Agricultural Systems 162 (2018) 179–190

Contents lists available at ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

Effects of shade and input management on economic performance of small-scale Peruvian coffee systems

Rosalien E. Jezeer[a,c,*], Maria J. Santos[a], René G.A. Boot[b,c], Martin Junginger[a], Pita A. Verweij[a]

[a] Copernicus Institute of Sustainable Development, Faculty of Geosciences, Utrecht University, Heidelberglaan 2, 3584, CS, Utrecht, The Netherlands
[b] Section of Ecology & Biodiversity, Institute of Environmental Biology, Utrecht University, Padualaan 8, 3584, CH, Utrecht, The Netherlands
[c] Tropenbos International, Lawickse Allee 11, 6701, AN, Wageningen, The Netherlands

ARTICLE INFO

Keywords:
Agroforestry systems
Arabica coffee
Benefit-cost ratio
Net income
Smallholders

ABSTRACT

Tropical agroforestry systems provide a number of ecosystem services that might help sustain the production of multiple crops, improve farmers' livelihoods and conserve biodiversity. A major drawback of agroforestry coffee systems is the perceived lower economic performance compared to high-input monoculture coffee systems, which is driving worldwide intensification practices of coffee systems. However, comprehensive cost-benefit analyses of small-scale coffee plantations are scarce. Consequently, there is a need to improve our understanding of the economic performance of coffee systems under different shade and input management practices. We provide a comprehensive economic analysis of Arabica coffee farming practices where we compare productivity, costs, net income and benefit-cost ratio (BCR) of 162 small-scale, Peruvian coffee plantations under different shade and input management practices along an elevation gradient. By using a cluster analysis, three shade and three input classes (low, medium and high) were defined. We found similar economic performance for all shade classes, but reduced net income and BCR in the High-Input class. More specifically, there was no difference in net income or BCR between low, medium and high shade classes. The High-Input class had significantly lower net income and BCR, mainly due to increased costs of (hired) labour, land, and fertilizer and fungicides; costs which were not fully compensated for by higher coffee yields. Coffee yield decreased with elevation, whereas gate coffee price and quality, as well as shade levels, increased with elevation. Additional revenues from timber could increase farmers' income and overall economic performance of shaded plantations in the future. Our analysis provides evidence that for small-scale coffee production, agroforestry systems perform equally well or better than unshaded plantations with high input levels, reinforcing the theory that good economic performance can coincide with conservation of biodiversity and associated ecosystem services. Additional comprehensive and transparent economic analyses for other geographic regions are needed to be able to draw generalizable conclusions for smallholder coffee farming worldwide. We advise that future economic performance studies simultaneously address the effects of shade and input management on economic performance indicators and take biophysical variation into account.

1. Introduction

Millions of smallholder farmers in the humid tropics depend on tree crops such as cocoa, coffee, oil palm and rubber for their livelihoods (Schroth et al., 2014). In 2011, the annual retail value of coffee was approximately US$ 90 billion, making it the world's most valued tropical export crop (Jaramillo et al., 2011). An estimated 25 million farmers are growing coffee on over 11 million ha in > 60 countries (Waller et al., 2007), predominantly by smallholders who account for approximately 70% of worldwide coffee production (Bacon, 2005). In recent decades, there has been a transformation of coffee farming systems worldwide to more intensified systems by eliminating shade trees, increasing agro-chemical inputs and selecting genotypes (Bosselmann, 2012; Jha et al., 2014; Perfecto et al., 1996). Consequently, a large share of coffee production area worldwide is currently being managed without shade, and only less than a quarter of coffee plantations has multi-layered, diversified shade (Jha et al., 2014; Perfecto et al., 1996). This transformation is driven by the perceived higher economic performance of intensified systems, aiming to increase short term income (Clough et al., 2011; Siebert, 2002). Economic performance indicators such as yield, costs and profitability are important determinants for decision making of small-scale coffee farmers (Bravo-

* Corresponding author at: Copernicus Institute of Sustainable Development, Utrecht University, Heidelberglaan 2, 3584, CS, Utrecht, The Netherlands.
E-mail addresses: R.E.Jezeer@uu.nl (R.E. Jezeer), M.J.FerreiraDosSantos@uu.nl (M.J. Santos), rene.boot@tropenbos.org (R.G.A. Boot), H.M.Junginger@uu.nl (M. Junginger), P.A.Verweij@uu.nl (P.A. Verweij).

https://doi.org/10.1016/j.agsy.2018.01.014
Received 8 July 2017; Received in revised form 17 January 2018; Accepted 17 January 2018

Monroy et al., 2016). This intensification trend, however, appears to come at the expense of long-term maintenance of ecosystem services relevant for agricultural production (Foley et al., 2011), as intensified farming systems are known to cause environmental problems, such as loss of biodiversity and increased soil erosion (Perfecto and Vandermeer, 2015).

Fluctuating (global) market prices and increased incidence of pest and disease are putting pressure on smallholder coffee farmers, and climate change is expected to exacerbate their vulnerability (Morton, 2007). In the face of current and future challenges, it is important to identify farming practices that meet both economic and environmental goals while being resilient to current and future changes. Tropical agroforestry systems have been proposed as farming systems which can reconcile economic and environmental goals (e.g., Schroth et al., 2004; Steffan-Dewenter et al., 2007). Ample research has shown that agroforestry systems can sustain high biodiversity levels (e.g., De Beenhouwer et al., 2013). The shade trees planted with coffee can provide other important ecosystem services such as enhanced soil fertility (Tscharntke et al., 2011) and stabilized microclimate (Lin, 2007), which are expected to reduce the vulnerability of farms to climate change (Perfecto and Vandermeer, 2015). However, because agroforestry is perceived to have lower economic performance, it is questionable whether it decreases farmers' vulnerability in face of fluctuating market prices.

In a recent review article on economic performance of shaded coffee and cocoa systems, we concluded that the general perception of lower economic performance of agroforestry systems is often based on incomplete economic analyses (Jezeer et al., 2017). Firstly, coffee yield is often used as the sole indicator of economic performance. Multiple studies have shown a negative relation between coffee yield and shade (Jaramillo-Botero et al., 2010; Vaast et al., 2006), yet this assumption is challenged by several recent studies showing that shade had no effect on coffee productivity (Cerda et al., 2016; Meylan et al., 2017). Also, despite lower coffee productivity, higher coffee prices due to improved quality or certification premiums have been linked to higher levels of shade (Muschler, 2001; Vaast et al., 2006). Secondly, the costs associated with producing coffee are not always taken into account and it is debated whether these production costs of agroforestry systems are higher than those of more intensified systems (Cerda et al., 2016) or the opposite (Lyngbæk et al., 2001). Thirdly, benefits derived from shade-tree products like fruits and firewood are frequently overlooked, underestimating potential income from agroforestry plantations. The studies that include these benefits show that shade tree products can significantly contribute to farmers' income (Cerda et al., 2014; Gobbi, 2000; Wulan et al., 2008). Overall, outcomes of previous studies suggest that it is important to not only consider coffee yield but also production costs and other revenues to evaluate economic performance because these indicators are likely to influence economic performance. To be able to compare economic performance across studies and draw generalizable lessons, more comprehensive analyses are needed that include multiple economic performance indicators.

The transformation towards more intensified coffee systems (which we define as increased use of input and lower levels of shade) has resulted in a broad spectrum of coffee plantation management practices, ranging from low-input shaded plantations to high-input full-sun plantations. For agroforestry systems, both the forestry (shade tree) and the agricultural components (e.g., input use, pruning or weeding practices) are expected to affect the productivity and economic performance of the coffee plantation and studies should reflect both simultaneously. A recent study by Cerda et al. (2016) observed an interaction between shade and input management, confirming the need to include both dimensions in comprehensive economic analyses. Additionally, it is important to take specific biophysical conditions into account, which may have a large effect on coffee productivity, bean quality and the management/productivity relation, as the coffee crop is very sensitive to changes in for example temperature, precipitation and insolation (Avelino et al., 2006; Perfecto and Vandermeer, 2015). Comparing the effect of shade and input management on performance of coffee plantations without looking into the biophysical conditions may therefore result in an incomplete or incorrect picture. In general, we expect coffee management practices to be adjusted to variation in biophysical conditions, which will in turn affect economic performance.

We aim to address the following research questions: (i) what is the economic performance of small scale coffee systems under different shade and input levels? and (ii) what are the options to enhance the economic performance of coffee agroforestry systems? We hypothesize that the benefits of high shade low input systems are at least similar to unshaded, high input coffee plantations. To this regard, we analyse the economic performance of Peruvian coffee farming practices in the department of San Martín, which is one of the major coffee producing regions of the country (Valqui et al., 2015). Here we compare productivity, costs, net income and benefit-cost ratio of small-scale coffee plantations and link this to shade and input management practices. The information compiled in this study can be useful to enhance the economic performance of smallholder coffee agroforestry systems, especially in the face of current and future challenges posed on smallholder coffee farmers worldwide.

2. Methods

2.1. Study region

The study was conducted in the department of San Martín, Peru, distributed over an area of approximately 2000 km^2 with an average altitude of 1066 m (Fig. 1a; 673–1497 m). Most plantations (n = 143) were situated in the provinces of Moyobamba and Rioja, which together form the 'Alto Mayo', a tropical highland with an average altitude of 1101 m (range 850–1497 m). The average rainfall is 1512 mm per year, the mean temperature 22.8 °C. The remaining 19 plantations were situated in the lowland province of Picota, with an average altitude of 861 m (range 673–1001 m.). The nearest weather station lies approximately 20 km from each of these plantations at an altitude of 218 m and reports a mean temperature of 26.5 °C and a mean annual rainfall of 937 mm. The dry season occurs from May to September (Gobierno Regional de San Martín, 2008).

2.2. Sampling and surveying method

Household surveys were conducted with 162 coffee to characterise coffee management practices both on shade management (e.g. canopy closure, tree species richness) and on input management (e.g. application of fertilizer and pesticides), and used these to classify coffee systems in terms of shade and input. Plantations were selected to cover the range of shade and input intensity found in the study area, from full sun monoculture coffee to multi-layered shaded plantations, and from high agro-chemical input, use of organic inputs or without inputs. We chose coffee plantations older than three years and producing coffee berries with marketable beans, which were owned by smallholder farmers. Plantation elevation was measured with a GPS (Garmin GPS 62 s).

We performed household surveys twice; the first time in 2014 and the second time in 2016. This was necessary because the sample from 2014 did not include information on coffee bean quality and thus we collected additional information on 2016 (see below and Fig. S1 for hierarchy of collected data). On both cases we performed household surveys using a semi-structured questionnaire and we collected data on (i) farm characteristics (e.g., size (ha), age (y)), (ii) shade tree species and approximate density (2014; trees ha^{-1}), (iii) harvested coffee yield (2010–2016; kg ha^{-1} y^{-1}), (iv) costs of inputs, labour and land (2014; € ha^{-1} y^{-1}), (v) coffee price (2010–2016; € kg^{-1}), (vi) coffee quality of dry green beans (2014–2016; at the farm gate, local scale from 0 to 100), and (vii) benefits derived from other products (firewood, fruit, livestock; 2014; € ha^{-1} y^{-1}). Data for coffee yield, price and quality for