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Profitability analysis and determinants of fruit tree based agroforestry system in Wondo District, Ethiopia

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Fruit-tree based agroforestry represents a more environmentally friendly system, the economic returns and adoption determinants of which have only been modestly studied to date. This study investigated the determinants of practicing fruit-tree based agroforestry and the associated costs incurred and returns earned by practitioners. It contrasted the economic performance of agroforestry based systems versus monocropping systems using economic performance indicators at the household level in Wondo District. Data were collected from 149 selected households through structured interviews, focus group discussions, key informant interviews, market assessments as well as field observation. Variables including nearness to the main road, farming experience, labor, landsize and income significantly affected the practice of fruit tree based agroforestry system. Attention is needed in the design of policies and strategies for promoting the fruit-tree based agroforestry system which is more attractive financially, in addition to being labor saving and less risky investment than the monocropping systems.

Key words: Agroforestry, annual equivalent value, benefit cost ratio, cost benefit analysis, net present value.

INTRODUCTION

In the past, monocropping systems were considered to be the most desirable agricultural development since high production under such systems was presumed to solve the problem of food shortages (Tesfaye, 2005). Recently, concerns have developed on the long-term sustainability and environmental consequences of the environmentally destructive practice of intensive monoculture. Because of its various positive contributions, emphasis has been given promoting agroforestry as a viable land use particularly in developing countries (Rasul and Thapa, 2002).

Agroforestry involves the cultivation and use of trees in farming systems and is a practical and low-cost means of implementing many forms of integrated land management, especially for small-scale producers (Leakey, 2010). Agroforestry is found to be one of the appropriate means of achieving sustainable production without causing any environmental destruction (Padmavathy and Poyyamoli, 2013). According to Dhyani et al. (2009) agroforestry is a key path to prosperity for millions of farm families, leading to extra income, employment generation, greater food and nutritional security and meeting other basic human needs in a sustainable manner. In addition to satisfying basic human

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needs, agroforestry has positive impacts on the conservation of the natural resource base and in the protection of the environment (Ajayi et al., 2005). Ultimately, agroforestry can significantly contribute for the achievement of the MDGs; Goal 1 (eradicating extreme poverty and hunger) and Goal 7 (ensuring environmental sustainability) on the same piece of land (Weidner et al., 2011).

Agroforestry is an age-old practice in Ethiopian farming systems. The practice differs in different agro-ecological zones mainly driven by farmers' strategy for maximizing production and maintaining livelihood options with a limited resource such as land. For instance, in Sidama, the main agroforestry practices include (i) tree–enset–coffee, (ii) tree–enset (iii) Eucalyptus woodlot (iv) scattered/parkland trees on maize (v) boundary planting, and (vi) scattered trees on grazing fields (Zebene and Agren, 2007). In Gedeo area, three basic agroforestry systems are practiced: trees agroforestry system, enset-coffee-trees agroforestry system and coffee-fruit crops-trees agroforestry system (SLUF, 2006). However, in addition to the aged traditional practices new agroforestry technologies are being introduced in different areas. Intercropping of fruit trees with other perennials in Wondo area is one such example.

While agroforestry has made tremendous strides in recent years, many challenges remain in terms of its wider application (SWF, 2005) and its success largely depends upon how it is accepted by farmers (Dwivedi et al., 2007). Simply, the wider acceptance of agroforestry practices depends on the potential economic benefits it generates to farmers (Neupane and Thapa, 2001). However, studies to assess the economic benefits of agroforestry are rather limited, although the extent to promote this technology critically depends on the size and nature of the benefits (Otsuki, 2010). Especially in Ethiopia, despite the tremendous economic and ecological benefits of multi-strata agroforestry land-uses, no systematic efforts have been made to document and improve the practice (SLUF, 2006). This was the basis for undertaking this study.

The objectives of this study were:

i. To estimate the production costs involved and the tangible benefits obtained by farm households,
ii. To analyze and compare the profitability of the fruit tree based agroforestry system and the monocropping systems, and
iii. To identify factors that influence the practice of fruit tree based agroforestry by farm households in the study area.

MATERIALS AND METHODS

Study area

The study was conducted in Wondo District which is located about 267 km away from Addis Ababa between 38^0 04' 04" - 39^0 46' 08" East longitude and 6^0 12' 29" - 7^0 42' 55" North latitude. The landscape of the study area varies with an altitude ranging between 1700 and 2300 m.a.s.l. The rainfall distribution of the study area is bi-modal where short rain falls during spring and the major rain comes in summer and stays for the first two months of autumn season. The annual temperature and rainfall range between 17 to 19°C and 700 to 1400 mm, respectively.

Data collection

Wondo District was selected purposively based on the presence of fruit-tree based agroforestry systems. From the district, two Kebeles were selected based on the presence of fruit production and ease of accessibility. Several rules-of-thumbs were suggested for determining the minimum number of households required to conduct logistic regression analyses. In this study, the rule-of-thumb that N ≥ 50 + 8 m was adopted, where N is the minimum required number of households and m is explanatory variables (Green, 1991) to limit the size of sampled households for the interview. The explanatory variables were ten. Thus, the minimum sample size was 130. For this study a total sample of 149 individuals was selected and interviewed. Stratified sampling was employed to identify farmers as practitioners of the fruit-tree based agroforestry system and non practitioners (those who practice the monocropping system).

Both primary and secondary data were collected for the purpose of this study. Primary data were collected through key informant interviews, structured questionnaire, focus group discussions, field observation and market assessment. Individuals who have lived in the area for a long time, active and knowledgeable of their localities were selected as key informants (six individuals in each kebele) by adapting the snow-ball method and one-on-one interviews were conducted with the selected key informants to know the history of land use practice and introduction of fruit-trees in the area. For focus group discussions, individuals who have good experience in fruit production were selected to discuss specific issues related to the purpose of the study by forming small groups (members of 5-6) with a homogenous composition and members sharing similar background and experience on the issues under study.

Data analysis

To meet the objectives of the study, both cost benefit analysis and econometric analysis were employed. The data collected were analyzed using Stata 11 and Excel 2007. In the cost benefit analysis (CBA) economic performance indicators such as net present value (NPV), benefit cost ratio (BCR) and annual equivalent value (AEV) were calculated to address the first two objectives. The mathematical procedure for each of the economic performance evaluation parameters is displayed in Table 1.

Econometric model was used to analyze the factors that influence the adoption of the fruit-tree based agroforestry system. The logit model was used because it is computationally easier to use and leads itself to a meaningful interpretation than the other types such as probit and tobit (Gujarati, 1995). The logistic distribution function for practicing the fruit-tree based agroforestry system can be specified as (Hosmer and Lemeshew, 1989):

$$P_i = \frac{1}{1+e^{-Z_i}} = \frac{e^Z}{1+e^Z} \quad (1)$$

Where P_i is the probability of practicing the fruit-tree based agroforestry system for the i^{th} farmer and it ranges from 0-1. P is the observed response of the i^{th} farmer (that is, the binary variable, P =

Table 1. Equations of economic performance indicators with critical min values.

Financial indicator	Computation	Critical min value
Net present value	$NPV=\sum_{i=1}^{t}\frac{Bt}{(1+r)^t}-\sum_{i=0}^{t}\frac{Ct}{(1+r)^t}$	NPV>0
Benefit cost ratio	$BCR=\sum_{i=1}^{t}\frac{Bt}{(1+r)^t}\Big/\sum_{i=0}^{t}\frac{Ct}{(1+r)^t}$	BCR>1
Annual equivalent value	$AEV=NPV/\sum_{t=1}^{n}\frac{1}{(1+i)^t}$	

Where t = time in number of years (1, 2,… n), r = discounting rate, B_t = total revenue earned from sale of the outputs in year t, Ct = total cost incurred from the different activities at the time of production in year t.

1 for a practitioner, P = 0 for a non practitioner) and Z_i is a function of *m* explanatory variables (X_i) which is expressed as:

$$Z_i=\beta_0+\beta_1X_1+\beta_2X_2+---+\beta_mX_m \quad (2)$$

Where β_0 is the intercept and β_i are the slope parameters in the model. The slope tells how the log-odds in favor of being practitioner of the fruit-tree based agroforestry system as independent variables change.

If P_i is the probability of occurrence of an event, then (1 - P_i), the probability of non occurrence event will be (Gujarati, 2004):

$$1-P_i=\frac{1}{1+e^{Z_i}} \quad (3)$$

Then, P_i/ (1-P_i) are simply the odds ratio in favor of occurrence of the event - the ratio of probability of occurrence of an event to the probability of non-occurrence of an event will be specified as:

$$\frac{P_i}{1-P_i}=\frac{1+e^{Z_i}}{1+e^{-Z_i}}=e^{Z_i} \quad (4)$$

And

$$\frac{P_i}{1-P_i}=\frac{1+e^{Z_i}}{1+e^{-Z_i}}=e^{\beta_0+\sum_{i=1}^{m}\beta_i X_i} \quad (5)$$

Z_i - is a function of m- explanatory variables (X_i) which is also expressed by taking natural log in both sides of Equation (4):

$$Ln\left[\frac{P_i}{1-P_i}\right]=Ln\left[e^{\beta_0+\sum_{i=1}^{m}\beta_i X_i}\right]=e^{Z_i} \quad (6)$$

If the disturbance term Ui is taken into account, the logit model becomes:

$$Z_i=\beta_0+\sum\beta_i X_i+U_i \quad (7)$$

RESULTS

Demographic and socio-economic characteristics of households

Among the total sampled respondents, 83.22% were male headed households and 16.78% were female headed households. The average family size of the respondents was 6.94. The mean age of the respondents was about 43.53 years. About 28.77% of the respondents were unable to read and write whereas 71.23% of the respondents had attended from primary school up to college at the time of survey. The average educational attainment of the respondents was 4.16 years.

On the average, total land holding in the area was 0.43 ha (Table 2) representing land shortage is a basic problem that resulted in small scale production. The average number of livestock in the area was small and it was about 2.18 tlu (tropical livestock unit). The main problems in the area were shortage of grazing lands and insufficient health care service. 70.33% of non practitioners used irrigated agriculture. However, only 47.27% of practitioners used irrigated agriculture. The major components of the agroforestry system were avocado, banana, papaya, coffee and enset.

Economic performance evaluation of the two land use systems

The NPV measures the present value of the streams of net benefits from any land use system. In order for the land use system to be acceptable, the NPV must be greater than zero (that is, positive). Note that the life span of the whole practice is 25 years. So the costs and benefits are the sum of the whole life of each practice. Since the net present values of mutually exclusive projects with different lives cannot be compared, we

Table 2. Household characteristic and land holding (ha) of the sampled respondents.

Household characteristic	Family size	Age (year)	Education (Year)	Total land holding (ha)
Minimum	2	20	0	0.2
Maximum	11	75	12	2
Mean	6.94	43.53	4.16	0.43

replicated the projects till they have the same life (or) convert the net present values into annuities. A discount rate of 10% was used.

Results of the cost benefit analysis (Table 3) revealed that the NPV of fruit-tree based agroforestry system was found to be about one and half times higher than the NPV of sugarcane, more than two times higher than the NPV of the sequential monocrop of tomato with maize, and nearly four times higher than the NPV of the sequential monocrop of potato with maize, respectively. The BCR of fruit-tree based agroforestry system was also found to be 1.41 times higher than the BCR of sugarcane monocrop, 1.81 times higher than the BCR of the sequential monocrop of tomato with maize, and 2.38 times higher than the BCR of the sequential monocrop of potato with maize, respectively.

The annual equivalent value (AEV) for the fruit-tree based agroforestry system indicated that the expected annual income of the fruit-tree based agroforestry system was 80,600.28 ETB per annum, whereas the AEV for sugarcane monocrop was 52,089.97 ETB per annum, AEV for the sequential monocrop of tomato with maize was 36,445.68 ETB per annum, and AEV for the sequential monocrop of potato with maize was 20,625.17 ETB per annum.

The sensitivity of NPVs was examined in both benefits and costs structures of the model. At the best case scenario (increase in price/yield and simultaneous decline in discount rate and wage), the monocropping systems were more favored than the fruit-tree based agroforestry system. Whereas, at the worst case scenario (decline in price/yield and simultaneous rise in labor and discount rate), the agroforestry-based system was highly favored than the monocropping systems. The result of the sensitivity analysis is presented in Appendix 1.

Determinants of fruit tree based agroforestry practice

Binary logistic regression was run to identify factors affecting practice of FTBAFS (Table 4). The Goodness of Fit test showed that the overall model fits reasonably well as indicated by a Wald Chi-square value of 39.72 with 10 degrees of freedom with a probability value of over 0.0000. Five variables were significant at the 10% probability level. These variables were size of land holding (landsize), farming experience (experie), nearness to the main road (road) , total income of the household (income), and family labor (famlabor).

Consistent with the prior expectation nearness to the main road was found to be negatively associated with agroforestry practice. The odd ratio of 0.02 indicated that, other factors held constant, the likelihood of a household in favor of practicing the fruit-tree based agroforestry system increases by a factor of 0.02 over those who are practicing monocropping land use system. Farming experience was found to have a positive effect at less than 1% significance level on the adoption of fruit-tree based agroforestry system. The experience of the farmers in practicing the modern agroforestry system is attributed to practicing the traditional agroforestry system. The odd ratio of 1.21 indicated that, other factors held constant, the likelihood of a household in favor practicing the fruit tree based agroforestry system increases by a factor of 1.21 over those who are practicing the monocrop land use. Contrary to the prior expectation, family labor was negatively associated with the practice of fruit-tree based agroforestry system at less than 5% significance level. The odds ratio showed that, other variables held constant, the probability of practicing the fruit-tree based agroforestry system will decrease by 0.573 than for those who practice the monocropping systems.

Total land size influenced the probability of adopting fruit-tree based agroforestry system at less than 10% significance level. The odds ratio for land size indicated that, other variables held constant, the odds of practicing the fruit based agroforestry system will increase by 3.24 when compared to those who do not practice it. In line with the prior expectation, income is positively associated with the adoption of fruit-tree based agroforestry system at less than 10% significance level. The odds ratio 1.05 indicated that, other variables held constant, the probability of the household to practice the fruit-tree based agroforestry system will increase by a factor of 1.05 when compared to those who practice monocropping systems.

DISCUSSION

Economic performance evaluation

The results from the three economic performance indicators showed that the fruit-tree based agroforestry system has the highest NPV, BCR and expected annual

Table 3. Results of NPV, BCR and AEV per ha (Ethiopian Birr (ETB)).

Financial indicator	Agroforestry land use	Mono crop land use		
	FTBAFS	Sugarcane	Tomato + maize	Potato + maize
NPV	731,608.35	472,820.76	330,817.59	187,214.76
BCR	3.43	2.43	1.90	1.44
AEV	80,600.28	52,089.97	36,445.68	20,625.17

1USD = 17.80 ETB.

Table 4. The maximum likelihood estimates of the binary logit model for FTBAFS.

E/variables	Coefficients	Std. Err.	Significance (p value)	Odds ratio
landsize	1.177	0.697	0.092	3.243*
tlu	-0.070	0.140	0.617	0.932
experie	0.188	0.056	0.001	1.207***
educ	0.027	0.108	0.805	1.027
road	-3.932	0.797	0.000	0.0196***
market	0.0206	0.063	0.745	1.021
income	0.049	0.027	0.069	1.051*
offfarm	0.236	0.588	0.688	0.789
famlabor	-0.557	0.226	0.014	0.573**
gender	-0.317	0.776	0.683	0.729
_cons	4.204	1.903	0.027	

Wald chi2(10) = 39.72; N = 149; Prob > chi2 = 0.0000; Pseudo R2 = 0.5955; Log pseudo likelihood = -38.72857; *, **, and *** represents statistical significance at 10%, 5% and 1%, respectively.

income (AEV) followed by monocrop of sugarcane, sequential monocrop of tomato with maize, and sequential monocrop of potato with maize, respectively. Therefore, this result revealed that the agroforestry land use is the best land use practice with the highest financial return than that of the monocrop land use.

In line with this, a study conducted in Vietnam by Kham and Thuy (1999) revealed that AFSI (forest trees + fruit trees + annual crops) is the most profitable system with a net present value (NPV) of $5,950 and an annualized income of $874. Another study conducted in Sri Lanka on economic feasibility and biological productivity of coconut-based agroforestry revealed that the NPV of agroforestry was about 4-5 times greater than that of the monocrop at different discount rates, indicating that investment in mixed farming is more beneficial than the adoption of monocropping (Peiris et al., 2003). In addition, a finding in Bangladesh in the case of multi-strata agroforestry and traditional monocropping agriculture revealed that agroforestry was substantially more profitable in terms of net present value (NPV), benefit-cost-ratio (B/C), internal return rate (IRR) and annual net cash rate (ANCR) than the traditional system (Rahman et al., 2007).

Accordingly, Muhammad et al. (2011) also confirmed that in agroforestry, the combination of trees with the annual crops increases the overall farm income of per unit land area of farmland and reduces the risks and broadens the sphere of alternatives. Similarly the finding of Neupane and Thapa (2001) who studied the impact of agroforestry intervention on farm income under the subsistence farming system in Nepal, revealed that the mean annual net return of farming 'with' agroforestry was estimated to be $1582/ha compared to $804/ha 'without' agroforestry intervention.

Factors influencing the practice of FTBAFS

In this study, variables that showed significant differences for the practice of fruit tree based agroforestry practice were nearness to the main road, farming experience, family labor, total household income and total land holding.

Nearness to the main road was found to be negatively associated with agroforestry practice. Therefore, those residing far away from the main road have fewer tendencies to practice the agroforestry land use system as compared to those who reside nearby the main road. The nearer to the main road, the better would be the access to market and information so that the better would be the rate of adoption (practicing).

Farming experience was another variable found to be positively associated with agroforestry practice . In line with this finding, a study conducted in western Sudan by Gibreel and Bauer (2007) found positive effect of farming experience on gum agro-forestry system adoption at 1% level of significance. Another finding by Nkamleu and Manyong (2005) on factors affecting the adoption of agroforestry practices by farmers in Cameroon revealed that farmers' experience positively and significantly influences the adoption of improved fallow, suggesting that the higher the level of experience, the greater the likelihood of farmers using improved fallow.

In this study, family labor negatively affected agroforestry adoption, suggesting that monocropping systems are labor intensive farming system than the agroforestry-based system. In line with this result, a study on factor affecting farmers land use options in gum-belt of western Sudan revealed that total working days is found to be negatively associated with adoption decision (Gibreel and Bauer, 2007). However, a contrasting finding by Thangata and Alavalapati (2003) who studied on agroforestry adoption in southern Malawi revealed that a positive relationship between agroforestry adoption and the number of people in the household who contribute to farm work. Another contrasting finding by Nkamleu and Manyong (2005) also revealed that household family size is positively and significantly related to farmers' adoption of agroforestry implying that larger families with increased labor supply are more likely to adopt the technologies than smaller households.

As an important variable, total land holding was positively associated with the practice of fruit tree based agroforestry system. This finding complies with the finding by Siddig (2008) who studied the adoption determinant factors in Sudan and in the finding it is revealed that the total area of owned land ranked as an important significant determinant of the respondents' innovativeness. In the same study, the positive relation between land holding and adoption is justified as since one of the main constraints of agroforestry adoption is the perception that trees compete with agricultural crops for land particularly when the size of holding is small, this perception will not hold true when the size of the farmers holding is large enough to accommodate both agricultural crops and trees (Siddig, 2008).

Income is another important variable that positively affected the practice of fruit tree based agroforestry system. This result complies with the finding of Kham and Thuy (1999) which revealed that income of the household is a very important factor that affects the adoption decision of farmers in Vietnam. Thus, the higher the income of the farmer, the greater is the probability of adoption.

CONCLUSIONS AND POLICY IMPLICATIONS

Agroforestry land use, the combination of fruit trees with perennials like Enset and Coffee, generated the highest economic profit than the crops cultivated in the monocrop land use system. It is economically more attractively profitable, labor saving and less risky investment with a diversified income sources than the monocropping systems. However, the practice of fruit tree based agroforestry system was influenced by a number of factors. Total land holding, family labor, farming experience, nearness to main road, and gross annual income significantly affected the practice of fruit tree based agroforestry system. Therefore, differences in the above factors should be considered in promoting the fruit tree based agroforestry.

Based on the findings, the following recommendations are offered:

i. The economic performance evaluation has shown that the fruit-tree based agroforestry system is financially more attractive than that of the different crop components in the monocropping systems. Hence, the fruit-tree based agroforestry should be promoted by smallholder farmers in the study area and nearby localities,
ii. It was found that the agroforestry practice is more sensitive to high cost of capital (discount rate). So, it would be better to provide improved varieties of perennials with short maturity period to counteract the effect of higher discount rate,
iii. Since only the marketable benefits were evaluated in this study, further study is needed to estimate the total economic value of the fruit-tree based agroforestry system including the environmental functions served by the system.

Conflict of Interest

The authors have not declared any conflict of interest.

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Appendix 1. Results of sensitivity analysis.

Change of key variable	FTBAFS (%)	Sugarcane (%)	Tomato + maize (%)	Potato + maize (%)
Price increase (10%)	114.11	116.61	120.75	132.62
Price decrease (10%)	85.89	82.59	78.51	67.46
Wage increase (10%)	98.70	98.47	96.56	94.82
Discount rate increase (10%)	89.37	91.67	92.71	92.7
Best case scenario (p↑,w↓, i↓)	129.29	129.21	134.48	149.22
Worst case scenario (p↓, w↑, i↑)	75.50	74.91	69.58	57.7