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Productivity and profitability of robusta coffee agroforestry systems in central Uganda

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Abstract

To contribute to understanding the socio-economic impact of shade trees and the returns fromrobusta coffee farming systems, this study compared the financial profitability of shaded coffee fields which are dependent on nutrient cycling to sustain production (traditional system) and shaded coffee fields where compost manure are applied, under small-scale farmer conditions. It also analysed the contribution of shade trees to the overall profitability of robusta coffee farming in central Uganda. The study revealed that shaded coffee yielded substantial returns from shade tree products,amounting to 53.3 and 42.5 % of the gross annual income in traditional and compost coffee options respectively. Although the mean coffee productivity per acre from coffee fields with compost manure (748 kg acre^{-1} yr^{-1}) and traditional low input (486 kg acre^{-1} yr^{-1}) were significantly different (p-value < 0.05), the difference in net present values was small due to the higher annual maintenance costs in the compost option. The discounted cash flow at 10% real discount rate indicated that the net present values of the traditional and compost options were (US$4927 acre^{-1}) and (US$5607 acre^{-1}) respectively, considering exclusive use of family labour. Profitability of the coffee agroforestry system can be significantly improved by increasing coffee stocking density from the current average (340 coffee trees acre^{-1}) to the recommended stocking density of 450 coffee trees acre^{-1} and by farmers providing own manure instead of buying.

Key words: Management, shade, trees

Introduction

Coffee still contributes between 20–30% of Uganda's foreign exchange earnings, despite government efforts to diversify the economy. The coffee industry employs about 1.2 million households at production level and over 5 million people through coffee production related activities (UCDA, 2008). Robusta coffee is grown in the low altitude areas of Central, Eastern, Western and South western Uganda within 900 – 1200 metres above sea level. Coffee in Uganda is mainly grown by smallholders with an average coffee farm size of 0.6 hectares (UCDA, 2002; Okecho *et al*., 2004). In the 2009/2010 crop-year, Uganda exported two million bags of robusta coffee worth US$ 164 million. It is a major cash cropto the Ugandan economy, contributing about 17% to the country's foreign exchange earnings (Baffes, 2006).

Typically, robusta coffee is grown under retained indigenous and planted trees, which diversify products from the coffee agroforestry system (Isabirye *et al*., 2008). Previous studies have reported 4–6 m^3 ha^{-1} year^{-1} of merchantable timber from commercial species such as *Cordia alliodora* in cocoa agroforests in Central America (IFOAM, 1996). Shade trees also suppress weed growth and provide wind breaks in addition to ecological services such as water catchment and nitrogen fixation (Beer, 1987; Beer *et al*., 1998; Lyngbæk *et al*., 2001). Whereas, the socio-economic benefits of shade trees are fairly well known, their economic value and contribution to the profitability of the coffee agroforestry system is not well documented.

The reduction in coffee productivity in Uganda has partly been attributed to inappropriate land use and soil management practices. Interventions to remedy the above situation have among others included addition of external nutrients to the shaded coffee system (UCDA, 2008).Whereas, some farmers are still using the traditional low-input shaded coffee system, which is entirely dependent on nutrient cycling to sustain production, others have adopted the application of compost manure to the shaded coffee system (UCDA, 2008). Although,the application of external nutrient inputs is expected to produce higher coffee yields (Babbar, 1993; Rice and Ward, 1996), it is also associated with higher variable costs. According to Lyngbæk (2000), reliance on purchased inputs creates serious economic risks, particularly for small and medium scale producers, due to high variable costs and unstable world market prices for coffee. Economic data on these trade-offs under small-scale farmer conditions in Uganda are not well documented.

Therefore, to contribute to the understanding of the socio-economic impact of shade trees in coffee and the financial feasibility of compost manure application in the shaded coffee agroforestry system, this study investigated the following research questions:

Is the productivity and financial profitability of shaded coffee fields which are dependent on nutrient cycling to sustain production (traditional system) different from shaded coffee fields where compost manureis applied, under small-scale farmer conditions. What is the contribution of shade trees to farmers' livelihood and the overall profitability of robusta coffee agroforestry systemin central Uganda?

Materials and methods

Study area

The study was conducted in Kimenyedde, Kasawo and Kyampisi sub-counties in Mukono district, locatedin central Uganda (Figure 1). The district covers an area of 14,241 km^2 of which 9,648 km^2 is open water and swamps (FD, 2002). The study area falls within the Lake Victoria crescent agro-ecological zone with comparatively small variations in humidity and wind throughout the year. The rainfall pattern is bi-modal with two peaks during March to May and September to December. The mean annual rainfall ranges between 1400 – 1600 mm but may be as high as 1600 – 2000 mm in areas close to the lakes and forest reserves (NEMA, 2001).

The area economy is heavily dependent on the coffee – banana farming system characterised by intercropping coffee with shade trees and in some cases food crops such as matooke, cassava and potatoes supplemented by small-scale animal husbandry. Although, most farmers exclusively use family labour, a significant number use a combination of family and hired labour. Hired labour is normally used for land preparation, initial planting, harvesting and weeding. Farmers normally sell dry unprocessed coffee, locally known as Kiboko, to village middlemen for processing and subsequent delivery to larger export companies.

Farmer selection and data collection

Three sub-counties were selected for the study due to the predominance of robusta coffee growing and availability of coffee farmers' list provided by the national union of coffee agribusinesses and farm enterprises (NUCAFE). Focus group discussions were conducted with coffee farmers to characterise robusta coffee farming. The discussions provided information about the typical coffee management regimes, market price of outputs and inputs and functions of shade trees. A disproportionate stratified sample of 60 and

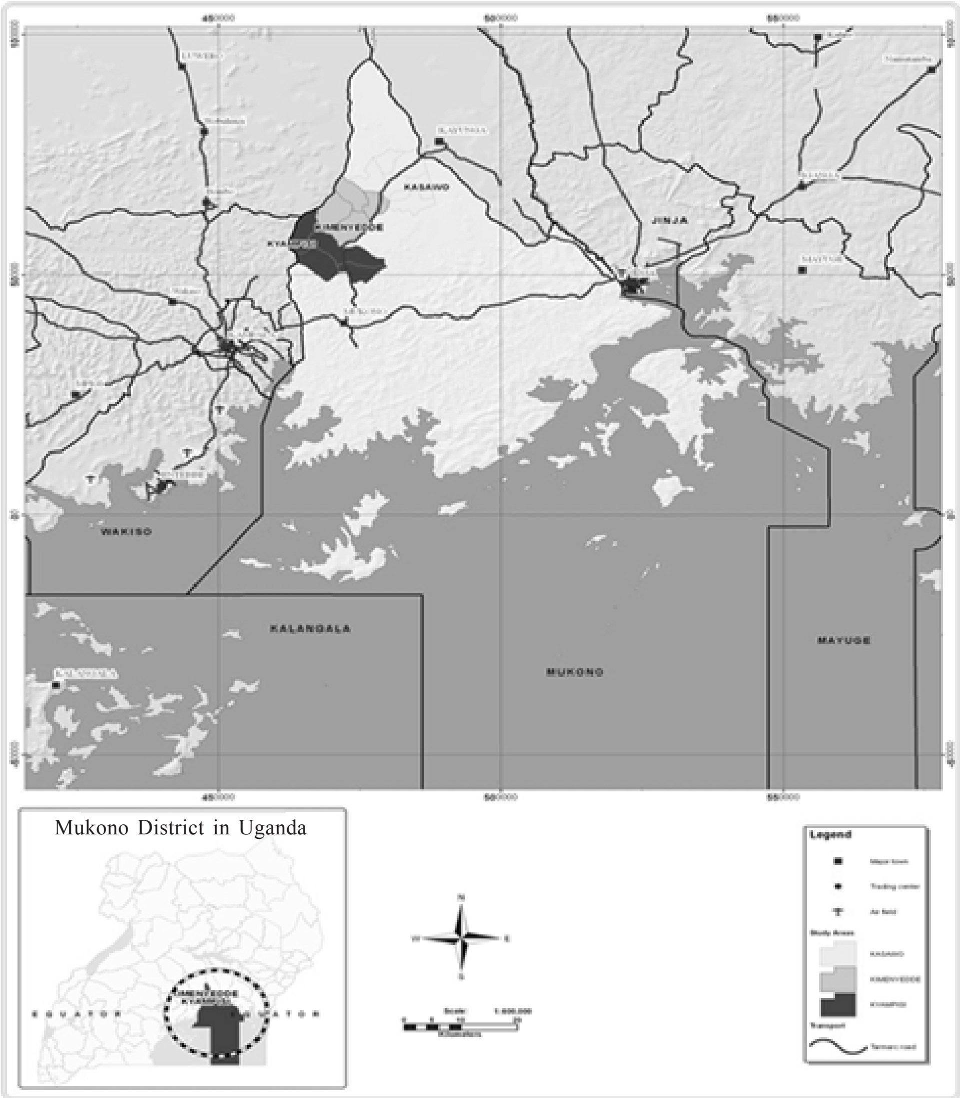

Figure 1. Location of the study sites in Mukono district, Uganda.

20 coffee fields using compost manure (mainly cow dung) and traditional (no external nutrient input), respectively, were randomly selected from the three sub-counties. A coffee farmers' list provided by NUCAFE was used to select farmers in the two categories. Whenever a selected farmer could not provide useful information, a farmer in the same category was selected among the neighbouring households.

Using questionnaire interviews, data on coffee yields and farm inputs, management regimes, labour requirements, farm-gate prices and other socio-economic characteristics were collected. The quantity of coffee harvested in the last two seasons,weekly firewood usage (head loads) from each coffee garden and quantity of manure (number of cow dung trucks or wheel burrows) applied per season were recorded as reported by the farmers. Following each interview, the acreage of each farmer's coffee plot was measured using a global positioning system and the number of coffee bushes within counted. Shade trees in the plot with dbhe" 5 cm were identified and enumerated. The number of fruits on each *Persia americana* (Avocado), *Artocarpus heterophylus* (Jack fruit), *Carica papaya* (pawpaw) and *Mangifera indica* (mango) tree in the fruiting season were counted. These were the most economically important fruit species on coffee farms.

Data analysis

The average annual quantities of coffee, shade trees, firewood, and fruits harvested per acre and the average annual costs per acrewere computed for each management regime. The coffee productivity of the compost and traditional options was compared using the t-test. Farm outputs were valued using farm-gate prices and average annual quantities harvested per acre. Although, firewood and fruits are generally home consumed, they have market value and they were included in the cash flow analysis. The market price of firewood was derived from a local market survey.

The real discount rate was determined by applying the equation:

Nominal discount rate = real discount rate + Inflation rate

The market interest rate at the time of data collection was 22% and the inflation was 12%. Consequently, a cash flow analysis was conducted at a real discount rate of 10% over a 40 year rotation, using 2010 constant prices (Gittinger, 1982). A financial analysis was conducted to capture returns to the farmers from a private view point. The profitability indicators (Table 1) were benefit-cost (B/C) ratio and net present value (NPV) (Bagamba *et al*., 1998; Bright, 2001; Obiri *et al*., 2007).

A 40 year rotation was used in the discounted cash flow because it is the productive lifetime of a coffee tree (UCDA, 2008). Shade trees were categorised into commercial timber species and non-timber shade tree species and their residual value computed using average farm-gate price of standing harvestable tree and average number of standing trees per acre. This was based on the fact that there is a substantial difference between the residual value of commercial timber species and other shade tree species.

To ease analysis, the residual value of shade trees was assumed to be evenly spread throughout the rotation. Production in the base year was assumed to represent the rest of the rotation (40 years). The cost of tools and equipment was not considered because most farmers used small hand tools for many other farm based activities. The analysis assumed exclusive use of family labour as observed among most farmers. However, sensitivity to use of hired labour at the market rate, 30% reduction of coffee productivity and full coffee stocking densitywere examined. Hired labour costs and inputs considered include coffee seedlings, fertilizer application (compost), land preparation, initial planting, weeding and harvesting. Mean labour usage, percentage distribution of variable costs and frequency distribution of shade trees were computed.

Table 1. Indicators used in financial analysis

Profitability indicator	Formula	Decision criteria
B/C Ratio	$\frac{\sum B_t}{(1+p)^t} \div \frac{\sum C_t}{(1+p)^t}$	BCR ≥ 1
NPV	$\sum_{t=0}^{t=n} \frac{B_t - C_t}{(1+p)^t}$	NPV ≥ 0

B = Benefit; C = Cost; t = Production Period (Years); p = Discount Rate; n = Rotation length in years.

Results and discussion

Coffee farming outputs

A t-test showed that the mean coffee productivity per acre from coffee fields with compost manure (748 kg $acre^{-1}$ yr^{-1}) and traditional low input (486 kg $acre^{-1}yr^{-1}$) weresignificantly different (p-value < 0.05). On per plant basis, the average annual coffee (Kiboko) yield from traditional low input and compost coffee fields was 1.43 and 2.2 kg $tree^{-1}$ respectively, with an average stocking density of 340 coffee trees $acre^{-1}$.

According to UCDA (2008), these figures are much lower than the expected annual productivity per plantunder medium management (2.7 – 5 kg Kiboko per tree) and recommended stocking density of 450 coffee trees $acrea^{-1}$. Farmers complained that coffee wilt disease and coffee stem borers were key contributors to reduced coffee productivity in this area. Previous studies have also indicated that the high incidence of coffee wilt disease and coffee stem borer reduce coffee productivity (Okecho *et al*., 2004; UCDA, 2008).

The UCDA 2003/2004 annual report indicated that by 2003 the CWD had infected 45 per cent of the original robusta coffee trees, equivalent to an annual production loss of 53,400 tonnes (UCDA, 2003). The report also showed that the infection rate in Mukono district was as high as 67.2%.The only effective measure against coffee wilt disease is to uproot and burn the infected tree and replace it with a new disease-free plant (Bolwig and You, 2007; UCDA, 2008). However, replanting rates have been low, leading to a substantial decline in stocking rate and productivity.

A total of 3719 shade trees were enumerated in 80 coffee gardens comprising 42 species. *Ficus natalensis, Albizia chinensis, Artocarpus heterophylus, Markhamia lutea, Persia Americana, Albizia coriaria, Measopsis eminii* and *Mangifera indica* were among the most abundant shade tree species. Fruit tree species (10.4 trees $acre^{-1}$), commercial timber species (5 trees $acre^{-1}$) and other shade trees (21.6 trees $acre^{-1}$), provided fuelwood, fruits and timber to farmers.

Focus group discussions indicated that although shade trees were multipurpose, most had a primary purpose. Categorisation of shade trees according to primary purpose indicated that shade trees for soil fertility maintenance and fruit trees accounted for 66% of trees in coffee fields (Figure 2).

Shaded coffee yielded substantial returns from shade tree products, more especially fuelwood and fruits (avocado, jack fruit, mango and pawpaw) to compensate for the low coffee yields (Figure 3). Whereas, shade tree products provided home consumed production in the majority of farmers' households, they sometimes provided income (home consumed production and cash income) amounting to 53.3 and 42.5 % of the gross annual income in traditional and compost coffee options respectively. These results show that shade trees contributed significantly to household income and may limit the risk of coffee failure by providing supplementary home consumption products. The unstable coffee prices on the world market (Figure 4), make the extra income from shade tree products more important.

Coffee farming inputs and labour usage

Mean labour usage in the two management regimes was highest for manual weeding (36.3 man-days $acre^{-1}$ $season^{-1}$) and coffee harvesting (10.1 man-days $acre^{-1}$ $season^{-1}$). While 74% of farmers exclusively used family labour, 24% combined family labour with hired labour. Costing labour and farming inputs at the going market rate indicated that, annual maintenance costs were higher in the compost option (US$ 158 $acre^{-1}$ yr^{-1}) than in the traditional low input option (US$ 80.88 $acre^{-1}$ yr^{-1}) mainly due to the additional cost of manuring (Figure 5). The predominant costs were labour for manual weeding, fertilization (cow dung) and harvesting. Apart from farmers who practiced small-scale animal husbandry, other farmers bought compost manure from animal farmers.

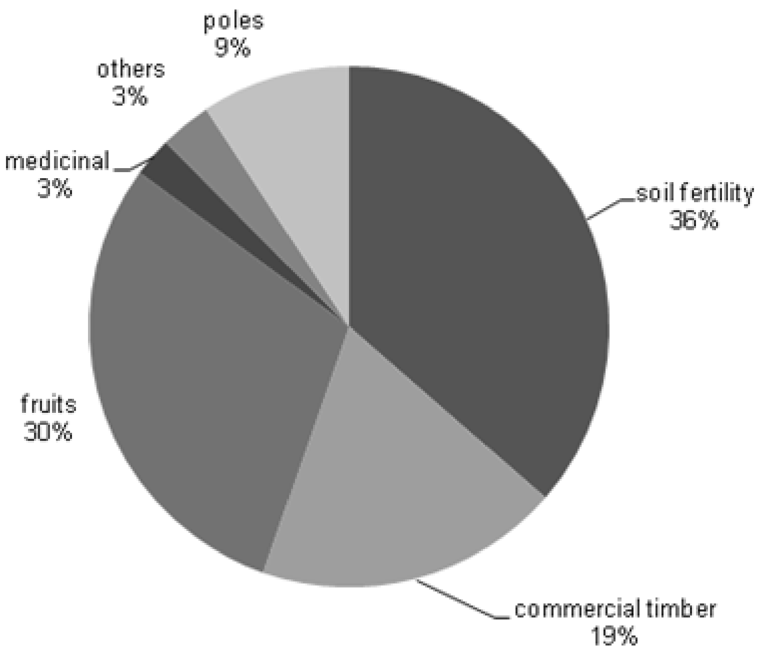

Figure 2. Primary purpose of shade trees in coffee fields.

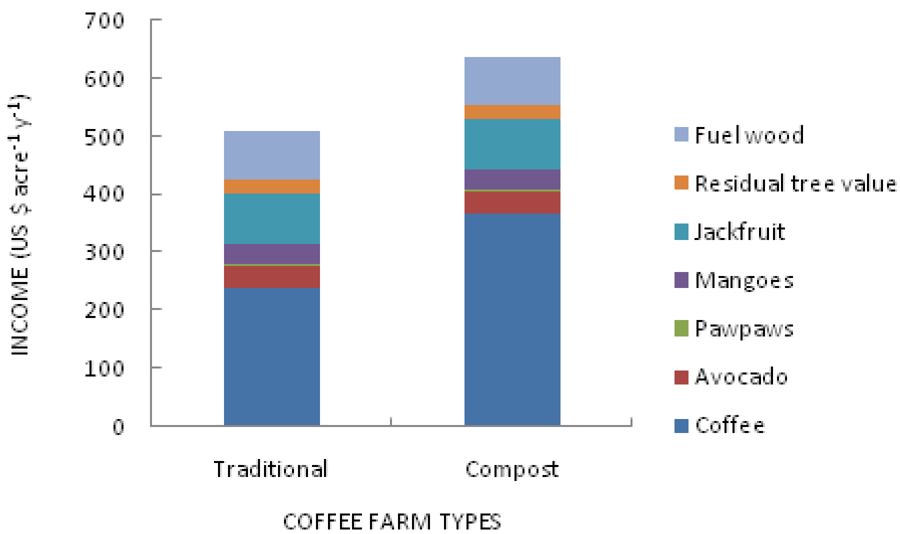

Figure 3. Annual income from shaded coffee farming.

Financial analysis

The discounted cash flow indicated that the NPV and B/C of the two coffee management options are positive at 10% real discount rate considering exclusive use of family labour (Table 2). Overall, financial indicators show low profitability of shaded coffee farming in this area, which may be attributed to low coffee productivity. The small difference in NPVs indicates that the compost option is slightly more profitable than the traditional option under the conditions analysed.

Although the difference, shown earlier, in coffee (Kiboko) productivity from the two

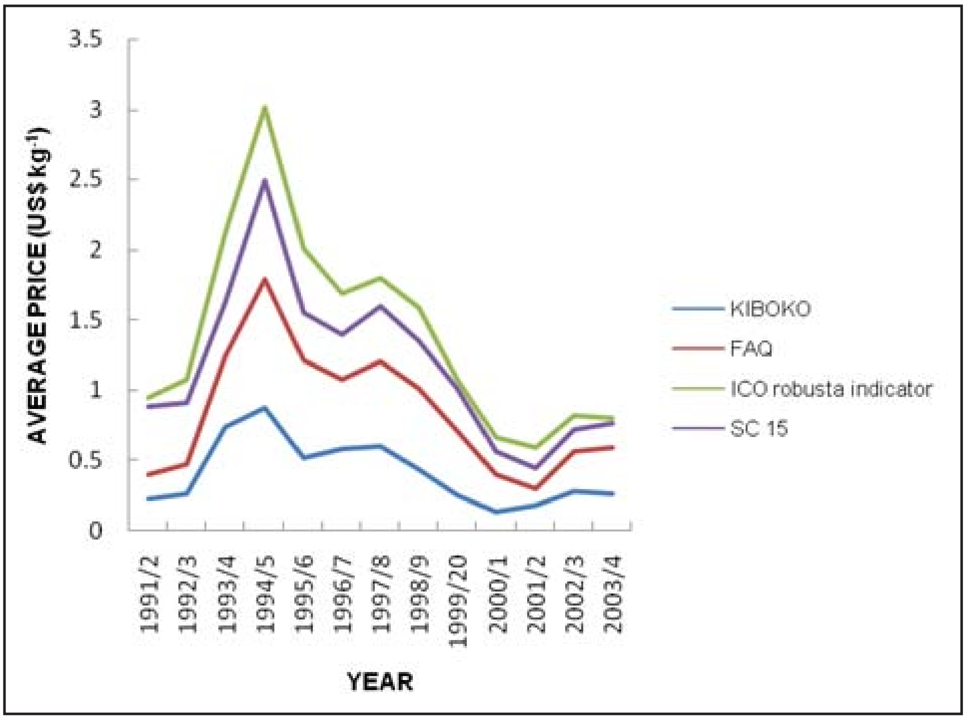

Figure 4. Trends of October – September robusta coffee price averages (Source: Uganda Coffee Development Authority).The ICO price indicators are daily averages obtained by the International Coffee Organisation (ICO), Kiboko refers to dry unprocessed coffee, FAQ refers to fair average quality and represents price paid by exporters to the FAQ traders, SC 15 refers to screen 1500 and represents the price received by exporters.

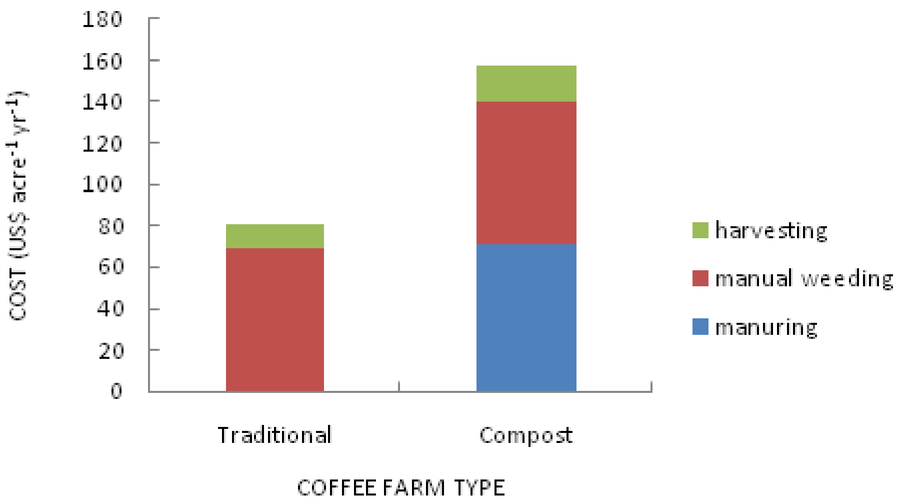

Figure 5. Annual maintenance costs for shaded robusta coffee using hired labour.

Table 2. Summary cash flow for shaded coffee

Profitability indicator	Traditional	Compost
Shaded coffee using family labour		
NPV (US$ acre^{-1})	4927	5607
B/C ratio	75.4	9.7
Sensitivity of coffee profitability		
Hired labour		
NPV (US$acre^{-1})	4136	4637
B/C ratio	5.8	3.8
30% productivityreduction		
NPV (US$acre^{-1})	4228	4531
B/C ratio	64.8	8
Full coffee stocking density		
NPV (US$acre^{-1})	5682	6767
B/C ratio	86.8	11.5

(1 US$ = Ug. Shillings 2040 in June 2010)

management regimes was statistically significant, the difference in profitability indicators was small. This may be attributed to the higher annual maintenance costs in the compost option, mainly contributed by manuring (Figure 5). The cost of cow dung, which was used by most farmers in the compost option is likely to continue raising due to increasing demand from alternative crops. Farmers complained that coffee husks, which were previously used for manuring coffee gardens have already become unaffordable due to competition from alternative uses.

Sensitivity analysis

The cashflow was assessed for sensitivity to 30% reduction of coffee productivity, use of hired labourand full coffee stocking density (recommended at 450 coffee trees acre^{-1}) while holding other factors constant (Table 2). Sensitivity to use of hired labour and 30% reduction of coffee productivity indicated that the two options would still be minimally profitable.

NPVs fell across the board while the fall of B/C ratio wasbigger in the traditional than the compost option. Finally, increasing coffee stocking density from the current average (340 coffee trees acre^{-1}) to the recommended stocking density of 450 coffee trees acre^{-1} significantly improved the NPV and B/C ratio. This indicates the impact of low coffee stocking density on the overall coffee profitability.

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