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Economic Profitability and Carbon Stock Potential of Cereals and Pulses Under Harar and Aonla Based Agroforestry Systems in The Low Hill Zone of Himachal Pradesh

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Abstract

Practicing wheat-maize cropping system by the farmers of Himachal Pradesh is less economical viable as compared to pulses. Besides this, pulses have high potential of soil improvement through nitrogen fixation. Hence, the experiment was premeditated to evaluate the carbon stock potential and economic profitability of cereals and pulses under Harar and Aonla based agroforestry systems in the low hill zone of Himachal Pradesh. The experiment was conducted with nine treatment combinations with four replications in RBD. Highest biomass (77.80 t ha^{-1}) and carbon stock (38.05 t ha^{-1}) were recorded under maize+Harar. In term of economics, maximum gross returns (80,471.49 ₹ ha^{-1}) were obtained for maize+Aonla yet, the maximum net returns (42,684.40 ₹ ha^{-1}) and BC ratio (2.14) were found for mash+Aonla.

Keywords: Agroforestry system, aonla, biomass, carbon stock, harar, economics

1. Introduction

Agriculture is going to face the daunting challenge of feeding a global population of 9.7 billion by 2050 besides mitigating the negative environmental and social impacts. The most suitable land for agriculture has been diverted for housing, highways, industrial activities etc. resulting in shrinkage of the area under arable land (Tiwari, 2003). The increasing population is generating higher demands for forest products whereas, production in the forestry sector even today is not enough to meet current demands, which is bringing down the forest reserves under immense pressure. The farmers of the lower Himachal Pradesh follow wheat- maize rotation which is not an economically viable proposition. Agroforestry is a viable alternative to tackle such challenges and can meet the demands of rapidly increasing human population along with sustainability and biodiversity conservation. Harar (*Terminalia chebula* Retz.), member of family Combretaceae, and Aonla (*Phyllanthus emblica* L.), of Phyllanthaceae, besides climate resilient are well suited to varied environmental conditions. Due to their high medicinal value, these are in great demand and hence, fetch remunerative prices in the market. Harar and Aonla are main constituents of "triphala" which is considered as panacea for stomach disorders. Besides medicinal properties, Harar and Aonla are used for making preserves and pickle.

For millennia, pulses in India are grown for providing the people with nutritionally healthy food. Black gram or Mash (*Vigna Mungo* L.) is one of the important pulses grown throughout the country. The crop is resistant to adverse climatic conditions and improves the soil fertility by fixing atmospheric nitrogen in the soil. India is the main producer of black gram with a production of about 1.5 million tonnes of seeds per annum (Sharma et al., 2011). Pigeonpea (*Cajanus cajan* L.); also known as arhar, tur or red gram; is also one of the most important kharif pulse crops cultivated in India. World production of pigeon peas is estimated at 4.49 million tons. About 63% of this production comes from India (FAOSTAT, 2018). Therefore, by all these considerations the present study was conducted with objectives (i) to estimate the carbon stock and biomass production and (ii) to work out the economics of Harar and Aonla based agroforestry systems.

2. Materials and Methods

2.1. Location and climate

The present study was conducted during the year 2019 in eight-year-old Harar and Aonla orchard established at Khaggal (Neri-II) Experimental Farm of Department of Silviculture and Agroforestry, College of Horticulture and Forestry, Neri - Hamirpur (HP). The site is located at 31°40'23.0"N latitude, 76°29'15.5"E longitude and 650 m elevation above the mean sea level. The study area falls in sub-tropical sub- montane and low hills agro-climatic zone of Himachal Pradesh, India. There is a considerable variation in the seasonal and diurnal temperature of the experimental site. May and June are the hottest months, whereas December and January the coldest ones. During summer, the temperature often crosses 40°C.

2.2. Experimental details

The experiments were designed to evaluate the carbon stock and biomass production along with bio-economics appraisal under different tree-crop combinations. The trial was laid out in Randomized Block Design, having nine treatment combinations (sole maize, maize+Harar, maize+Aonla, sole mash, mash+Harar, mash+Aonla, sole arhar, arhar+Harar and arhar+Aonla) with four replications.

2.3. Structural and functional components of the agroforestry systems

A. Trees

i. Harar (*Terminalia chebula* Retz.) Improved landrace

ii. Aonla (*Phyllanthus emblica* L.) cv. NA-7

Spacing: 8×8 m^2

Year of planting : 2011

Age of the trees : 8 years

B. Field Crops

i. Maize (*Zea mays* L.) var. Parvati

Spacing : 60× 20 cm^2

ii. Black Gram (*Vigna mungo* L.) var. Him Mash-1 (*UPU-0031)*

iii. Arhar (*Cajanus cajan* L.) var. Sarita (ICPL-85010)

Spacing : 50×20 cm^2

2.4. Field preparation

The experimental field was prepared by ploughing the land with the help of tractor, 15 days prior to the sowing. Stones and pebbles were removed and the field was made smooth by harrowing followed by planking. It was leveled properly with adequate provision for channels required to drain out excess water during rainy season. Thereafter, the layout of the experiment was done preparing plots and allocating treatments according to the layout plan. The agricultural crops were raised as per package and practices recommended by the Directorate of Extension Education, CSK HPKV, Palampur (HP). FYM was applied @ 10 t ha^{-1} for all crops whereas, doses of N, P and K applied crop wise are 90:45:30 in Maize, 20:40:20 in Mash and 15:45:0 in case of Arhar. N, P and K were applied in the form of urea, single super phosphate (SSP) and muriate of potash (MOP), respectively.

2.5. Estimation of biomass

2.5.1. Trees

The non-destructive method was used to estimate biomass of standing trees employing volume equations developed for specific tree species for specific region (FSI, 1996). The volume equations used for Harar and Aonla are as under:

V= -0.05004-0.03440D+6.35715D2 (*Terminalia chebula*)

V=-0.406+3.540D-3.231D2 (*Phyllanthus emblica*)

Where, V=Volume

D=Diameter

Stem biomass was calculated by multiplying the stem volume with wood density.

Stem biomass (t ha^{-1})=VOB x WD

Where, VOB=Volume Over Bark

WD=Wood Density

The wood density i.e. 0.96 g cm^{-3} for *Terminalia chebula* and 0.80 g cm^{-3} for *Phyllanthus emblica* was used as recommended by FAO (1997).

2.5.1.1. Above ground biomass

The above ground biomass of trees (stem+leaves+branches) was calculated by multiplying biomass of stem with a biomass expansion factor as suggested by IPCC (2006).

Above ground biomass (t ha^{-1})=Stem biomass (t ha^{-1})×BEF

Where, BEF=biomass expansion factor

The biomass expansion factor i.e. 1.50 was used as suggested by Brown and Lugo (1992) for Harar and Aonla.

2.5.1.2. Below ground biomass

Below ground biomass of the tree species was calculated by multiplying its above ground biomass with the root: shoot ratio. Due to unavailability of the root: shoot ratio, a standard factor of 0.20 (IPCC, 2006) was used. The sum of above ground and below ground biomass was taken as total biomass of the tree.

2.5.2. Crop biomass

The biomass production of different agricultural crops was determined by harvesting all the plants from 1 m x 1 m quadrat replicated four times for each treatment combination. Total harvest method was carried out by digging out the crop plants along with the roots. The soil was gently removed by tapping. All crop samples were then washed to completely remove the soil particles and stored properly. Roots and shoot(s) of plants were separated and oven dried at 70°C till a constant weight was achieved. The dried samples of root and shoot were weighed to determine above ground and below ground biomass of each crop.

2.6. Carbon stock

Carbon stock (ha^{-1}) was worked out by multiplying biomass (ha^{-1}) with 0.5 in case of trees (IPCC, 2006) and with 0.45 in agricultural crops (Woomer, 1999).

2.7. Economic analysis

Economic appraisal of different treatments (tree-crop combinations and sole crops) was done for comparison and selecting the best combination for recommendation to the farmers. Productivity of the sole crops and tree-crop combinations was subjected to economic analysis by calculating cost of cultivation, gross and net returns per hectare. All these parameters were calculated on the basis of prevailing market prices at the time of termination of the experiment.

2.7.1. Cost of cultivation (Rs.)

The cost of cultivation of different field crops was worked out on the basis of net cropped area per hectare. The requirements of labour and mechanical power for different operations such as ploughing, harrowing, weeding and harvesting were calculated as per the rate prevalent at the Experimental Farm. Cost of inputs such as seeds, farm yard manure, fertilizers and pesticides was calculated based on the actual amounts applied to different crops. Similarly, cost of cultivation of trees (*Terminalia chebula* and *Phyllanthus emblica*) including harvest of their fruits was computed with respect to variable cost involved in maintenance and harvesting of fruits on per hectare basis during the year of the study.

2.7.2. Gross returns (Rs.)

The prevailing local market prices were used to convert yield of field crops and fruits of *Terminalia chebula* and *Phyllanthus emblica* into gross returns (ha^{-1}). Gross returns were obtained by multiplying the quantity of produce with the prevailing prices in the market.

2.7.3. Net returns (Rs.)

Net returns were worked out by subtracting the cost of cultivation from the gross returns.

Net returns (ha^{-1})=Gross returns (ha^{-1})–Cost of cultivation (ha^{-1})

2.7.4. Benefit Cost ratio

Ratio of the gross returns per rupee invested was calculated as per following formula:

Benefit:Cost ratio=Gross returns (Rs. ha^{-1})/Cost of cultivation (Rs. ha^{-1}).

3. Results and Discussion

3.1. Carbon stock of Harar (Terminalia chebula Retz.) and Aonla (Phyllanthus emblica L.) based agroforestry systems

Significant variation was observed among the different tree-crop combinations with respect to total biomass and total carbon stock of the systems (Table 1). Sole cultivation of agricultural crops has far less total biomass and total carbon stock as compared to that of tree-crop associations. The highest total biomass (77.80 t ha^{-1}) was, however, recorded under maize + Harar and lowest (5.47 t ha^{-1}) in case of sole mash cropping. All the treatments (combinations) varied significantly with respect to total biomass and total carbon stock except maize+Aonla (73.71 t ha^{-1}) and arhar+Harar (73.65 t ha^{-1}), where non-significant difference was noticed. Like biomass, total carbon stock was also found maximum (38.05 t ha^{-1}) in maize+Harar and minimum (2.46 t ha^{-1}) in case of sole mash. Among sole cropping, maize had the highest (16.91 t ha^{-1} and 7.60 t ha^{-1}) biomass and carbon stock followed by arhar (12.86 t ha^{-1} and 5.78 t ha^{-1}) and least were observed in mash (5.47 t ha^{-1} and 2.46 t ha^{-1}).

Table 1: Biomass and carbon stock of Harar (*Terminalia chebula* Retz.) and Aonla (*Phyllanthus emblica* L.) based agroforestry systems

Tree-crop combination (Treatment)	Total biomass of the system (t ha^{-1})	Total carbon stock of the system (t ha^{-1})
Sole maize	16.91	7.60
Maize+Harar	77.80	38.05
Maize+Aonla	73.71	36.00
Sole Mash	5.47	2.46
Mash+Harar	65.11	32.28
Mash+Aonla	62.60	31.02
Sole Arhar	12.86	5.78
Arhar+Harar	73.65	36.17
Arhar+Aonla	69.63	34.16
CD (*p*=0.005)	1.85	0.94

Combination of Harar with different agricultural crops showed higher biomass and carbon stock over Aonla+respective agricultural crops. Maize+Harar revealed the highest carbon sequestration potential which may be plausibly due to inherent growth potential of Harar and maize under existing environmental conditions, besides compatibility between both the crops. The agroforestry systems revealed higher carbon sequestration potential over sole cropping of agricultural crops. The low biomass and carbon sequestration potential of agricultural crops and higher total biomass and carbon sequestration potential of the agroforestry systems incorporating trees have also been reported by Albrecht and Kandji (2003), Montagnini and Nair (2004) and Kirby and Potvin (2007).

3.2. Economics of Harar (Terminalia chebula Retz.) and Aonla (Phyllanthus emblica L.) based agroforestry systems

The economics of Harar (*Terminalia chebula* Retz.) and Aonla (*Phyllanthus emblica* L.) based agroforestry systems comprising of maize, mash and arhar as intercrops has been worked out by calculating cost of cultivation, gross returns, net returns and benefit cost ratio of sole agricultural crops and tree-crop combinations to know the economic feasibility of different land uses. The data pertaining to the bio-economics of the agroforestry systems are presented in Table 2.

Table 2: Economic of Harar (*Terminalia chebula* Retz.) and Aonla (*Phyllanthus emblica* L.) based agroforestry systems

Tree-crop combination (Treatment)	Cost of cultivation (₹ ha^{-1})	Total gross returns (₹ ha^{-1})	Total net returns (₹ ha^{-1})	B:C Ratio
Sole maize	41040.47	63620	22219.53	1.55
Maize+Harar	43378.04	79470.34	36092.30	1.83
Maize+Aonla	43194.54	80471.49	37276.95	1.86
Sole mash	35172.02	63800	28087.98	1.81
Mash+Harar	37509.59	79704.34	42194.75	2.12
Mash+Aonla	37326.09	80010.49	42684.40	2.14
Sole Arhar	36378.17	63240	26861.83	1.73
Arhar+Harar	38715.74	76504.34	37788.60	1.97
Arhar+Aonla	38532.24	75980.49	37448.25	1.97

3.2.1. Cost of cultivation

Among all tree-crop combinations, maximum cost of cultivation (43378.04 ₹ ha^{-1}) was worked out in case of maize+Harar and minimum (35172.02 ₹ ha^{-1}) for sole mash.

3.2.2. Gross returns

Perusal of the data presented in Table 2 revealed the maximum gross returns (80471.49 ₹ ha^{-1}) for maize+Aonla closely followed by mash+Aonla (80010.49 ₹ ha^{-1}), while minimum (63240 ₹ ha^{-1}) in sole arhar.

3.2.3. Net returns

Wide variation was observed with respect to net returns from different sole crops and tree-crop combinations which ranged between 22219.53 ₹ ha^{-1} (sole maize) and 42684.40 ₹ ha^{-1} (mash+Aonla). Association with trees with agricultural crops revealed higher net returns over sole agricultural crops.

3.2.4. Benefit-cost ratio

Association of growing trees with agricultural crops marginally increased the cost of cultivation; however, substantial increase was noticed with respect to net returns by integrating tree component, which resulted in higher benefit-cost ratio. Among all the tree-crop combinations, highest benefit-cost ratio (2.14) was registered under mash+Aonla while the lowest (1.55) was revealed by sole maize cropping.

Results of the present investigations showed that growing agricultural crops under trees is profitable over sole agricultural crop cultivation. This shows that agroforestry is an efficient land use system which makes judicious use of space and other limiting factors like light, nutrients, moisture, etc. The net returns were higher when pulses (mash and arhar) were integrated with trees (Harar and Aonla) over cereal (maize). It reflected that pulses should be preferred over maize under present set of conditions. Between pulses, sole mash registered higher net returns over sole arhar cropping which rests the choice of the farmer with mash. The results of the present investigations are in line with the findings of Dwivedi et al. (2007), Banerjee et al. (2009), Prem and Pant (2015) who reported higher net returns from the agroforestry systems as compared to the sole cropping.

4. Conclusion

Higher returns obtained under pulses-based agroforestry system in this study indicated that pulses should be preferred over maize; however, the growth of crops under trees was unfortunate but incorporation of both improved biomasses substantially.

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