare of the four management systems and natural forest; b) daytime air temperature; c) daytime air humidity and d) relation between level of shade and soil nitrogen content.

rust outbreak (*Hemileia vastatrix*) and 10 percent due to the coffee berry borer (*Hypothenemus hampei*). Overall, losses due to coffee rust were highest in shaded systems with (57 percent) and lowest in conventional systems (35 percent). Research confirms that the vegetation complexity and management of coffee systems influence the incidence and severity of pests and diseases in coffee agroforestry systems. Other empirical studies illustrate some of the mechanisms that influence these relations, but report contradictory findings. For example, a favourable micro-climate in shaded plantations can decrease the impact of the coffee berry borer, as it this insect benefits from increasing temperatures (Jonsson et al., 2015). Additionally, shade can provide a habitat for *Azteca* ants, which can protect coffee shrubs against coffee leaf rust (Vandermeer et al., 2014). More shade is, however, also associated with increased humidity, which facilitates the growth of fungi, such as coffee leaf rust (López-Bravo et al., 2012). Additionally, fertilization is supposed to enhance the pest resilience of coffee plants, while research suggests that fertilization was positively correlated to the incidence of coffee rust and the berry borer in Pasco, Peru (Otiniano et al., 2008).



There is a lack of agreement among farmers and scientists as to the question whether shade trees reduce or increase diseases and pests of economic importance, such as leaf rust and the coffee berry borer. Despite this lack of clarity, the risk of pests and diseases plays a major role in the day-to-day management decisions of small-scale coffee farmers, as they, for example, remove shade trees to reduce losses due to coffee rust or plant new coffee varieties less prone to coffee rust. This emphasises the importance of ecological and agricultural research aimed at gaining insight into the potential for coffee agroforestry systems to contribute to natural pest control, and the development of coffee varieties that are more resilient to pests and diseases.

Photo 13
Drying of coffee beans
in the sun

5 BIODIVERSITY BUSINESS: KEY INSIGHTS

This study systematically has assessed the performance of small-scale shaded coffee plantations in Peru, in terms of socio-economic benefits and biodiversity conservation. The objective was to demonstrate whether the goals of local development and biodiversity conservation can be reconciled and to identify which factors are important in that regard.

In summary, our findings show that shaded coffee plantations provide a viable business case as an alternative to more conventional plantations, while at the same time conserving biodiversity and ecosystem services. Here we address the key opportunities and challenges faced by small-scale coffee farmers growing biodiversity friendly coffee, according to the three pillars of agroforestry systems: productivity, profitability and sustainability (Atangana et al., 2014).

5.1 IMPROVED OVERALL PRODUCTIVITY

In San Martín, we saw that coffee plantations with diversified shade and organic input had improved overall productivity compared to the other small-scale coffee farming systems in the region. An important observation was the absence of a negative relation between the level of shade and productivity, which is in line with an increasing number of studies claiming that moderate levels of shade do not affect coffee yield. The lack of a negative effect of moderate levels on shade coffee productivity is an important opportunity for farmers to combine biodiversity conservation and local development. However, environmental conditions can influence this relation, as for example at higher altitudes a negative effect of shade on yield and productivity was observed in different studies. Management advice should therefore be very site specific and more research on the combined effects of ecological conditions and management practices on (long-term) coffee productivity is recommended. The selection of shade tolerant (Arabica) coffee varieties also important in that regard.

Additionally, this report shows that products provided by shade trees can indeed contribute greatly to farmers' livelihoods by providing food and extra revenues. Small-scale coffee farmers can especially benefit from income derived from timber, as it has the potential to provide them with considerable amounts of cash revenues. We saw, however, that the commercialisation of timber faces some challenges, both ecological and economic in nature. First of all, information on the proper management of these shade trees and technical assistance is essential for the improvement of timber quality and the control of the canopy size in order to achieve and maintain moderate levels of shade. Ecological interactions such as competition for nutrients or water and canopy size make some tree species more suited to be intercropped with coffee than others. Commercial timber value and market accessibility should be taken into consideration when valuing the economic potential of tree species.

These priorities of the farmers and market availability need to be verified before promoting the use of specific fruit or timber species as shade trees for coffee. Long-term studies addressing both the ecological and economic barriers of the commercialisation of shade trees is recommended. If these barriers are overcome, benefits derived from shade trees can provide important contributions to farmers' livelihoods, especially in times of low coffee prices or low coffee productivity, thereby increasing their economic resilience.

5.2 IMPROVED PROFITABILITY

One of the fundamental determinants of the adoption of any new land use system by small-scale farmers is profitability. This study shows that shaded organic systems can be just as profitable as conventional systems or even more profitable. Although the business case for conventional coffee plantations may be more straightforward, we saw that the calculation of costs and benefits for shade plantations is more complex, and coffee yield alone is a poor indicator for the functioning of agroforestry systems in this sense. We therefore recommend more comprehensive cost and benefit calculations to compare the business cases of different land use systems. The lower costs we derived for the shaded organic farmers in San Martín are comparable with other studies on the cost benefit analysis of agroforestry systems (Gobbi, 2000). Since small-scale farmers often have limited access to resources and finance, lower overall costs are in that light a more attractive option for many small-scale farmers.

Besides lower costs, we saw that farmers in San Martín with diversified shade and organic management systems received the highest prices for their coffee. The majority of these farmers are organised in farmer associations and produce certified coffee, which we assume contributes to the increased coffee price as a result of a price premium. However, this increased price does not have to be a direct result of a price premium, but can also follow from the organisation of farmers in associations, as organised farmers generally have improved market access and more management information, which amongst other things can improve bean quality. Furthermore, we observed that coffee price is strongly driven by bean quality, which is known from the literature to be higher for coffee grown under shade. Bean quality is, however, not only influenced by shade, but also depends on site-specific environmental conditions such as rainfall and soil fertility. Detailed research on the impact of management practices on bean quality under different environmental conditions is recommended. This will help align certification goals with the goals of coffee farmers, which is crucial in order for certification schemes to improve farmers' livelihoods.

A higher price of shade grown coffee has important implications, as shade can increase bean quality while enabling the produced coffee to qualify for environmental certification schemes. Producing certified coffee and being a member of an association in turn is expected to improve the market position and farmers' knowledge on coffee management. In this regard, capacity building, technical assistance and access to information as a result of environmental certification can play a key role in improved livelihoods and economic resilience.

5.3 IMPROVED ECOLOGICAL SUSTAINABILITY

More complex systems such as shaded coffee plantations and the associated biodiversity are assumed to supply environmental services, but the extent of these benefits is not clear. As expected, we saw that diversified shaded systems have a higher potential to conserve biodiversity. Not only is shade important in this regard, but also the complexity of shade and

the use of agro-chemicals affected biodiversity in the plantations in San Martín. We indeed saw that diversified shaded plantations with only organic input have considerable potential to conserve forest biodiversity, while a reduction of shade or agrochemical input reduces this potential. Though these shaded systems showed largest potential of the four systems to conserve biodiversity, loss of forest area is expected to result in loss of biodiversity. However, it is important to quantify the potential of different land-use types to conserve biodiversity and associated ecosystems. In this sense agroforestry systems can play an important role.

In this study, biodiversity measurements are based on the species richness of one animal group, butterflies. Butterfly diversity itself is not of direct importance to coffee farmers, but as explained, this indicator group serves as a proxy for habitat quality and the impact of land-use change. However, more comprehensive biodiversity measurements are recommended, especially those of functional groups such as ants, birds or bats, as these groups are known for their natural pest control and therefore more direct relation with productivity and positive contribution to farmers' livelihoods.

Diversified shaded systems are expected to have considerable potential to supply environmental services, some of which are especially important for their mitigation and adaptation effects on climate change. Carbon storage in shaded plantations was indeed higher when the vegetation structure complexity increased. As these are indirect benefits for coffee farmers, mechanisms of payment for ecosystem services are proposed as economic instruments to incentivise the provision of ecosystem services. In the case of carbon storage opportunities do arise, such as the implementation of the concept of Reducing Emissions from Deforestation and forest Degradation (REDD+) (Clough et al., 2009)

We saw that shade trees also provide more direct benefits to farmers as they have the potential to buffer and stabilise micro-climates. Shaded plantations in San Martín had lower daytime temperatures and higher air humidity. As climate variability is only expected to increase due to climate change, the buffering function of shade trees on micro-climates is expected to become increasingly important. Shade trees are therefore expected to improve farmers' livelihoods by increasing their resilience to climatic variability and stabilising their productivity and income. Planting shade trees in that sense provides a sustainable and financially viable strategy to cope with climate variability for small-scale coffee farmers, who usually have limited access to technological improvements.

There is a lack of agreement among farmers and scientists as to whether shade trees and the associated biodiversity reduce or increase diseases and pests of economic importance. Despite this lack of clarity, the risk of pests and diseases plays a major role in the management decision making of these small-scale coffee farmers. For example, shade trees are removed to reduce losses due to coffee rust, or new coffee varieties less prone to coffee rust are planted. This shows the importance of ecological research that will gain insight into these relationships, and to identify the potential for coffee agroforestry systems to contribute to natural pest control.



BOX 9: INCREASED SOCIO-ECONOMIC AND ECOLOGICAL RESILIENCE

Photo 14
Town of Shamboyacu,
San Martín

The improvement of overall productivity, profitability and sustainability are expected to improve farmers' livelihoods and overall resilience (Atangana et al., 2014). Here we summarise the key opportunities of shaded coffee systems to improve the socio-economic and ecological resilience of small-scale coffee farmers.

- The degree of shade does not have a marked effect on productivity.
 - The better economic performance of shade plantations makes this an attractive option for smallholder farmers.
 - The diversification of products increases farmers' incomes and decreases vulnerability to fluctuating coffee yields and prices.
 - Forestry practices involving timber and fruit trees have great potential to increase long-term income for coffee farmers.
 - Certification schemes provide higher and more stable coffee prices and can improve market access.
 - Shaded systems are associated with higher biodiversity and the associated ecosystem services.
 - Shade trees provide a sustainable and financially viable strategy to cope with climate variability.
 - Payments for ecosystem services, in particular for carbon sequestration, can increase farmers' incomes.
-

6 CONCLUSIONS AND RECOMMENDATIONS

We set out to learn whether biodiversity friendly management systems offer a viable business case for smallholder coffee farmers and under which conditions. Table 2 provides an overview of the assessment of the business case of shaded systems and the associated biodiversity benefits.

In short we can say that shaded organic systems have great potential to combine the twin challenges of local development and biodiversity conservation. Although there are different types of shaded plantations ranging in management intensity and vegetation complexity, the presence of shade trees is expected to positively contribute to the farmers' livelihoods in multiple ways and increase their overall resilience. The most important economic opportunities for shaded systems are the diversification of income, especially income from timber, lower costs and certification. Ecological opportunities are found in higher sustained biodiversity and the associated ecosystems services, which contribute to climate change mitigation. Shaded coffee systems thus offer great potential to offer a more biodiversity friendly and financially accessible way of sustaining coffee production in the future, especially in areas where farmers have limited access to financial resources.

Although reconciling biodiversity conservation and local development is promising, there are important preconditions for their successful implementation. Training and technical assistance are needed to help farmers achieve the desired level of productivity, both for coffee as for other products. In Information and technical assistance on the choice of shade tree species, tree management and the market access of timber is required. Certification schemes and farmer associations can play an important role in that sense by providing clear recommendations on plantation management and improving the market access of both coffee and other products. Goals of farmers and certification schemes need to be aligned as well in order for certification schemes to improve farmers' livelihoods.

More knowledge on the long-term effects of shade on productivity under different environmental conditions is needed, as well as more information on natural pest control and the underlying ecologic processes. This information is essential for providing the right knowledge to local stakeholders on which management decisions are based.

Besides capacity building and ecological knowledge, local governments play a key role in promoting biodiversity friendly management. The expansion of coffee areas should be carefully managed via land tenure and property rights, and new coffee areas should avoid biodiversity hotspots and national parks. Furthermore, local regulations need to favour and promote biodiversity friendly management.

TABLE 2: SUMMARY OF THE RESULTS AS THE FOUR MANAGEMENT SYSTEMS ARE SCORED BASED ON THE RESULTS PRESENTED IN THIS REPORT.

		CONVENTIONAL	TRADITIONAL	SHADED INTENSIFIED	SHADED ORGANIC
Economic performance	Coffee yield	+++	++	++	++
	Coffee price	++	+	++	+++
	Income from other products	+	+	++	+++
	Costs appreciation	+	++	+	+++
	Cost efficiency	+	++	+	+++
	Net income coffee	+++	++	+	+++
	Net coffee income & other products	++	+	++	+++
Biodiversity & other ecosystem services	Biodiversity	+	++	++	+++
	Carbon storage	+	-	++	+++
	Micro-climate control	-	-	++	+++

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