# COST-BENEFIT ANALYSIS OF AGROFORESTRY TECHNOLOGIES IN SEMI-ARID REGIONS OF WEST-POKOT COUNTY, KENYA

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## ABSTRACT

West-Pokot County, Kenya experiences harsh arid and semi-arid climatic conditions associated with high poverty indicators. To alleviate poverty, Non-Governmental Organizations initiated projects to promote agroforestry in order to increase sustainable farm forestry management for food, energy security and wealth creation. However, adoption of agroforestry technologies has been slow in these regions due to scanty information on their profitability. This study determined costs, benefits and benefit-cost ratios (B/C) of agroforestry technologies in West-Pokot with the aim of scaling up of profitable and sustainable agroforestry. Purposive sampling technique was used to select two sub-locations of the county, Lelan and Chepareria. Systematic random sampling technique was used to select 91 and 90 households respectively. Questionnaire based interviews and field observations were used in collecting data. Mann–Whitney *U* test was used for pair wise analysis to determine B/C ratios of agroforestry technologies in Chepareria and Lelan that were significantly different. Boundary tree planting had the highest B/C in Lelan (9.4) and Chepareria (6.88), while scattered trees on farm had the lowest B/C of 0.68 in Lelan and 1.11 in Chepareria. Mann Whitney *U* test indicated that the B/C ratios of agroforestry technologies in Chepareria and Lelan were significantly different ($U$= 210.500, $P < 0.005$). Boundary planting and fodder bank technologies had higher B/C in Lelan as compared to Chepareria. In conclusion, all agroforestry technologies, except scattered trees on farms in Lelan were profitable in West-Pokot as they had a B/C greater than 1.

**Keywords.** Agroforestry, technologies, profitability, cost-benefit, ASALs

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## INTRODUCTION

Arid and semi-arid lands (ASALs) experience harsh climatic conditions with low precipitations, high evapotranspiration rates, high temperatures, unreliable rainfalls and periodic droughts (Muneer, 2008; Mabhuye *et al*., 2015). These conditions are threatening survival of human, livestock and crops in the region (Kyule *et al*., 2015). In Kenya, ASALs occupy about 75% of the national territory, and include parts of West-Pokot County which experience low and unreliable rainfall, ranging from 100 mm to 1200 mm, frequent and high velocity winds, and high temperatures (Mowo *et al*., 2010). These conditions have led to increased food insecurity, reduced fodder availability, fuelwood inaccessibility, soil fertility decline and biodiversity loss (Jama and Zeila, 2005).

To alleviate the problem, non-governmental organizations (NGOs are encouraging adoption of environmental friendly and conservation-conscious strategies such as agroforestry to improve survival (Kiptot *et al*., 2007; Nolet *et al*., 2009; Mowo *et al*., 2010). Agroforestry tree leaves and branches help in filtering and absorbing pollutants, and create cooler environments (FAO, 2013). Agroforestry improves farm biodiversity by creating conducive habitats and provision of shelter to a variety of fauna and flora in agricultural farms (Noble and Dirzo, 1997; Pandyey, 2007). Valuable Agroforestry products including food, fodder, timber, domestic wood supply and woodfuel improve households' economic conditions (Batish *et al*., 2008; FAO, 2013).

Paradoxically, farmers have been reluctant in adopting agroforestry practices to address the above challenges (Mandila *et al*., 2015). This may be due to inadequate and scanty documented evidence that benefits accrued from agroforestry technologies may outweigh the costs incurred by farmers in ASALs.

This study aimed at determining the profitability of various agroforestry technologies and practices in Semi-arid parts of West-Pokot County in Kenya. The specific objectives of the study were to: a) establish the costs incurred at different stages of agroforestry technology establishment, b) estimate the benefits accrued from practicing agroforestry, and c) establish the benefit cost ratio of different agroforestry technologies/ practices. Information generated in this study could be used in developing training manuals to educate farmers in ASALs on the cost incurred, the benefits accrued and the most profitable agroforestry technologies/practices. This will help in up-scaling adoption of profitable agroforestry technologies/practices in conserving the environment and alleviating the negative impacts of harsh climatic conditions in ASAL.

## MATERIALS AND METHODS

### Study area

The study was conducted in Chepareria, and Lelan Sub-locations of West-Pokot County, Kenya. The county lies between $10^0$ 10' N and $30^0$ 40'N, and $34^0$ 50'E and $35^0$ 50'E. Mean annual temperatures in Chepareria and Lelan ranges from 10 °C to 30 °C depending on the altitude. Chepareria is less populated, located at relatively lower altitude and drier than Lelan. The main economic activity in Lelan is mixed farming while in Chepareria is agro-pastoralism.

### Sampling and sample size

Chepareria and Lelan sub-locations were purposively selected based on different economic activities taking place in the two areas. Purposeful sampling has been used by Linger (2014) when selecting the study areas to research on the role of home-garden agroforestry. A total of 91 and 90 households were selected in Lelan and Chepareria respectively through systematic random sampling technique where every 5$^{th}$ household was included in the sample.  Systematic random sampling technique was appropriate as it increases the precision of a sample mean (Raynor and Bay, 1993).The sample size was determined as tabulated by Israel (2012).

### Data collection

Data was collected using field observations and questionnaires. Field research assistants were selected with the help of the area sub-chief and trained on different agroforestry technologies/practices, how to conduct field observations and how to sample participants and administer questionnaires. Field observations were used to identify agroforestry technologies practiced and most common tree species in the study sites. Questionnaires were used to collect information on the adopted technologies, the costs and benefits of agroforestry technologies based on willingness to pay by farmers.

### Discounting

Discounting of benefits and costs were estimated using equation 1, at 8 % - a lower social discounting rate of environmental projects in developing countries (Asian Development Bank, 2013). A lower discounting rate is recommended by Kenya Wildlife Service *et al*. (2011) for projects with benefits accruing in future especially in natural resources, and has the ability to mitigate against individual and commercial short-sightedness in exploiting natural resources.

$$PV=\sum_{i-1}^{n}\frac{Bi}{(1+r)^{n}} \quad \text{.........................................(1)}$$

Where: PV= present value, Bi= benefit or cost in year i, n= number of year evaluation period, r=real discount rate

### Data Analysis

The farmer-level average cost for every activity was computed by adding all the discounted costs incurred by farmers on that particular practice and dividing it by the number of farmers carrying out such activity in their farms (equation 2).

$$Cai=\frac{[\sum_{i-1}^{n}(Ci)]}{n} \quad \text{.......................................... (2)}$$

Where: *Cai*; Average discounted cost of the i$^{th}$ activity,

$\sum_{i=1}^{n} C_i$ Sum of dicounted cost attributed to the i$^{th}$ activity, *n*=Number of farmers undertaking the i$^{th}$ activity.

From the individual costs, the total cost of the k$^{th}$ agroforestry technology was calculated by summing up the average discounted costs of individual activities entailed in that technology.

The farmer-level average discounted benefits from every source of income was obtained by adding all the discounted income from every sampled farmer obtained on that particular source and dividing it by the number of farmers obtaining income from such a source (Equation 3)

$$\textbf{Bai} = \frac{[\sum_{i-1}^{n}(Bi)]}{n} \quad \text{.................................................(3)}$$

Where: Bai; Average discounted benefits from i[th] source

$[\sum_{i-1}^{n}(Bi)]$;the sum of discounted income attributed to the i[th] source of income by the farmers, n=number of farmers obtaining income fro the i[th] source.

From the individual Benefits, the total benefits (income) of the k[th] agroforestry technology were calculated by summing up the average discounted benefits of individual sources from k[th] agroforestry technology (Equation 4).

$$\textbf{Bak} = \boldsymbol{Ba1} + \boldsymbol{Ba2} + \ \dots . + \boldsymbol{Ban} \quad \text{................................(4)}$$

Where: Bak; Average dicounted benefits obtained from k[th] agroforestry technology, *Ba1, Ba2 Ban*; average discounted benefits of the 1[st], 2[nd] and n[th] activities respectively

The benefit cost ratio (B/C) was calculated based on equation5, while the average B/C is as indicated in Equation 6.

$$\textbf{B/C} = \frac{\boldsymbol{discounted\ Benefits}}{\boldsymbol{discounted\ Costs}} \quad \text{.........................................(5)}$$

**Average B/C =** ..............................(6)

Where: $\left(\frac{B}{C}\right)1, \left(\frac{B}{C}\right)2, \left(\frac{B}{C}\right)n$ is the 1[st], 2[nd], and n[th] farmer practicing a particular agroforestry technology

Relative costs and relative benefits were computed for various technologies as percentages of the totals. Mann Whitney *U* test was used for pair wise analysis to determine significant difference in B/C ratios of agroforestry technologies in Chepareria and Lelan. According to Laerd Statistics (2018), Mann Whitney *U* test is used when comparing differences between two groups of independent variables when the dependent variable is either ordinal or continuous data.

## RESULTS

### Costs Analysis at Different Stages of Agroforestry Technology Establishment

Averagely, land preparation, planting materials and damages on other farm components by agroforestry were the costly operations in establishing agroforestry technologies and practices in both Lelan and Chepareria as each account for over 20% of all costs involved (Tables I and II).

TABLE I- COSTS AT DIFFERENT STAGES OF AGROFORESTRY TECHNOLOGY ESTABLISHMENT IN LELAN

| | | **Boundary planting** | | **Woodlot** | | **Home-garden** | | **Scattered trees** | | **Strip planting** | | **Fodder bank** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Item** | **Cost KES)** | **%** | **Cost (Kshs)** | **%** | **Cost (KES)** | **%** | **Cost (KES)** | **%** | **Cost (KES)** | **%** | **Cost (KES)** | **%** | **Mean%** |
| Tools &Equipments | Hand tools | 2,000 | 3.9 | 2,500 | 2.8 | 1,500 | 4.2 | 600 | 4.1 | 5,000 | 9.6 | 7,000 | 13.8 | 6. 4 |
| | Total | 2,000 | 3.9 | 2,500 | 2.8 | 1,500 | 4.2 | 600 | 4.1 | 5,000 | 9.6 | 7,000 | 13.8 | 6. 4 |
| Land preparation | Site Clearing | 500 | 1.0 | 7,400 | 8.2 | 300 | 0.9 | 200 | 1.4 | 3,000 | 5.8 | 1,400 | 2.8 | 3.3 |
| | Land ploughing | 1,200 | 2.3 | 25,000 | 27.6 | 3,270 | 37.4 | 500 | 3.4 | 6,430 | 12.3 | 4,300 | 8.5 | 15.2 |
| | Pitting | 3,200 | 6.2 | 8,500 | 9. 4 | 5,400 | 15.2 | 320 | 2.2 | 4,780 | 9.2 | 3,200 | 6.3 | 8.1 |
| | Totals | 4900 | 9.5 | 40900 | 45.2 | 18970 | 53.5 | 1020 | 7.0 | 14210 | 27.3 | 8900 | 17.6 | 26.6 |
| Planting materials | Seeds/cuttings | - | - | - | - | 2,100 | 5.9 | - | - | 1,420 | 2.7 | 12,400 | 24.4 | 5.5 |
| | Seedlings | 11,400 | 22.0 | 20,900 | 23.0 | 360 | 1.0 | 480 | 3.3 | 8,640 | 16.6 | 1,560 | 3.1 | 11.5 |
| | Sub-total | 11,400 | 22.0 | 20,900 | 23.0 | 2,460 | 6.9 | 480 | 3.3 | 10,060 | 19.3 | 13,960 | 27. 5 | 17.0 |
| | Planting costs | 1,500 | 2.9 | 3,200 | 3.5 | 800 | 2.3 | 300 | 2.0 | 3,500 | 6.7 | 3,700 | 7.3 | 4.1 |
| | Totals | 12,900 | 24.9 | 24,100 | 26. 5 | 3,260 | 9.2 | 780 | 5.3 | 13,560 | 25.7 | 17,660 | 35.3 | 21.7 |
| Maintenance and management | Watering costs | - | - | - | - | 2,000 | 5.6 | - | - | 2,400 | 4.6 | - | - | 2.1 |
| | Weeding | 1,000 | 1.9 | 2,500 | 2.8 | 1,500 | 4.2 | 200 | 1. 4 | 1,680 | 3.2 | 1,300 | 2.6 | 2.3 |
| | Pesticides | - | - | - | - | 700 | 2.0 | - | - | 500 | 1.0 | - | - | 0.5 |
| | Fertilizers/ manure | 1,500 | 2.9 | 2,400 | 2.6 | 1,800 | 5.1 | - | - | 4,200 | 8.1 | 2,870 | 5.7 | 4.1 |
| | Pruning | 300 | 0.6 | 620 | 0.7 | 250 | 0.7 | 450 | 3.1 | 850 | 1.6 | 250 | 0. 5 | 1.2 |
| | Totals | 2800 | 5.4 | 5,520 | 6.1 | 6250 | 17.6 | 650 | 4.5 | 9630 | 18. 5 | 4420 | 6.2 | 10.2 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Harvesting Storage | Harvesting | 8,000 | 15.4 | 9,500 | 10. 5 | 500 | 1.4 | - | - | 1,900 | 3.6 | 2,300 | 4.5 | 5.9 |
| | Storage | - | - | 2,500 | 2.8 | - | - | - | - | 2,500 | 4.8 | 2,100 | 4.1 | 2.0 |
| | Transportation | - | - | - | - | 500 | 1.4 | - | - | 1,000 | 1.9 | - | - | 0.6 |
| | Totals | 8,000 | 15.4 | 12000 | 13.3 | 1,000 | 2.8 | - | - | 5,400 | 10.3 | 4,400 | 8.6 | 8.5 |
| Damage on other components | Damages to crops | 13,500 | 26.0 | 400 | 0.4 | 2,500 | 7.1 | 7,000 | 47.5 | 3,200 | 6.1 | 2,100 | 4.1 | 15.2 |
| | Other damages | 7,800 | 15.0 | 5,300 | 5.8 | 2,000 | 5.6 | 4,680 | 31.8 | 1,200 | 2.30 | 6,300 | 12.4 | 12.1 |
| | Totals | 21300 | 41.0 | 5700 | 6.2 | 4500 | 12.8 | 11680 | 79.3 | 4400 | 29.1 | 8400 | 16. 5 | 27.3 |
| Totals ($Ca_k$) | | 51,900 | 100 | 90,720 | 100.0 | 35,480 | 100.0 | 14,730 | 100 | 52,200 | 1000 | 50,780 | 100 | 100 |

**Comparative Costs among Agroforestry Technologies/**

TABLE II - COSTS AT DIFFERENT STAGES OF AGROFORESTRY TECHNOLOGY ESTABLISHMENT IN CHEPARERIA

| | | **Boundary planting** | | **woodlot** | | **Home-garden** | | **Scattered trees** | | **Strip planting** | | **Fodder bank** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Item** | **Cost (KES)** | **%** | **Cost (KES)** | **%** | **Cost (KES)** | **%** | **Cost (KES)** | **%** | **Cost (KES)** | **%** | **Cost (KES)** | **%** | **Mean %** |
| Tools | Hand tools | 1,500 | 3.2 | 500 | 0.7 | 700 | 2.5 | 800 | 7.3 | 640 | 1.3 | 560 | 1.5 | 2.8 |
| | Totals | 1,500 | 3.2 | 500 | 0.7 | 700 | 2.5 | 800 | 7.3 | 640 | 1.3 | 560 | 1.5 | 2.8 |
| Land preparation | Site Clearing | 1,000 | 2.1 | 300 | 0.4 | 250 | 0.9 | - | - | 4,600 | 9.4 | 1,400 | 3.8 | 2.8 |
| | Land ploughing | 1,400 | 3.0 | 16,000 | 21.3 | 6,430 | 23.3 | - | - | 3,800 | 7.7 | 2,980 | 8.1 | 10.6 |
| | Pitting | 2,200 | 4.7 | 7,000 | 9.3 | 3,250 | 11.8 | - | - | 4,780 | 9.7 | 3,600 | 9.8 | 7.6 |
| | Totals | 4,600 | 9.8 | 23,300 | 31.0 | 9,930 | 36.0 | - | - | 13,180 | 26.8 | 7,980 | 21.7 | 20.8 |
| Planting materials | Seeds/cuttings/stems | - | - | - | - | 1,100 | 4.0 | - | - | 2,310 | 4.7 | 11,050 | 30.1 | 6.5 |
| | Seedlings | 10,600 | 22.4 | 23,100 | 30.8 | 480 | 1.7 | 600 | 5. 5 | 10,900 | 22.2 | 2,060 | 5.6 | 14.7 |
| | Sub-Total | 10,600 | 22.4 | 23,100 | 30.8 | 1580 | 5.7 | 600 | 5. 5 | 13,210 | 26.9 | 13,110 | 35. 7 | 21.2 |
| | Planting costs | 1,800 | 3.8 | 2,350 | 3.1 | 800 | 2.9 | 760 | 6.9 | 4,300 | 8.8 | 3,800 | 10. 4 | 5.9 |
| | Totals | 12, 400 | 26.2 | 25,450 | 33.9 | 2,380 | 9.6 | 1,360 | 12. 4 | 17,510 | 35.7 | 16,910 | 46.1 | 27.1 |
| Maintenance and management | Watering costs | - | - | - | - | 3,500 | 12.7 | - | - | 2,400 | 4.9 | - | - | 2.9 |
| | Weeding | 700 | 1. 5 | 3,400 | 4.5 | 2,000 | 7.2 | - | - | 2,300 | 4.7 | 2,000 | 5.5 | 3.9 |
| | Pesticides | - | - | - | - | 300 | 1.1 | - | - | 200 | 0.4 | - | - | 0.3 |
| | Fertilizers/manure | 2,000 | 4.2 | 1,200 | 1.6 | 1,300 | 4.7 | - | - | 4,200 | 8.6 | 2,870 | 7.8 | 4.5 |
| | Pruning | 800 | 1.7 | 500 | 0.7 | 600 | 2.2 | 300 | 2.7 | 1,070 | 2.2 | - | - | 1.6 |
| | Total | 3,500 | 7. 4 | 5,100 | 6.8 | 7,700 | 27.9 | 300 | 2.7 | 10,170 | 20.8 | 4,870 | 13.3 | 13.2 |
| Harvesting & storage | Harvesting | 5,200 | 11.0 | 11,200 | 14.9 | 700 | 2.5 | - | - | 1,000 | 2.0 | - | - | 5.1 |
| | Storage | 2,000 | 4.2 | 1,200 | 1.6 | - | - | - | - | 2,900 | 5.9 | 2,100 | 5.7 | 2.9 |
| | Transportation | - | - | - | - | 1,500 | 5.4 | - | - | 600 | 1.2 | - | - | 1.1 |
| | Total | 7,200 | 15.2 | 12, 400 | 16. 5 | 2,200 | 7.9 | - | - | 4,500 | 9.1 | 2,100 | 5.7 | 9.1 |
| Damage on other components | Damages to crops | 10,280 | 21.7 | 900 | 1.2 | 1,200 | 4. 4 | 4,300 | 39.2 | 2,100 | 4.3 | 2,100 | 5.7 | 12.8 |
| | Other damages | 7,800 | 16.5 | 7,400 | 9.9 | 3,500 | 12.7 | 4,220 | 38.4 | 1,000 | 2.0 | 2,200 | 5.6 | 14.2 |
| | Total | 18,080 | 38.2 | 8,300 | 11.1 | 4,700 | 17.1 | 8,520 | 77.6 | 3,100 | 6.3 | 4,300 | 11.3 | 27.0 |
| Totals ($Ca_k$ | | 47,280 | 100 | 75,050 | 100 | 27,610 | 100 | 10,980 | 100 | 49,100 | 100 | 36,720 | 100 | 100 |

**Comparative costs among Agoforestry Technologies/ Practices**

Woodlot was the most expensive agroforestry technology in Lelan and Chepareria with its costs accounting for 30.7% and 30.4% of all total costs incurred in establishing identified agroforestry technologies and practices respectively (Table III). Scattered tree planting was the least expensive technology both in Chepareria and Lelan with its costs accounting for 5% and 4.5% of total costs in Lelan and Chepareria respectively (Table III).

**Benefits accruing from practising Agroforestry**

Although agroforestry benefits in terms of wood, non-timber and environmental services are similar across Lelan and Chepareria sub-locations, they differ in terms of percentages. For instance, woodlot technology dominated by *Cupressus lusitanica* and Eucalyptus species contributes 89.1% (Table IV) of timber/poles in Lelan which is slightly higher than 88.5% (Table V) in Chepareria.

**Comparative Benefits among Agroforestry Technologies/Practices**

Boundary planting was the most profitable agroforestry technology in Chepareria and Lelan, accounting for over 35% (Table VI) of accrued benefits from all the identified technologies. However, boundary planting is slightly profitable in Lelan (39.5%) than in Chepareria (36.5%). Contrary, the practice of scattered trees on farms is more profitable in Chepareria (1.4%) than Lelan (0.8%) (Table VI).

**Relative Profitability (B/C Ratio) Among Agroforestry Technologies / Practices**

Overall, all technologies were profitable with B/C ratio > 1 except for scattered trees on farms dominated by *Albizia lebbeck* and Acacia species in Lelan (0.68) (Table VII). Mann Whitney *U* test indicated that the B/C ratios of agroforestry technologies in Chepareria and Lelan were significantly different ($U$= 210.500, $P < 0.005$); meaning the presence of significant differences in the profitability of agroforestry technologies in Chepareria and Lelan sub-locations within West-Pokot. Pairwise analysis indicated that profitability of boundary tree planting and fodder banks differed significantly between the two sub-locations (Chepareria and Lelan) as indicated by alphabet letters in Table VII. The two agroforestry technologies were more profitable in Lelan than in Chepareria. However, profitability of home-garden, woodlot, scattered trees, and alley technologies did not vary significantly between the two sub-locations.

TABLE III - RELATIVE (COMPARATIVE) COSTS AMONG AGROFORESTRY TECHNOLOGIES / PRACTICES

| Agroforestry Technology/Practice | Lelan % | Chepareria % |
|---|---|---|
| Woodlot Technology | 30.7 | 30.4 |
| Strip planting | 17.6 | 19.9 |
| Boundary planting technology | 17.5 | 19.2 |
| Fodder bank technology | 17.2 | 14.9 |
| Home-garden Technology | 12.0 | 11.2 |
| Scattered trees | 5.0 | 4.5 |
| **TOTAL** | **100** | **100** |

TABLE IV -AVERAGE BENEFITS AMONG AGROFORESTRY TECHNOLOGIES/PRACTICES IN LELAN

| | **Boundary planting** | | **Woodlot** | | **Home-garden** | | **Scattered trees** | | **Strip planting** | | **Fodder bank** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Item** | **Income (KES)** | **%** | **Income (KES)** | **%** | **Income (KES)** | **%** | **Income (KES)** | **%** | **Income (shs)** | **%** | **Income (KES)** | **%** |
| Food products | - | - | - | - | 19,700 | 15.2 | - | - | 31,200 | 17.6 | - | - |
| Timber/poles | 56,100 | 11.5 | 248,030 | 89.1 | 4,100 | 3.2 | 1,000 | 10.0 | - | - | - | - |
| Firewood | 3,000 | 0.6 | 2,320 | 0.8 | 9,760 | 7.5 | 700 | 7.0 | 3,150 | 1.8 | 4,600 | 3.0 |
| Charcoal | 4,700 | 1.0 | - | - | 2,500 | 1.9 | 2,500 | 25.0 | - | - | 1,300 | 0.9 |
| Fruits | - | - | - | - | 17,800 | 13.8 | - | - | 25,420 | 14.4 | - | - |
| Fodder | 53,210 | 10.9 | - | - | 4,500 | 3.5 | - | - | 6,730 | 3.8 | 9,520 | 6.2 |
| Medicine | 3,200 | 0.7 | - | - | - | - | 900 | 9.0 | - | - | - | - |
| Milk production | 14,230 | 2.9 | - | - | 16,700 | 12.9 | 2,180 | 21.8 | 8,700 | 4.9 | 24,900 | 16.2 |
| increased soil fertility | 47,920 | 9.8 | - | - | 13,200 | 10.2 | - | - | 24,980 | 14.1 | 19,420 | 12.7 |
| Weed suppression | 21,900 | 4.5 | - | - | - | - | - | - | 5,420 | 3.1 | - | - |
| Improved soil structure | 31,200 | 6.4 | - | - | 9,490 | 7.3 | - | - | 15,630 | 8.8 | 26,520 | 17.3 |
| Soil erosion prevention | 26,510 | 5.4 | 13,100 | 4.7 | 8,640 | 6.7 | 960 | 9.6 | 17,600 | 9.9 | 14,500 | 9.56 |
| Water purification | 23,400 | 4.8 | - | - | - | - | - | - | 3,410 | 1.9 | 19,520 | 12.7 |
| Improved aesthetic | 1,400 | 0.3 | 15,080 | 5.4 | 2,210 | 1.7 | 1,760 | 17.6 | 16,770 | 9.5 | 18,430 | 12.0 |
| Prevention of house damages caused by wind | 123,400 | 25.3 | - | - | 6,310 | 4.9 | - | - | - | - | - | - |
| Prevention of crop damages by winds | 38,950 | 8.0 | - | - | 6,700 | 5.2 | - | - | 4,800 | 2.7 | 4,300 | 2.8 |
| Increased farm productivity | 38,700 | 7.9 | - | - | 7,840 | 6.1 | - | - | 13,200 | 7.5 | 10,310 | 6.7 |
| Total ($Ba_k$) | 487,820 | 100 | 278,530 | 100 | 129,450 | 100 | 10,000 | 100 | 177,010 | 100 | 153,320 | 100 |

TABLE V - BENEFITS FROM AGROFORESTRY TECHNOLOGIES/PRACTICES IN CHEPARERIA

| | **Boundary planting** | | **Woodlot** | | **Home-garden** | | **Scattered tree** | | **Strip planting** | | **Fodder bank** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Item** | **Income (KES)** | **%** | **Income (KES)** | **%** | **Income (KES)** | **%** | **Income (KES)** | **%** | **Income (KES)** | **%** | **Income (KES)** | **%** |
| Food products | - | - | - | - | 15,870 | 17.7 | 500 | 4.1 | 30,680 | 23.3 | - | - |
| Timber/poles | 43,000 | 13.2 | 220,200 | 88.5 | 2,000 | 2.2 | 2,500 | 20.5 | - | - | - | - |
| Firewood | 4,070 | 1.3 | 5,690 | 2.3 | 13,500 | 15.0 | 1,400 | 11.5 | 3,780 | 2.9 | 2,500 | 3.0 |
| Charcoal | 3,000 | 0.9 | - | - | 2,000 | 2.2 | 1,300 | 10.7 | 2,000 | 1.5 | - | - |
| Fruits | - | - | - | - | 12,000 | 13.4 | - | - | 13,740 | 10.4 | - | - |
| Fodder | 2,560 | 0.8 | - | - | 2,000 | 2.2 | - | - | 3,000 | 2.3 | 24,600 | 29.3 |
| Medicine | 2,000 | 0.6 | - | - | - | - | 1,200 | 9.8 | - | - | - | - |
| Milk production | 11,500 | 3.5 | - | - | 8,900 | 9.9 | 2,100 | 17.2 | 12,300 | 9.3 | 9,000 | 10.7 |
| increased soil fertility | 60,800 | 18.7 | - | - | 10,700 | 11.9 | - | - | 20,200 | 15.3 | 7,690 | 9.2 |
| Weed suppression | 15,000 | 4.6 | 2,000 | 0.8 | - | - | - | - | 1,000 | 0.8 | - | - |
| Improved soil structure | 18,830 | 5.8 | 15,500 | 6.2 | 3,800 | 4.2 | - | - | 10,100 | 7.7 | 11,450 | 13.7 |
| Soil erosion prevention | 24,700 | 7.6 | 2,780 | 1.1 | 7,250 | 8.1 | 1,200 | 9.8 | 9,300 | 7.1 | 7,600 | 9.1 |
| Water purification | 14,000 | 4.3 | - | - | - | - | - | - | 1,200 | 0.9 | 2,000 | 2.4 |
| Improved aesthetic | 2,700 | 0.8 | 2,600 | 1.1 | 5,280 | 5.9 | 2,000 | 16.4 | 8,690 | 6.6 | 6,700 | 8.0 |
| Prevention of house damages caused by wind | 54,500 | 16.8 | - | - | 2,290 | 2.6 | - | - | - | - | - | - |
| Prevention of crop damages by winds | 23,600 | 7.3 | - | - | 2,300 | 2.6 | - | - | 5,670 | 4.3 | - | - |
| Increased farm productivity | 45,000 | 13.8 | - | - | 2,000 | 2.2 | - | - | 10,090 | 7.7 | 12,340 | 14.7 |
| Total ($Ba_k$) | 325,260 | 100 | 248,770 | 100 | 89,890 | 100 | 12,200 | 100 | 131,750 | 100 | 83,880 | 100 |

TABLE VI - RELATIVE (COMPARATIVE) BENEFITS AMONG AGROFORESTRY TECHNOLOGIES / PRACTICES

| **Agroforestry Technology/Practice** | **Lelan %** | **Chepareria %** |
|---|---|---|
| Boundary planting technology | 39.5 | 36.5 |
| Woodlot Technology | 22.5 | 27.9 |
| Strip planting | 14.3 | 14.8 |
| Fodder bank technology | 12.4 | 9.4 |
| Home-garden Technology | 10.5 | 10.1 |
| Scattered trees | 0.8 | 1.4 |
| **Total** | **100** | **100** |

TABLE VII - RELATIVE PROFITABILITY (B/C RATIO) AMONG AGROFORESTRY TECHNOLOGIES / PRACTICES

| **Agroforestry Technology/Practice** | **Lelan** | **Chepareria** |
|---|---|---|
| Boundary planting technology | 9.40[a] | 6.88[b] |
| Home-garden Technology | 3.65[a] | 3.26[a] |
| Strip planting | 3.39[a] | 2.68[a] |
| woodlot Technology | 3.07[a] | 3.31[a] |
| Fodder bank technology | 3.02[a] | 2.28[b] |
| Scattered trees | 0.68[a] | 1.11[a] |

**Note:** B/C ratio values followed by the same letter in rows are not significantly different at 5 % probability level ($p > 0.05$).

In Chepareria, B/C of boundary planting dominated by *Croton megalocarpus* and *Grevillea robusta*was significantly higher ($p < 0.05$) than all other technologies and practices (Table VIII).

In Lelan, while the B/C of boundary planting was significantly higher ($p < 0.05$) than all other technologies, the B/C of scattered tree planting was significantly lower than other technologies (Table IX).

TABLE VIII - PAIR-WISE ANALYSIS OF AGROFORESTRY TECHNOLOGIES B/C IN CHEPARERIA SUB-LOCATION

| | **Homegarden (3.26 %)** | **Woodlot (3.31 %)** | **Scattered trees (1.11 %)** | **Strip planting (2.68 %)** | **Fodder (2.28 %)** |
|---|---|---|---|---|---|
| Boundary tree planting (6.88 %) | * | * | * | * | * |
| Homegarden (3.26 %) | | ns | Ns | ns | ns |
| Woodlot (3.31 %) | | | Ns | ns | ns |
| Scattered trees (1.11 %) | | | | ns | ns |
| Strip planting (2.68 %) | | | | | ns |

* = significantly different at 5 % probability level , ns = not significantly different at 5 % probability level

TABLE IX - PAIR-WISE ANALYSIS OF AGROFORESTRY TECHNOLOGIES B/C IN LELAN SUB-LOCATION

| | **Homegarden (3.65 %)** | **Woodlot (3.07 %)** | **Scattered trees (0.68 %)** | **Strip planting (3.39 %)** | **Fodder (3.02 %)** |
|---|---|---|---|---|---|
| Boundary tree planting (9.40 %) | * | * | * | * | * |
| Homegarden (3.65 %) | | ns | * | ns | * |
| Woodlot (3.07 %) | | | * | ns | ns |
| Scattered trees (0.68 %) | | | | ns | * |
| Strip planting (3.39 %) | | | | | ns |

* = significantly different at 5 % probability level, ns = not significantly different at 5 % probability level

## DISCUSSIONS

There are various costs that can be incurred at different stages in establishing an agroforestry technology/practice. The costs can be grouped into purchase of tools and equipment, land preparation costs, purchase of planting materials like seedlings, maintenance costs like weeding, harvesting and storage costs and costs emanating from damages on other farm components by agroforestry components. This concurs with Garrett and Godsey (2008) that undertaking successful agroforestry requires adequate understanding of involved variable and fixed costs. The benefits accrued from agroforestry technologies and practices are many including; food products, environmental services like water purification and protection against strong winds. Therefore, agroforestry can help in land reclamation, carbon sequestration, and secure peoples livelihood especially in the rural areas (Mbow *et al*., 2014). Different agroforestry technologies have different tree arrangement patterns that affect profitability of a technology as it results to difference in tree-crop interface (Noordwijk and Hairiah, 2000). For instance, boundary tree planting where trees are planted at the perimeter of the farm prevents soil erosion, demarcate land and provide protection to crops as well as houses from strong winds (Nolet *et al*., 2009). The ability of boundary planting to shelter houses from destruction by strong winds makes it more profitable in Lelan and Chepareria sub-locations compared to other agroforestry technologies and practices. However, boundary planting is slightly profitable in Lelan compared to Chepareria because Lelan is considered a zone for growing a variety of crops and building permanent houses that require protection from strong winds. Contrary, scattered trees on farm are slightly profitable in Chepareria than Lelan because of higher perceived value of shade provided by scattered trees for herders in Chepareria than Lelan. In Lelan, trees scattered on farms are perceived destructive because they compete with other farm crops like maize for light and nutrients, making it less profitable (Mandila *et al*., 2015).

The profitability of any agroforestry system may be influenced by prevailing environmental conditions like wind velocity, rainfall and terrain, and higher costs of setting up trees, maintaining them and opportunity costs (Nolet *et al*., 2009). For example, strip planting may have lower profitability in areas with average rainfall less than 800 mm (Tengnas, 1994).

Trees in agroforestry systems have both positive and negative interaction based on the management practices, eventually affecting the profitability of the technology. Well-managed trees increase profitability by contributing to increased soil biomass which adds organic matter to the soil, hence improving soil condition and productivity (Batish *et al*., 2008; Ajayi *et al*., 2009; Ehrmann and Ritz, 2014). For instance, the presence of well managed leguminous tree species on farms inform of strip planting aids in increasing soil nitrogen that improves soil fertility, and provide nutritious fodder to dairy cattle (Bekele-Tesemma, 2007). Strip planting technology trees also provide the benefits of weed suppression and soil conservation in terms of erosion control across the slope though the technology was still young. However, poorly managed practices especially scattered trees may compete with food crops for light, hence lowering their potential benefits (Mandila *et al*., 2015). Agroforestry contributes to microclimate amelioration which favored crops and animals within the farm. This is because agroforestry trees provide shade that lower soil surface temperature and reduces evapotranspiration of soil moisture (Siriri *et al*., 2013).

## CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

In this study, profitability of agroforestry technologies in the semi-arid regions of West-Pokot County based on B/C ranges from 0.68 to 9.40. The ratio depends on the agroforestry technology adopted by the farmer and the main economic activities of the farmer's location. Boundary planting is the most profitable technology/practice because of its major benefit of protecting houses and farm crops from strong wind damages. Scattered tree technology/practice is the least profitable because of its potential cost emanating from its potential to compete with farm crops for light, nutrients and hindrance to farm mechanization. In general, all identified technologies/practices in West-Pokot County have B/C >1 apart from scattered trees on farm.

## RECOMMENDATION

We recommend that famers should be trained on agroforestry tree management options like pollarding and pruning that reduces competition for light between trees/shrubs with crops especially on scattered trees on farms to reduce the costs of some agroforestry technologies. Government agencies and NGOs should train famers on how they can access markets for agroforestry products including passion fruits and milk in order to increase their profits.

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