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Profitability and Economic Efficacy of Tamarind (*Tamarindus indica L.*) Production: A Case of Green Money in the Drylands of Northern Uganda

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Abstract: Indigenous fruit tree species have since time immemorial been used as an alternative source of food and nutrition for many people especially in the drylands during droughts when there is food shortage. A better knowledge of the economic viability of *Tamarindus indica* production is critical for the improved management of this indigenous tree in the north-eastern belt of Uganda. Sustainability of this management will depend on the resources' tangible benefits. This study makes an attempt to compare the net benefits and costs from *T. indica* in the open woodland and that from the cropland. Production and household surveys were carried out in Kamuli and Kaliro districts from July 2004 to February 2005. Costs and revenues of *T. indica* production were collected from local cottage firms trading in the product. Net benefits from open woodlands and croplands were determined using the Net Present Value criterion. The estimated mean productions were 127 kg/ha/yr from the open woodland areas and 84 kg/ha/yr for cropland. A significant difference ($p<0.05$) was observed between per tree mean *T. indica* yield from open woodland and cropland sites. The average fodder harvest from open woodland was 2660 kg/ha/yr. The financial NPVs were Ush. 1,791,000 ha^{-1} from *T. indica* products in open woodland and Ush. 1,343,400 ha^{-1} for cropland areas ($r = 0.0842$). These values were larger by Ush 981,400 ha^{-1} and by Ushs. 450,800 ha^{-1}, than the sum of NPV from farm crops and crop residuals of the two sites, respectively. Exporting of *T. indica* juice could generate foreign exchange of Ushs. 60 ha^{-1} and Ush 42 ha^{-1} from *T. indica* in open woodlands and cropland sites, respectively. Rural households earn 74% of their annual total revenue as wage for collecting *T. indica* fruits. Sensitivity analysis showed that managing *T. indica* in open woodlands always generates a higher NPV than when left as croplands. Therefore, managing the *T. indica* stands as open woodlands is a competitive land-use alternative and provides more net benefits than both the croplands and open woodlands.

Key words: Cost, financial analysis, open woodland, revenue, NPV, Uganda

INTRODUCTION

In Africa, peoples livelihoods revolve around direct dependence on productivity of the land. However, in many instances the ability of the land to support livelihoods has long been eroded by varying degrees of land degradation caused by overgrazing, over-cultivation, drought, deforestation and other causes linked to acute poverty. Soil productivity in many places has long been lost and previously fertile farmlands have already become so badly damaged that they are in a desert-like condition. This has made land degradation one of the most serious social, economic and environmental problems confronting humanity today with direct dire consequences to the livelihoods of the poor.

In Uganda, a large proportion of the country is covered by semi-arid landscape which is increasingly under threat from desertification as more land gets degraded and more arid due to various factors, including climatic variations and human activities. The effect of further degradation of these already fragile dryland areas is causing serious consequences on the livelihoods of millions of its inhabitants, with some being forced to abandon them altogether.

Tamarind is a multi-purpose tree belonging to the Fabaceae family (Caesalpinioideae sub-family). It is indigenous to tropical Africa and India, though currently distributed throughout the tropical countries. It is an important tree with multiple products that support the livelihoods of many rural people (Gunasena and Hughes,

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2000; ICRAF-ECA, 2005). The species is found both on farms and in the wild. The trees on farm were initially in the wild but after clearing land for farming, they were retained as boundary demarcations, contours or scattered on the cropland. Some tree species date back as 100 years and they are on farms and in the wild (ICRAF-ECA, 2005). Tamarind occurs widely throughout tropical Africa, where it is frequently planted as a shade tree. Mandeira wood is used for many purposes including making furniture, mortars, well construction and other products because they are hard and durable; *T. indica* leaves and fruits are essential for medicinal uses to cure diseases. Tarimand is used as a raw material for the manufacture of several industrial products, such as *T. indica* kernel powder, pectins, tartaric acid, *T. indica* Juice Concetrate (TJC), *T. indica* juice, jam, syrup, candy, champoy and many other uses (Gunasena and Hughes, 2000).

Tamarind tree, a valuable resource for semi-arid part of Africa, occurs on a large land surface area, regenerates well and is traditionally protected during clearing and favored by farmers (Maghembe and Seyani, 1991). Ecologically, it combines well with cereal crops. It is an important economic commodity, both locally, where it is used as a cooking fat, ointment, cosmetic and for soap manufacture and internationally, where it is exported to food, cosmetic and pharmaceutical industries. Tamarind populations have been subject to increased pressure from agriculture, drought and parasitism in recent years and may decline further in coming years (Gunasena and Hughes, 2000). Relatively little research has been undertaken on this species since the 1940s and 1950s, hence a demand-driven approach is needed to re-vitalize the *T. indica* fruit market (Meghwal, 1997; Coronel, 1991).

Recently, efforts have been taking place to address the problem by closing degraded forests to assist natural regeneration and rehabilitation. However, the sustain ability of this management practice will largely depend on the net economic benefits to the rural households. In addition, sustainable forest management and planning requires data on both production and economic value of the resource. Therefore, there is a need for information on marketing and economic value of *T. Indica* in the drylands of Uganda. Secondly, although *T. indica* is an important economic commodity, both locally, where it is used as a cooking fat, ointment, cosmetic and for soap manufacture and internationally, where it is exported to food, cosmetic and pharmaceutical industries. Tarimand tree populations have been subject to increased pressure from agriculture, drought and parasitism in recent years and may decline further in coming years (Coronel, 1991). Relatively little research has been undertaken on the economic value of this species. The objective of this study, was to determine the costs and benefits associated with management of *T. indica* tree in a open woodland as compared cropland areas. However, the potential of *T.Indica* in socio-economic, domestic and industrial use is being underlooked with limited silvicultural management just like many other Indigenous Fruit Tree Species (IFTS) in Uganda. This is mainly due to the conventional forestry approach in the colonial era that put much emphasis on the management of soft wood plantations and exotic species while ignoring indigenous tree species. Consequently, not much work has been done on the utilization, improvement, domestication, commercialization and conservation of *T. indica* tree species. (ICRAF-ECA, 2005; FAO, 2004). There is therefore need, to compare the net benefits from *T. indica* in the open woodland and the croplands in Uganda.

MATERIALS AND METHODS

Study area: The study was carried out in Kaliro and Kamuli districts, eastern Uganda. The open woodland (site I) is located in Kaliro and the cropland (site II) is in Kamuli. The physical outputs of site I and II to rural households are *T. indica* fruits and fodder. The inputs are land and labour. To estimate fruit yield per hectare of each site, 16 permanent square sample plots of 2500 m^2 each were selected per site. A list of *T. indica* trees with a minimum diameter of 10 cm at breast height (dbh) was established for each plot and used as sampling frame. The trees were grouped into three classes of equal diameter range taking their maximum and minimum diameter into account and a total of 96 random sample trees were selected. Each tree in the sample was marked with a permanent metallic plate bearing an identification number and was mapped for later reference. The distribution of diameter at breast height (dbh), tree height (measured with a telescopic meter) and crown diameter of sampled trees were recorded. The average diameter of the 96 trees was 25.5 cm (s = 8.0), average height 6.5 m (s = 1.3), average crown diameter 5.5 m (s = 1.6).

Collecting *T. indica* fruits from sample trees was undertaken in 11 and 10 rounds, respectively, during the harvesting season between December 2003 and June 2004 within an average interval of 18 days. The collected fruits were weighed, dried, graded and weighed again for each sample tree, where six grades were used: T1, T2, T3 and T4-special are export standards, while T4 and T5 are sold on the domestic market. The grading was based on size, color and purity and conducted at the Jinja town.

For each site, the yield of every sample tree was extrapolated to the estimated yield of all trees in that particular diameter class. The overall mean per tree and plot was then estimated from these per-diameter-class values. Total yield per hectare was then estimated by multiplying the estimated mean value by the determined number of *T. indica* trees per hectare.

To estimate the annual fodder production per hectare of the open woodland site, 3 square sub-plots with each 1 m^2 size were randomly sampled from each of the 16 observation plots. From each of these sub-plots, fodder were cut and weighed. The annual fodder harvest per hectare was then estimated by expanding the sample plot values. We corrected the resulting values to account for the tree basal area (7.52m^2 ha^{-1}) due to the fact the area was not entirely covered with fodder.

In order to estimate the input and output quantities of crop production, a questionnaire was developed for farm household interviews near the study sites. Complete lists of these households were obtained from District Agricultural Officer, Kaliro district. A total of 104 households (30% of the population) were selected using systematic random sampling.

All fruits produced by sample trees were harvested manually. Fruits of individual trees were counted and the fruit harvest per tree was weighed with and without the outer pulp. Average fruit production per tree over the harvesting season was projected at the field level on the basis of average tree densities, tree productivity and field size obtained in the sample of fields. The yield of juice in dry kernels used in this study was 20%.

The base year (2002/2003) prices of *T. indica* fruit and the costs of processing and trading each quality grade of the product were obtained from Ministry of Trade, Industry and Tourism. The price per 100 kg of fruits was considered as wage for collecting mature fruits from the forest.

Market prices of major crops and livestock were obtained from the District Agricultural Office. In the study area, the market prices for fodder and agricultural crops were obtained through interviews with local people in the study area. In the case, where the *T. indica* were located in a open woodland, the foregone alternative wood consumption was calculated assuming a total wood volume of 22 m^3 ha^{-1} for site I and 21.3 m^3 ha^{-1} for site II. The land-use fee paid by farmers was calculated based on the ratio of the government revenues from rural land-use fee (Ushs. 22,600 million) to total cultivated agricultural cropland (2.6 million hectares) (MAAIF, 1999).

Data analysis: Cost-Benefit Analysis (CBA) is a widely used project assessment method that quantifies the monetary value of all project consequences to the society (Boardman *et al*., 2001). Furthermore, it is also used for the economic evaluation of the positive and negative effects of different land uses. In our study, we conducted a financial analysis of costs and benefits by taking the viewpoint of a private enterprise using market prices for

Table 1: Price index and interest rates in Uganda, 1998/99 to 2004/05

	Price index	Lending interest rate
1998/99	98.2	10.5-12
1999/00	102.8	10.5-13
2000/01	109.2	10.5-13.5
2001/02	103.5	10.5-15
2002/03	96	7.5-13
2004/05	110.5	7.5-13

Source: MFEPD, 2005/06

valuing project advantages and disadvantages. We discounted benefits and costs to make project effects comparable that occur at different points in time. In the case, where project calculations are based on nominal values, i.e. referring to a nominal prices including inflation, a nominal discount rate i has to be applied. In contrast, if real prices are considered, i.e. referring to a constant base year level, the real discount rate r has to be determined. This interest rate can be calculated by applying Eq. 1, where i is the nominal interest rate, 1t is the inflation rate (Boardmann *et al*., 2001):

$$r = \frac{i - \prod}{1 + \prod} \tag{1}$$

For general investment analysis, it is advisable to use the current Consumer Price Index (CPI) as an estimate for inflation. However, this estimate reflects the general development of all consumer prices, which might over-or underestimate the price development of the specific project outputs. However, with regard to this study, there are no specific statistics available; thus, the geometric mean of some general inflation data was used as a proxy and calculated according to Eq. 2 (Jacobs, 1997), where p is the price index and the subscript determines the specific year.

$$\prod = \left[\frac{p2}{p1} x \frac{p3}{p3} x \frac{p_n}{p_{n-1}}\right]^{\frac{1}{n-1}} - 1 \tag{2}$$

We determined an average inflation rate of $\prod \cong 2.4\%$ and a nominal interest rate of 12.5% based on the data given in Table 1. Consequently, the real interest rate r was 9.86%.

Decision criteria: Various investment criteria exist to compare the economic profitability of alternative projects. For our analysis we chose the Net Present Value (NPV), which sums up the discounted annual flow of net benefits according to Eq. 3 (Brent, 1998). In contrast to other criteria such as the Benefit-Cost Ratio and the Internal Rate of Return, NPV is the most reliable criterion because it is not vulnerable to generate ambiguous results.

$$NPV = \sum_{t=0}^{T}\left[(B_t - C_t)(1+r)^{-t}\right] \quad (3)$$

Where:

NPV = Net Present Value (Ush ha^{-1})
Bt = Benefits at time t (Ush ha^{-1})
Ct = Costs at time t (Ush ha^{-1})
r = Real discount rate
t = {0, 1, 2, 2….n} years

Tamarind trees found in Uganda, give up fruits once in a year and start bearing fruit after 15-20 years in the beginning and continues to do so every year for the rest of its life span. However, due to the fact that there were no reliable data available on the productive life of *T. indica* tree, project duration was assumed to be 20 years based on the common harvesting practice in the study area. According to this schedule, collection of mature fruits is conducted during 5 consecutive years, followed by a resting period of 3 years, which is necessary to for the tree to rejuvenate. This cycle repeated twice. Benefits and costs during the resting periods were assumed to be zero.

We used market prices for all inputs. The cost calculation included wages for fruits collectors, the cost of grading and processing of fruits, storage cost and transport cost, collection agents, local government levy charges, overhead expenses and other harvesting costs. Comparison of the open woodland with agricultural crop production was also made by calculating the NPV of croplands of farm households in the study area. Finally, a sensitivity analysis was made to determine the impacts of changes in discount rate, yields and input and output prices on NPV.

RESULTS

Estimated physical outputs and inputs: The production survey on the open woodland and cropland study sites resulted in four export quality grades (T1 to T4-special) and two domestic qualities (T4 and T5) of *T. indica* juice. Table 2 indicates that the mean annual yield of fruit and the different quality grades of juice from open woodland site were larger than the cropland site both at tree and per hectare level. This difference in yields could be attributed to the differences in tree density and management sites.

Table 3 indicates that the major agricultural crops grown by sample farm households were finger millet, sorghum, maize and soybean. These crops covered about 99% of the crop lands in site I and 91 % in site II. There was no significant difference between the average amounts of seed used per hectare of land for all crop types grown and sample households did not use commercial fertilizer. Crop productivity was highest for maize and lowest for finger millet in both sites. Crop residuals equivalent of 1.2 and 1.48 m^3 of fuel wood could be produced from a hectare of cropland in site I and II, respectively. The average market prices of inputs and outputs used in the calculation are shown in Table 3.

Financial analysis of forestry alternatives: Following our base year market conditions with a real discount rate of 9.86%, the NPV was Ushs. 1,791,000 ha^{-1} in site I and Ushs. 1,343,400 ha^{-1} in site II (Table 5). The difference was due to higher financial net returns from both *T. indica* fruits and fodder production in site I. The NPV from *T. indica* fruits accounted for only 4.65 % in each site. The remaining larger shares were attributed to the financial returns from fodder harvesting and free grazing. The

Table 2: Annual fruit and fodder production from *T. indica* tree resources

	Site I		Site II		t-test	
Products	Mean	Standard error	Mean	Standard error	t-test	Sign. (2-tailed)
Trees/plot (N_1=N_2=16)	63.188	6.771	54.688	5.849	0.950	0.350
T. indica fruits (kg $tree^{-1}$) ($n_2 = n_2 = 3$)						
T_1	502.827	43.797	386.486	32.052	2.144	*0.040
T_2	64.139	5.703	49.272	5.174	1.931	0.063
T_3	6.467	1.349	7.175	0.944	-0.430	0.670
T_4 special	1.310	0.577	0.000	0.000	2.269	*0.031
T_4	115.565	11.515	107.977	9.153	0.516	0.610
T_5	171.017	20.683	107.305	16.331	2.418	*0.022
T. indica fruits (kg/ha)	119.261	9.194	108.865	6.604	0.918	0.366
Regular	127.09		84.54			
Export qualities	47.38		35.97			
$G_4 + G_5$	73.36		47.28			
Impurities	6.35		1.29			
Fodder (kg/m2/yr)	0.266	0.012	Free grazing			

n = number of sample trees in a plot, n* = number of sample sub plots in a sample plot, N = Number of sample plots

Table 3: Physical quantities of inputs and outputs of crop production

Input/Outputs	Site I Mean	Site I Standard error	Site II Mean	Site II Standard error	t-test t-test	t-test Sign. (2-tailed)
(a) Input						
Household cropland (ha)	2.485	0.158	1.9491	0.179	2.227	*0.028
	(n = 50)		(n = 54)		(df=102)	
Seed (quintals ha^{-1})						
Finger millet	0.3133	0.035	0.3233	0.026	-0.221	0.825
Sorghum	0.1826	0.022	0.1697	0.022	0.410	0.683
Maize	0.3541	0.038	0.4827	0.128	-0.914	0.364
Soybean	0.2660	0.021	0.2870	0.041	-0.512	0.612
Fertilizer in quintal ha-l	N/A		N/A		N/A	
Cattle (HH^{-1})	2		2			
(b) Output						
Crop (quintal ha^{-1})						
Finger millet	1.3126	0.149	0.7857	0.091	2.825	*0.006
Sorghum	2.7415	0.221	2.9135	0.284	-0.476	0.635
Maize	3.8091	0.721	4.3064	0.549	-0.555	0.581
Soybean	1.3950	0.172	1.4508	0.298	-0.174	0.863
Bean			1.8333	0.647		
Crop residuals for fuel (m^3/ha^{-1})	1.20			1.48		

n= number of sample households, * = mean values of site I and Site II are significantly different, 1 quintal = 100 kg

Table 4: Net present value of *T. indica* fruit open woodland (r = 0.0842)

Product	PVB Site I	PVB Site II	PVC Site I	PVC Site II	NPV Site I	NPV Site II
Export quality	653,800	474,200	437,600	323,200	216,200	151,000
$T_4 + T_5$	392,800	240,800	525,800	329,400	-133,000	-88,600
Fodder harvest	1,707,800	N/A	0	N/A	1,707,800	N/A
Free grazing	N/A	1,281,000	N/A	0	N/A	1,281,000
Total	2,754,400	1,996,000	963,400	652,600	1,791,000	1,343,400

Table 5: Net present value (Ushs ha^{-1}) of forestry alternatives (r = 0.0842)

Product	PVB Site I	PVB Site II	PVC Site I	PVC Site II	NPV Site I	NPV Site II
Timber	171.000	165.600	0	0	171.000	165.600
Farm crops	915.000	991.800	213.600	218.400	701.400	773.400
Crop residuals	108.200	119.200	0	0	108.200	119.200
Total	1.194.200	1.276.600	213.600	218.400	980.600	1,058,200

reason for this was that fruits production generates financial costs whereas fodder harvesting and free grazing involves only free family labour hence variable costs was equivalent to Zero. In addition, the Present Value of Costs per hectare (PVC) for producing T4 + T5 *T. indica* fruits was larger than the respective Present Value of Benefits (PVB) implying a negative financial NPV from these quality grades. With respect to export quality grades, a positive financial NPV was determined that accounted for 13 and 10 % of the total financial NPV of site I and site II, respectively.

Comparison of forestry alternatives and cropping: The financial NPV ha^{-1} from cultivation of the major farm crop grown in the study area (Table 5) was lower than the corresponding NPV from *T. indica* fruit open woodlands in both sites (Table 4). The NPV from the *T. indica* in open woodlands was Ush. 980,600 ha^{-1} higher, which is more than double the sum of NPV from crop and crop residuals of a hectare in the study area. The financial NPV ha^{-1} of *T. indica* from croplands was larger by Ush. 450,800 ha^{-1} than the sum of NPV from the agricultural crops and crop residuals of a hectare of cropland. If the open woodlands were to be converted to cropland the sum of NPV from timber, crop and crop residuals could result in a lesser value than forestry. The financial NPV ha^{-1} of *T. indica* fruit in open woodland was larger by Ush. 810,400 than the sum of NPV from wood, crop and crop residuals of the same open woodland if converted to cropland. This indicates that in addition to the environmental benefits that forests provide, managing the degraded open woodland in the study area could provide higher financial returns than converting the land for agricultural crop production.

Table 6: Net present value of foreign exchange (US\$ ha^{-1}) from *T. indica* fruit open woodland (r = 0.0842)

Export quality *T. indica* fruit	Site I		Site II	
	Annual	NPV	Annual	NPV
T1	30.94	250.23	22.32	152.45
T2	3.56	23.23	1.58	23.01
T3	0.8	2.54	0	0
T4-special	25.08	136.92	18.24	112.36
Total	60.38	412.92	42.14	287.82

Note: USD$ = Ush 1860 for the fiscal year 2004/2005

Table 7: Distribution of revenues from *T. indica* open woodland to factor inputs (Ush ha^{-1})

	Site I		Site II	
Product	Annual	NPV	Annual	NPV
Collectors wage	63,600	449,800	42,200	299,200
Fodder consumption	178,000	1,707,800	133,600	1,281,000
Total households income	241,600	2,157,600	175,800	1,580,200
Profit margin	11,800	83,200	8,800	62,400
Processors and graders (wage)	11,600	81,600	7,800	55,400
Other groups* (Income)	61,000	432,000	42,200	298,000
Revenue from *T. indica* juice	147,800	1,046,400	101,000	715,000
Total revenue	325,800	2,754,400	234,600	1,996,000

* = Transport charger, wages to employees and other expenses in trading *T. indica* juice

Annual foreign exchange revenues of US\$ 60.38 ha^{-1} and US\$ 42.14 ha^{-1} were obtained from the production and export of *T. indica* juice in the open woodlands of site I and II, respectively. About 58 % of the foreign exchange earnings could be assigned to T1 fruits in site I and about 53% in site II (Table 6).

Distribution of income from *T. indica* tree open woodland: This study indicated that the annual revenue per hectare of open woodland from site I was 1.39 times the corresponding revenue from site II (Table 7). The annual revenue from *T. indica* fruit production on a hectare of open woodland accounted for 45 % of the annual total revenue per hectare of open woodland in site I and 43 % in site II. The remaining proportions were generated by fodder harvesting and free grazing, respectively.

Rural households living near the study sites earned all of the revenue from fodder harvesting. This group of the population also gets income in the form of wages for tapping and collecting *T. indica* fruit. These revenues accounted for about 43 and 42% of the total *T. indica* fruit revenue per hectare in site I and site II, respectively. Thus, referring to the total annual revenue per hectare of open woodland, 74% in site I and 75% in site II were earned by rural people near the study sites.

This study indicated that 8% of the annual *T. indica* fruit revenue per hectare was distributed as wages to urban poor women engaged in grading and processing of *T. indica* juice. The profit for a *T. indica* juice trading firm accounted for 8 and 8.7% of the annual *T. indica* fruit revenue per hectare in site I and site II, respectively. The remaining proportion of annual revenue was attributed to other groups of the society that provide their factor input to the production and trading of *T. indica* fruit in the form of services like transport, employees of the trading firm and others.

Sensitivity analysis: The analyses conducted so far assumed constant prices, costs, yields and discount rate. It is desirable to study the impact of changes in these parameters on our results. A change in the real discount rate, which can result due to changes in either the nominal interest rate or inflation rate or both, has clear effect on the financial NPV per hectare of open woodland of both sites. An increase in real discount rate from 9.86 (base case) to 15% can decrease the financial NPVs of each of site I and II by 24.23 %.

The financial NPVs of both sites are highly sensitive to changes in prices of all output (Table 8), total yield, yield of fodder, price of fodder and prices of all inputs and it is less sensitive to changes in price of *T. indica* juice, fruits yield, transport cost and wage for collectors of grew. The change of forest product price showed the most significant effect on financial returns. A 50% reduction in prices of all forest products would result a 76.89 and 74.29 % reductions in financial NPV of open woodlands of site I and II, respectively. Of this reduction in NPV 29.21 and 26.61 % are due to the reduction in market price of *T. indica* fruit and the remaining is due to reaction in price of fodder.

Changes in prices of inputs of *T. indica* fruits production have little effect on NPV per hectare of open woodland mainly due the fact that it is only *T. indica* fruits production that generates financial costs whereas fodder harvesting and/or grazing involves free family

Table 8: Effect of changes in yield and prices on NPV in Ush/ha/yr (r = 0.0842)

	NPV							
Parameter	I	II	I	II	I	II	I	II
Change in parameter	+50%		+20%		-20%		- 50%	
Base year	8955	6717	8955	6717	8955	6717	8955	6717
Prices of all inputs	1,309,400	1,017,200	1,598,400	1,213,000	1,983,600	1,474,000	2,272,600	1,669,800
Wage for collectors	1,193,800	1,701,000	1,283,600	1,881,000	1,403,400	2,015,800	1,493,000	1,493,000
Transport costs	1,705,200	1,284,200	1,756,600	1,319,800	1,825,400	1,367,200	1,876,800	1,402,600
T. indica yield	9163	6874	9038	6780	8872	6655	8747	6561
Price of *T. indica* juice	2,314,200	1,701,000	2,000,400	1,486,400	1,581,800	1,200,400	1,267,800	986,000
Price of fodder	2,645,000	1,984,000	2,132,600	1,599,600	1,449,400	1,087,200	937,000	703,000
Fodder yield	13225	9920	10662	7998	7247	5436	4685	3515
Total yield	13433	10076	10746	8061	7164	5374	4478	3359
Price of all output	3,168,200	2,341,600	2,341,800	1,742,600	1,240,200	944,200	413,800	345,400

labour. As a result, an increase in the wage for collectors of *T. indica* fruits by 20%, for example, will decrease the NPV per hectare of open woodland by only 5.02 % in sites I and by 4.45% in site II. Increase in transport costs by 20% would result in reduction of the NPV by only 1.92 % in site I and 1.76% in site II of the study area. If the prices of all inputs of *T. indica* fruit production increase by 20%, the financial return per hectare of the open woodland will decease by only 10.76 % in site I and 9.71 % in site II.

On the other hand, the reduction of yield of *T. indica* fruit showed very little effect on financial returns of both sites. A 50 % reduction in total yield of the non-wood forests products (fruits and fodder) would result in a proportional reduction in NPVs. However of this change, a reduction in yield of *T. indica* fruit by 50% would result only a 2.3 % of reduction in NPV per hectare of each of the sites, the remaining 46.7% of reduction accounted by the 50% reduction of yield of fodder.

DISCUSSION

This study revealed that managing *T. indica* trees as a open woodland area and as cropland in the study area could provide positive financial Net Present Values. The monetary disadvantage based on forgone wood and crop production was lower than the net benefits from the current use of the open woodland. Moreover, the financial NPV of the *T. indica* fruit in open woodland was larger by Ushs. 447,600 ha^{-1} from that of the cropland.

Similar to Asian countries, in Uganda, *T. indica* trees annually produce 330-500 lbs (110-225 kg) of fruits, of which the pulp may contribute 30-55%, the shells and fibre, 11-30% and the seeds, 33-40% (Meghwal, 1997). The fruit pulp is edible and is popularly used as a spice in some cuisines and is also an important ingredient in sauce. The pulp of a young fruit is very sour and acidic and is most often used as a component of savory dishes. The ripened fruit is sweeter and can be used in desserts and drinks, or as a snack. The ripe fruit of the sweet type is usually eaten fresh, while the fruits of sour types are rich in tataric acids and are used in flavouring soups, making jams, chitneys, sauces, paste and juice. Livestock consume the foliage as fodder especially in the dry season when the tree is still green. Flowers are reported to be a good source of nector which is ideal for honey production.

Young leaves are applied to sores and wounds, or administered as poultice for inflammation of joints to reduce swelling and relieve pain. The pulp, leaves and bark also have medical applications. For example, the leaves have been traditionally used in herbal tea for reducing malaria fever. Due to its medicinal value, *T. indica* is used as a medicine for gastric and digestion problems (ICRAF-ECA, 2005). The leaves are eaten in spices, salads, as vegetables and are used in the drug industry for medicines (FAO, 1995; Nordeide *et al*., 1996). Due to its density and durability, *T. indica* heartwood can be used in making furniture and wood flooring. It is thus used locally for general carpentry, wheels, agricultural tools, mortors and furniture. The extended crown of *T. indica* offers shade giving it a popular reference as ‘rest and consultation’ tree in villages thus acting as a wind break because of its resistance to storms. Tamarind provides good firewood and it also produces excellent charcoal. However, it is not commonly used for charcoal since there are other tree species available as sources (Gunasena and Hughes, 2000). Trees growing on the riverine or the bounder are used as living fences or boundary markers, ornamentals and shade trees, planted along river banks, along avenues and in parks (Meghwal, 1997).

Developing countries often face a shortage of foreign exchange, which might be an obstacle for development. Uganda's economy is characterized by such a situation: the foreign exchange revenues from exports of the country do not cover import expenditures. Improving the quantity and quality of existing export commodities and diversification of exports are important measures to increase export earnings and to reduce the deficits in current account balance. Tamarind fruit is among the products with a high export potential. However, an increasing production of the quantity and quality of this commodity should be based on a sustainable management of these forests. Our results showed that foreign exchange earnings from the open woodland site were higher than that of the cropland site due to an enhanced productivity concerning high export quality grades of *T. indica* juice.

Assuming a current amount of 330,000 ha of *T. indica* fruit open woodland in our project region, a typical five-years tapping cycle with three years of rest and the estimated fruit yield per hectare indicated in (Table 2), the annual potential *T. indica* fruit yield of *T. indica* fruit forests in Uganda could range between 9.4 to 14.1, million kilograms. In terms of foreign exchange, the total *T. indica* fruit forest area could have a potential of generating 4.33 to 5.97 millions of USD/yr through exporting *T. indica* juice, that would represent about 0.9 to 1.24% of the country's total export revenues of 482.7 million USD in 2003/04 (2005).

The study indicated that the biggest share of revenues from the *T. indica* goes to the rural people who are the immediate decision makers in the management of the open woodland. Moreover, since most people in rural areas of Uganda in general and the study site in particular live in poverty, such a land use that favors the distribution of the larger share of income to these members of the society has to be encouraged. Moreover, the income from open woodland in the study area can diversify the economic activity of rural households, thereby reducing risks associated with frequent crop and fodder failures as a result of recurring droughts. These statements hold for both study sites, however, it has to be mentioned that annual income from open woodland was substantially higher in site I. This is due to the difference in the management of the *T. indica* fruit forest in the sites that resulted in higher tree density in site I than site II and as a consequence the yield of *T. indica* juice and fodder in the open woodland site was higher than the yields in the cropland site.

CONCLUSION

The present analysis showed that management of *T. indica* trees as a open woodland has higher net returns than the area cropland for free grazing. This was mainly due to a higher productivity of *T. indica* fruits and fodder production in the open woodland area. The major agricultural crops grown by sample farm households were sorghum, finger millet, maize and Soybean. There was no significant difference between the average amounts of seed used per hectare of land for all crop types grown and sample household did not use commercial fertilizer. Crop productivity was highest for maize and lowest for finger millet in 424 both study sites as depicted in Table 3.

Tamarind fruit production per ha from the open woodland area was 1.5 times higher than the production from the cropland site. Both *T. indica* fruit in open woodlands provide higher net financial returns than the nearby agricultural croplands. The highest share of annual revenue from the open woodlands is earned by rural households in the form of wage for tapping and collecting *T. indica* fruits and using fodder for their livestock. However, the annual income to rural households from the open woodland is higher than the income from the cropland one. The potential foreign exchange earning from open woodland through the production and export of *T. indica* juice is higher for the open woodland area than the cropland area. The positive NPV of *T. indica* juice production from open woodlands and cropland was due to relatively higher market prices and low costs of production of the export quality grades as compared to the domestically sold quality grades that showed a net negative return. This study also showed that the production and trading of *T. indica* juice would be a profitable business to firms who want to engage in exporting the product.

Future research should focus on the conditions for a sustainable management of *T. indica* fruit plantations, which not only has the potential to realize the benefits from fruits and fodder production described above, but also to provide other functions such as reducing soil erosion and environmental degradation. Additionally, rural households and *T. indica* juice trading firms should be made aware of the methods of tapping and collecting *T. indica* fruits in order to improve both the quality of *T. indica* juice and future productive life of the trees. Higher *T. indica* products revenues from open woodland could make rural people more aware of the economic importance of managing forest resources sustainably, including its link to poverty reduction and recurrent drought problems that they are facing.

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