Biological Forum – An International Journal **13(2): 413-419(2021)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Appraisal of Biological Yield and Economic Returns of Existing Agroforestry Systems in Tehsil Bangana of Una District of Himachal Pradesh, India

Jattin Sharma, Som Dutt Sharma*, Kamal Sharma and Dushyant Sharma
College of Horticulture and Forestry,
Dr. Y.S. Parmar University of Horticulture and Forestry, Neri, Hamirpur-173 230, (Himachal Pradesh), India.

(Corresponding author: Som Dutt Sharma)*
(Received 15 April 2021, Accepted 18 June, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Agroforestry systems exist in Tehsil Bangana of Una District, Himachal Pradesh are not so productive due to lack of scientific knowledge among the local people. These systems require improvement both in terms of structure as well as productivity. Therefore the present study was conducted to assess biological yield and economic returns of existing agroforestry systems in Tehsil Bangana of Una District of Himachal Pradesh, India, during the year 2019-20. For survey and data collection, 324 farmers were selected randomly from three categories viz., marginal, small, and medium based on landholding capacity. The study revealed that five agroforestry system types prevalent among different categories of farmers namely: Agri-silviculture (AS), Agri-horticulture(AH), Agri-Horti-silviculture (AHS), Horti-pastoral (HP), and Silvi-pastoral (SP). Total biological yield among existing agroforestry systems was found highest (31.02 t $ha^{-1}yr^{-1}$) under the Silvipastoral system (SP) due to a large number of middle-aged and matured trees along with the good growth of grasses. Under the agrisilviculture system, the net return was found highest (151761 Rs. ha^{-1} yr^{-1}) in the small category followed by marginal (125549 Rs. ha^{-1} yr^{-1}) and medium (61288 Rs. $ha^{-1}yr^{-1}$) category of farmers. Maximum net return (151761 Rs. $ha^{-1}yr^{-1}$) was obtained from AS System, followed by AH System (150452 Rs. ha^{-1} yr^{-1}) and AHS System (140802 Rs. ha^{-1} yr^{-1}). The coefficient of variation for biological yield was found highest (14.12%) for AH system type, followed by AHS (12.73%), AS (11.51%), and SP (5.08%) in the marginal category of farmers. It indicates that AH system types practiced by marginal farmers were highly unstable compared to other agroforestry system types practiced. In the case of a small category of farmers, values of coefficient of variation for biological yield and net returns were found maximum (11.18%) and (20.27%) for AHS and SP system types respectively. These system types were found unstable due to their highest values of coefficient of variation and thus require further scientific interventions for their improvements. Similarly, the variation in net returns was maximum in the AHS system (24.64). The higher variation in net returns of ASH system may be attributed to variation in the cost of production of each functional unit of agricultural component and presence of a various number of tree species as well as several individuals of each species of a particular species existing in different systems units. Awareness camps about the latest agroforestry technologies should be organized in the study area to increase biological yield and net returns of existing agroforestry systems.

Keywords: Agroforestry, Biomass, Coefficient of variation, Farmer's category, Net return, Production cost.

INTRODUCTION

Agroforestry is as old as the origin of agriculture. It is shown to be an efficient land management method to enhance soil quality and to conserve water resources (Brown *et al.,* 2018). It contributes to sustainable development and the enhancement of local people's livelihoods through their ecological, social, and economic benefits (Montagnini & Metzel, 2017). It is the most important type of farming system which improves the productivity of land on a sustainable basis. The Intergovernmental Panel on Climate Change recognized agroforestry as a potential carbon sequestration mechanism and found it a part of strategies to mitigate climate change (Abbas *et al.,* 2017). As of today, agroforestry is considered as a problem-solving agroforestry system that can take an almost infinite number of different forms as they have the potential to include any of the crops, animals, and tree species used in agriculture and forestry. This tremendous potential variability allows agroforestry systems to meet the needs of farmers under almost any set of environmental, economic, and social conditions and also reduces the risks of farmers' investments as these diversify their crop range and thereby the source of income (Lefroy, 2009). It provides an opportunity for diversification of existing land-use systems, beneficial environmental impacts, and higher returns as compared to sole cropping system (Sharma *et al.,* 2017).

Moreover, in rural areas, agroforestry improves socio-economic conditions by creating job opportunities and provides income, thereby reducing the scarcity of food production and improving the financial state (Gosling *et al.*, 2021; Goudarzian & Yazdani, 2015). As the rapid increase in human population has put tremendous pressure on natural resources, creating an environmental crisis that probably may increase in magnitude in the foreseeable future, the adoption of improved agroforestry systems is one of the alternative means to counter this ongoing process of resource exploitation and environmental degradation. Agroforestry has gained considerable attention in the scientific community which serves multiple functions and in turn, practitioners have seen these ecological benefits turn into economic benefits through the increase of agricultural output (Hildreth, 2008; Syahri, Larekeng, & Susilowati, 2020). Agroforestry is not a new concept in Himachal Pradesh but it has been practiced traditionally since time immemorial (Sharma *et al.*, 2017). It plays a vital role in achieving sustainability in the hills farming system (Tomar *et al.*, 2021). However, there is a need for improvement in agroforestry systems through scientific methods, research, etc. so that farmers can generate more economic benefits from agroforestry. Although various agroforestry systems exist in the sub-tropical low hill zone of Himachal Pradesh, due to lack of scientific knowledge among the local people, these systems are not so productive and require improvement both in terms of structure as well as productivity. Therefore, the present study was undertaken to find out the biological yield and economic returns of existing agroforestry systems among different categories of farmers in Tehsil Bangana of Una District, Himachal Pradesh.

Study Area: Bangana tehsil lies between 31°18' to 31°55' N latitude and 75°55' to 76°28'E longitude and its elevation varies from 650m-900 m above mean sea level. The study site was selected through a multi-stage random sampling technique in which twelve panchayats were chosen (Muchali, Dohgi, Dhundla, Malanga, Tanoh, Lathiani, Hatli kesru, Jasana, Piplu, Sihana, Thanakalan, Tihra) and from each selected Panchayat, three villages were selected. In each village, farmers were divided into three different categories *i.e.* marginal (<1 ha), small (1-2 ha) and medium (2-5 ha) based on their landholdings, and a random sample of three farmers from each category was taken as the ultimate unit of study.

MATERIAL AND METHOD

During the study, farmers were surveyed to know about agroforestry systems practiced in the area and their biological yield and economic returns were analyzed. Biological yields were calculated considering the harvested biomass of each functional unit of the system type**.** The biomass production of agriculture crops was determined by taking random samples of Kharif and Rabi crops from the cultivated land of the farmer's field by laying out 1 m × 1 m quadrates. The total harvest method was carried out by digging out the crop plant along with the root falling within the quadrate. Roots and shoots of crops were segregated and stored in different paper bags. All crop samples were washed to remove the soil and oven-dried at 70°C till a constant weight was achieved. The dried samples of root and shoot of each crop species were weighed to determine the above-ground and below-ground biomass of each species. The same procedure was used to determine the biomass of grasses but in this case, quadrate sizes were taken 50 cm × 50cm. The above-ground biomass of a tree (stem + leaves + branches) was calculated by multiplying the biomass of stem with a biomass expansion factor as calculated in the IPCC report (Eggleston *et al.*, 2006).

Above ground biomass (t/ha) of a tree = Stem biomass (t/ha) x BEF (Biomass Expansion Factor)

Below ground biomass of a particular tree species was calculated by multiplying its above-ground with the root: shoot ratio. In unavailability of the root: shoot ratio, a standard factor of 0.25**.**was used for its estimation. The sum of above-ground and belowground biomass was taken as the total biomass of a tree. Net return obtained from each agroforestry system type was determined by the following equation:

Net return = Gross return – Production cost

Relative variations in the biomass yield levels and net returns of a system type among different categories of farmers were worked out by calculating the coefficient of variation.

RESULTS AND DISCUSSION

Biological yield (t ha^{-1}yr^{-1}): Data on biological yield obtained from different existing agroforestry systems practiced by farmers in Bangana Tehsil of Una district of Himachal Pradesh have been presented in Table 1. It is evident from the data that the total biomass (AG+BG) of crop components was found to be highest (13.37 t ha^{-1}) in the marginal category and lowest (9.53 t ha^{-1}) in the medium category of farmers under AS system. While for tree component, it was found to be highest (17.50) in medium and lowest (11.20 t ha^{-1}) in the marginal category of farmers. Similarly, total biomass contribution under the AH system by crop components was highest (14.00 t ha^{-1}) in marginal and lowest (9.23 t ha^{-1}) in a small category of farmers. In the AHS system, the total biomass of crop components was recorded maximum (12.05 t ha^{-1}) in small and minimum (9.80 t ha^{-1}) in the medium category. Whereas tree component contribution to total biomass for small, medium and marginal categories of farmers was found to be 13.70, 11.07, and 9.78 tons per hectare, respectively. Grass component contribution to total biomass under HP system was observed 4.79 and 2.38 tons per hectare in a medium and small category of farmers respectively. While, horticulture component contribution in this system to total biomass was found to be highest (18.54 t ha^{-1}) in medium, followed by (16.96 t ha^{-1}) small farmer's category.

Table 1: Biological Yield obtained from different existing agroforestry systems practiced by the farmers in Bangana Tehsil of Una District of Himachal Pradesh.

Agroforestry Systems	Farmer's category		Crops(C)	Grasses(G)	Trees (T)	Total(C+G+T)
Biological yield(t/ha/yr)						
Agrisilviculture	Marginal	AG	10.76	-	9.34	20.10
		BG	2.61	-	1.86	4.47
		Total	**13.37**	**-**	**11.20**	**24.57**
	Small	AG	9.42	-	10.62	20.04
		BG	2.03	-	2.12	4.15
		Total	**11.45**	**-**	**12.74**	**24.19**
	Medium	AG	7.68	-	14.59	22.27
		BG	1.85	-	2.91	4.76
		Total	**9.53**	**-**	**17.50**	**27.03**
Agrihorticulture	Marginal	AG	11.13	-	8.48	19.61
		BG	2.87	-	1.69	4.56
		Total	**14.00**	**-**	**10.17**	**24.17**
	Small	AG	6.97	-	11.18	18.15
		BG	2.26	-	2.23	4.49
		Total	**9.23**	**-**	**13.41**	**22.64**
	Medium	AG	7.42	-	6.02	13.44
		BG	1.96	-	1.20	3.16
		Total	**9.38**	**-**	**7.22**	**16.60**
Agrihortisilviculture	Marginal	AG	8.78	-	8.15	16.93
		BG	1.75	-	1.63	3.38
		Total	**10.53**	**-**	**9.78**	**20.31**
	Small	AG	10.21	-	11.42	21.63
		BG	1.84	-	2.28	4.12
		Total	**12.05**	**-**	**13.70**	**25.75**
	Medium	AG	7.92	-	9.23	17.15
		BG	1.88	-	1.84	3.72
		Total	**9.80**	**-**	**11.07**	**20.87**
Hortipastoral	Marginal	AG	-		-	-
		BG	-		-	-
		Total	-		-	-
	Small	AG	-	1.55	14.14	15.69
		BG	-	0.83	2.82	3.65
		Total	**-**	**2.38**	**16.96**	**19.34**
	Medium	AG	-	3.04	15.45	18.49
		BG	-	1.75	3.09	4.84
		Total	**-**	**4.79**	**18.54**	**23.33**
Silvipastoral	Marginal	AG	-	3.81	21.14	24.95
		BG	-	1.02	4.22	5.24
		Total	**-**	**4.83**	**25.36**	**30.19**
	Small	AG	-	3.00	18.21	21.21
		BG	-	1.12	3.64	4.76
		Total	**-**	**4.12**	**21.85**	**25.97**
	Medium	AG	-	3.92	21.65	25.57
		BG	-	1.12	4.33	5.45
		Total	**-**	**5.04**	**25.98**	**31.02**

In the SP system, the total biomass of the grass component was recorded maximum (5.04 t ha^{-1}) in medium and minimum (4.12 t ha^{-1}) in the small farmer's category. While tree component contribution to it was found to be highest (25.98 t ha^{-1}) in medium and lowest (21.85 t ha^{-1}) in a small category of farmers.

Total biomass (Crops +Grasses +Trees): Under AS system, a total biological yield was found maximum (27.03 t $ha^{-1}yr^{-1}$) in the medium category and minimum (24.19 t $ha^{-1}yr^{-1}$) in a small category of farmers. Similarly for the AH system, the total biological yield among different farmers categories was found highest (24.17 t $ha^{-1}yr^{-1}$) in marginal and lowest (16.60 t ha^{-1} yr^{-1}) in the medium category of farmers. For AHS, total biological yield decreased in the manner Small (25.75 t $ha^{-1}yr^{-1}$) > Medium (20.87 t $ha^{-1}yr^{-1}$) >Marginal (20.31 t $ha^{-1}yr^{-1}$). For the HP system, total biological yield followed the decreasing trends of Medium (23.33 t $ha^{-1}yr^{-1}$) > Small (19.34 t $ha^{-1}yr^{-1}$). Whereas, for SP it decreased in the order medium (31.02 t $ha^{-1}yr^{-1}$) > marginal (30.19 t $ha^{-1}yr^{-1}$) > Small (25.97 t $ha^{-1}yr^{-1}$). In the present study, irrespective of different farmer's categories and functional components, total biological yield among existing agroforestry systems was found highest (31.02 t ha^{-1} yr^{-1}) under the silvopastoral system (SP), while lowest (16.60 t $ha^{-1}yr^{-1}$) under agrihorticulture (AH). The reason for the highest biomass yield in the SP system may be due to a large number of middle-aged and matured trees along with the good growth of grasses. Similar results were reported by Pradeep, 2016 in the sub temperate region of Solan district and Singh, 2017 in Kangra district of Himachal Pradesh. The amount of biological yield in all the agroforestry systems recorded in the present study

was lesser in comparison to the findings of (Masoodi, 2010, Rajput, 2016 and Sharma et *al.*, 2008) in Himachal Pradesh. Upadhyaya, (1997) reported that AS type was found to produce the maximum biological yield in marginal and small groups whereas in the medium group maximum biological yield was obtained from ASH system type which is contrary to our findings. The lower amount of biomass in pastoral agroforestry systems was also noticed by Canencia *et al*., (2015) and (Kumar, 2004). The production of any ecological system is governed by climatic conditions, edaphic characteristics, phenology, and floristic diversity (Bahar, 2003). Nair, 1993 has recommended that trees benefit understory by producing a unique environment that reduces evapotranspiration, conserves moisture in plants, buffers understory from extreme temperature, and suppresses many insidious problems of weeds. These attributes might have enhanced the growth of herbage under trees. Tree-based agroforestry systems have been reported to produce more biomass as compared to grasslands (Abbas *et al*., 2017). The results indicated that the biomass production of systems was influenced by their structure, especially the species and density of woody components, dominant species, and management of components and species richness. (S. Kumar, 2003) has reported five agroforestry systems *viz.*, Horti-pastoral, Silvi-pastoral, agri-horticulture, agri-silviculture, Agri-Horti-silviculture, and natural grassland in mid-hill conditions of Himachal Pradesh. These land-use systems had significant variation in their total biomass production potential. The silver-pastoral (59.72 t ha^{-1}) system produced the highest biomass, whereas natural grassland produces minimum biomass (5.79 t ha^{-1}). The estimation of biomass production in different tree-based systems of the central Himalayan Tarai region was carried out by Kanime *et al.,* (2013). They reported that the highest above (9.48 Mg ha^{-1}) and below ground (16.90 Mg ha^{-1}) biomass were recorded in the *Dalbergia sissoo* plantation. Whereas, lowest above (1.23 Mg ha^{-1}) and belowground (0.30 Mg ha^{-1}) biomass were recorded in *Populus deltoides* boundary plantation and *Populus salicina,* respectively.

Economic returns from agroforestry systems (Rs. $ha^{-1}yr^{-1}$): Data on economic returns (Rs. $ha^{-1}yr^{-1}$) from different agroforestry systems in marginal, small, and medium categories of farmers in the study area is given in Table 2. There were five agroforestry systems identified in the study area. For the agrisilviculture system, the net return was found highest (1,51,761 Rs. ha^{-1} yr^{-1}) in small category followed by marginal (1,25,549 Rs. ha^{-1} yr^{-1}) and medium (61,288 Rs. ha^{-1} yr^{-1}) categories of farmers. Whereas, for the AH system, the net return was observed maximum (1,50,452 Rs. ha^{-1} yr^{-1}) in marginal and minimum (1,29,402 Rs. ha^{-1} yr^{-1}) in the medium category of farmers. In the case of the agrihortisilviculture system, the net return was found maximum (1,40,802 Rs. ha^{-1} yr^{-1}) in small category followed by marginal (1,09,915 Rs. ha^{-1} yr^{-1}) and medium (72,843 Rs. ha^{-1} yr^{-1}) categories. Net returns for the HP system were found to be (1,30,292 Rs. ha-^{1} yr^{-1}) and (1,05,765 Rs. ha-^{1} yr^{-1}) in a medium and small category of farmers respectively. Net return was found maximum (7,620 Rs. ha^{-1} yr^{-1}) in medium and minimum (5,993 Rs. ha^{-1} yr^{-1}) in the marginal category of farmers in the case of the silvipastoral system. Irrespective of farmers category, maximum net return (1,51,761 Rs. ha^{-1} yr^{-1}) was obtained from AS System, followed by AH System (1,50,452 Rs. ha^{-1} yr^{-1}) and AHS System (1,40,802 Rs. ha^{-1} yr^{-1}). Result also shows that net returns from different agroforestry systems in the marginal category of farmers were found to follow a decreasing order of AH (1,50,452 Rs. ha^{-1} yr^{-1}) > AS (1,25,549 Rs. ha^{-1} yr^{-1}) > AHS (1,09,915 Rs. ha^{-1} yr^{-1}) > SP (5,993 Rs. ha^{-1} yr^{-1}). Whereas, net return in the case of a small category of farmers showed a decreasing order of AS (1,51,761 Rs. ha^{-1} yr^{-1}) > AH (1,42,997 Rs. ha^{-1} yr^{-1})> AHS (1,40,802 Rs. ha^{-1} yr^{-1}) > HP (1,05,765 Rs. ha^{-1} yr^{-1}) > SP (7,052 ha^{-1} yr^{-1}). The net returns for the medium category of farmers follow a decreasing order of HP (1,30,292 Rs. ha^{-1} yr^{-1}) > AH (1,29,402 Rs. ha^{-1} yr^{-1}) > AHS (72,843 Rs. ha^{-1} yr^{-1}) > AS (61,288 Rs. ha^{-1} yr^{-1})> SP (7,620 Rs. ha^{-1} yr^{-1}). The highest net returns in the AH system of marginal categories could be attributed to the reason that in this system, two main cash fetching components *viz*., agriculture and tree components had contributed for significant share to the net returns. Kumar, (1996) conducted a study on bio-economic appraisal of agroforestry systems in Himachal Pradesh and found that the agrihorticulture system gives the highest net return followed by agrihortisilviculture, agrisilviculture, and minimum in sole cropping. The present findings are comparable with Singh *et al.*, 2015. They also recommended that net returns from agroforestry systems decreased in the order agrisilviculture system (2,77,415 Rs. $ha^{-1}yr^{-1}$) > agrisilvihorticulture system (2,70,747 Rs.ha-lyr^{-1}) > agrihortisilviculture (2,69,033 ha^{-1} yr^{-1}) systems.

Table 2: Economic Returns (Rs./ha/yr) from Different Agroforestry Systems in Marginal, Small, and Medium Categories of Farmers in Bangana Tehsil of Una District of Himachal Pradesh.

System	Marginal			Small			Medium		
	Gross Return	Production Cost	Net Return	Gross Return	Production Cost	Net Return	Gross Return	Production Cost	Net Return
AS	2,73,132	1,47,583	1,25,549	3,32,556	1,80,795	1,51,761	1,36,862	75,574	61,288
AH	3,55,089	2,04,637	1,50,452	3,08,084	1,65,087	1,42,997	2,75,009	1,45,607	1,29,402
AHS	2,35,821	1,25,906	1,09,915	3,01,271	1,60,469	1,40,802	1,55,313	82,470	72,843
HP	-	-	-	2,53,960	1,48,195	1,05,765	2,76,812	1,46,520	1,30,292
SP	14,342	8,349	5,993	16,097	9,045	7,052	17,680	10,060	7,620

Variation in biological yield and net returns of the agroforestry systems among the different categories of farmers: Relative variation in the biomass yield levels and net returns of a system type among the different categories of farmers were worked out by calculating the coefficient of variation. Data on the Coefficient of variation (CV) for biological yield and net returns of existing agroforestry systems among the different categories of farmers have been presented in Table 3. It is evident from the data that the co-efficient of variation for biological yield was found highest (14.12%) for AH system type, followed by AHS (12.73), AS (11.51), and SP (5.08) in the marginal category of farmers. Whereas for net return these were found to be 23.71, 17.39, 12.98, and 12.72 percent for SP, AS, ASH, and AH system types respectively. It indicates that the AH system type practiced by marginal farmers was highly unstable compared to other agroforestry system types practiced in the study area. SP system type was found to be a more stable system among all prevailing agroforestry systems (Fig. 1). In the case of a small category of farmers, values of coefficient of variation for biological yield and net returns were found maximum (11.18%) and (20.27%) for AHS and SP system types respectively. These system types were found unstable due to their highest values of coefficient of variation and thus require further scientific interventions for their improvements. Whereas, AS and HP system types were found to be more stable systems due to their lowest values of Co-efficient of variation (7.67%) and (4.31) for biological yield and net returns respectively (Fig. 2). In the case of the medium category of farmers, coefficient of variation values given in Table 3 have shown that the variation in biological yield was maximum in the AH system followed by HP, AHS, AS, and SP system with respective values of 16.75, 15.38, 12.84, 6.48 and 6.06 percent. Similarly, the variation in net returns were maximum in AHS system (24.64%) followed by AH (16.80%), AS (13.42%), SP (11.68%) and HP (10.25%). The higher variation in net returns of the ASH system may be attributed to variation in the cost of production of each functional unit of agricultural component and presence of a various number of tree species as well as several individuals of each species of a particular species existing in different systems units. From these results, it can be thus concluded that ASH followed by AH, AS, SP and HP system types in the medium category of farmers is less stable and need suitable interventions for its improvement (Fig. 3).

Table 3: Coefficient of Variation (CV) for Total Biological Yield and Net Returns of Existing Agroforestry Systems Among Different Categories of Farmers in Bangana Tehsil of Una District of Himachal Pradesh.

AF systems	Coefficient of Variation (%)					
	Biological yield			Net return		
	Marginal	Small	Medium	Marginal	Small	Medium
AS	11.51	7.67	6.48	17.39	19.36	13.42
AH	14.12	7.92	16.75	12.72	14.02	16.80
AHS	12.73	11.18	12.84	12.98	18.48	24.64
HP	-	11.16	15.38	-	4.31	10.25
SP	5.08	7.68	6.06	23.71	20.27	11.68

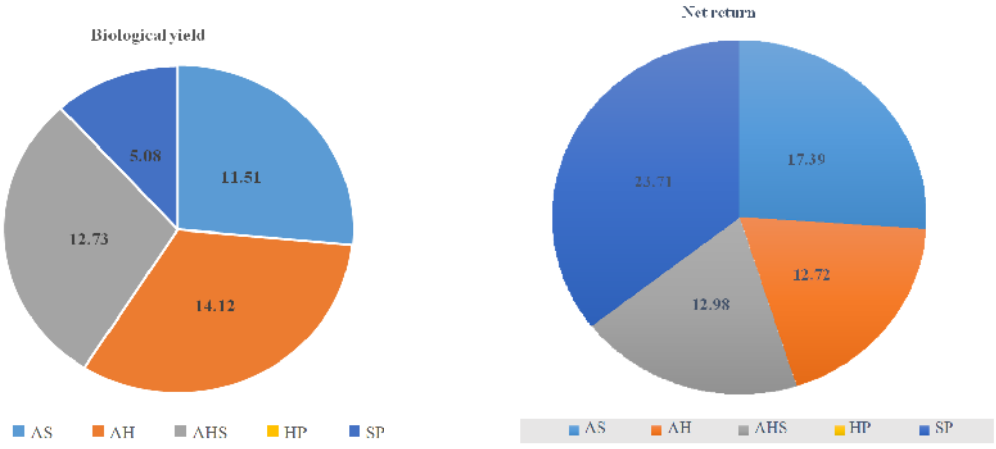

Fig. 1. Co-efficient of variation for B.Y. and N.R. of AFS in Marginal Category of Farmers.

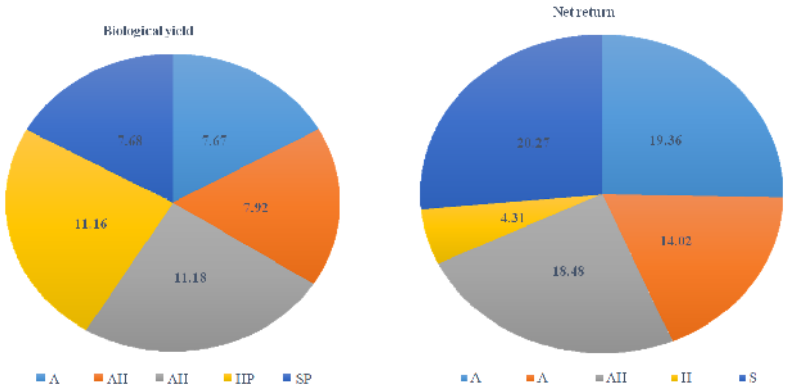

Fig. 2. Co-efficient of variation for B.Y. and N.R. of AFS in Small Category of Farmers**.**

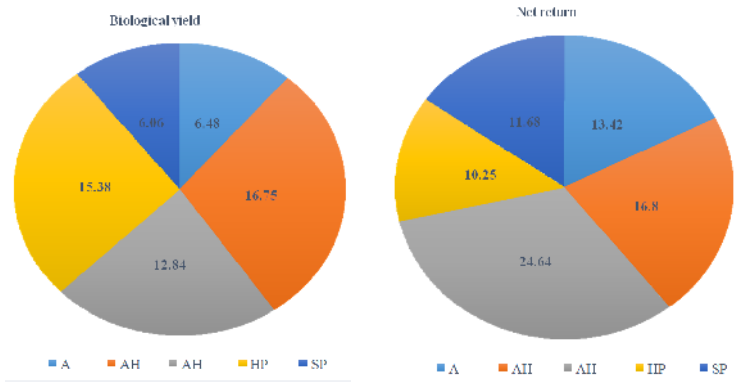

Fig. 3. Co-efficient of variation for B.Y. and N.R. of AFS in Medium Category of Farmers.

CONCLUSION

In the study area, five agroforestry system types were identified. The highest total biological yield (31.02t ha^{-1} yr-1) was found under SP and the lowest (16.60 t ha^{-1} yr^{-1}) under the AH system in the medium category of farmers. Whereas, maximum net return (1,51,761 Rs. ha^{-1} yr^{-1}) was obtained from AS and a minimum (5,993 Rs. ha^{-1} yr^{-1}) from SP System types irrespective of farmers category. AHS in the medium category of farmers was found to be less stable due to higher variation in net returns and needs suitable interventions for its improvement.

FUTURE SCOPE

During the study it has been identified that the farmers' are lacking awareness in the field of agroforestry which is the reason for their low income. From future perspective it is suggested to organize awareness camps for marginalized farmers so as to familiarize them with the latest techniques and equipment's for sustainable agroforestry system.

Acknowledgment. The authors are thankful to the Dean, College of Horticulture and Forestry, Neri, Hamirpur for providing necessary support. The authors are also thankful to the line department officials and villagers in the study area for their cooperation during the study.

Conflict of interest. No potential conflict of interest was reported by the author(s).

REFERENCES

Abbas, F., Hammad, H. M., Fahad, S., Cerdà, A., Rizwan, M., Farhad, W., & Bakhat, H. F. (2017). Agroforestry: a sustainable environmental practice for carbon sequestration under the climate change scenarios—a review. *Environmental Science and Pollution Research*, *24*(12): 11177–11191.

Bahar, N. (2003). Vegetation dynamics and biomass production of undergrowth vegetation in Eucalyptus tereticornis plantation. *Indian Forester*, *129*(11): 1361–1369.

Brown, S. E., Miller, D. C., Ordonez, P. J., & Baylis, K. (2018). Evidence for the impacts of agroforestry on agricultural productivity, ecosystem services, and human well-being in high-income countries: a systematic map protocol. *Environmental Evidence*, *7*(1): 1–16.

Canencia, O. P., Palma, R. A., Ansigbat, V., Lacang, G., Osio, A., Tulang, R., & Arnejo, B. (2015). Carbon sequestration potentials for agro-forestry system and grasslands in Bukidnon and Cagayan de Oro landscape. *Mindanao Journal of Science and Technology*, *13*.

Eggleston, S., Buendia, L., Miwa, K., Ngara, T., & Tanabe, K. (2006). IPCC guidelines for national greenhouse gas inventories.

Gosling, E., Knoke, T., Reith, E., Cáceres, A. R., & Paul, C. (2021). Which Socio-economic Conditions Drive the Selection of Agroforestry at the Forest Frontier? *Environmental Management*, *67*(6): 1119–1136.

Goudarzian, P., & Yazdani, M. R. (2015). Climate diversity in line with agroforestry systems: studying technicalities of agroforestry systems and allied components in two diverse climatic regions (Warm climate vs. cold climate)(Case study: Kazeroun & Sepidan in Fars Province, IR Iran).

Hildreth, L. A. (2008). The economic impacts of agroforestry in the Northern Plains of China. *Agroforestry Systems*, *72*(2): 119–126.

Kanime, N., Kaushal, R., Tewari, S. K., Raverkar, K. P., Chaturvedi, S., & Chaturvedi, O. P. (2013). Biomass production and carbon sequestration in different tree-based systems of Central Himalayan Tarai region. *Forests, Trees and Livelihoods*, *22*(1): 38–50.

Kumar, M. (1996). Bio-Econoic Appraisal of Agroforestry Land Use Systems. College of Forestry Dr. Yashwant Singh Parmar University of Horticulture And Forestry.

Kumar, N. (2004). Appraisal of Existing Agroforestry Systems In Sub-Tropical Region of Himachal Pradesh. Chaudhary Charan Singh Haryana Agricultural University; Hisar.

Kumar, S. (2003). Carbon dynamics studies in agroforestry systems of Western Himalaya. College of Forestry Dr. Yashwant Singh Parmar University of Horticulture And Forestry.

Lefroy, E. C. (2009). Agroforestry and the functional mimicry of natural ecosystems. *Agroforestry for Natural Resource Management. CSIRO Publishing, Melbourne, Australia*, 23–35.

Masoodi, H. U. R. (2010). Etation Dynamics and Land Use Cover of 'Ga3a'micro-Watershed of Giri River In Solan District of Himachal Pradesh, India. Uhf, Nauni, Solan.

Montagnini, F., & Metzel, R. (2017). The contribution of agroforestry to sustainable development goal 2: end hunger, achieve food security and improved nutrition, and promote sustainable agriculture. In *Integrating landscapes: Agroforestry for biodiversity conservation and food sovereignty* (pp. 11–45). Springer.

Nair, P. K. R. (1993). An Introduction to Agroforestry Kluwer academic publishers. *The Netherlands.*

Pradeep, K. (2016). Appraisal of Existing Agro Forestry Systems in Sub Temperate Region of Solan District of Himachal Pradesh. Uhf, Nauni.

Rajput, P. (2016). Carbon storage, soil enrichment potential and bio-economic appraisal of different land use systems in mid hill and sub-humid zone-II of Himachal Pradesh.

Sharma, K., Thakur, S., Sharma, R., & Kashyap, S. D. (2008). Production and economics of Kinnow cultivation with wheat and gobhi sarson in Himachal Pradesh. *Indian Journal of Soil Conservation*, *36*(2): 112–118.

Sharma, P., Singh, M. K., Tiwari, P., & Verma, K. (2017). Agroforestry systems: Opportunities and challenges in India. *Journal of Pharmacognosy and Phytochemistry*, *1*(sp), 953–957.

Singh, R. (2017). Studies on Identification And Socio-Economic Status of Existing Agroforestry Systems In Shimladistrict of Himachal Pradesh. Uhf, Nauni.

Syahri, Y. F., Larekeng, S. H., & Susilowati, A. (2020). Assessment of Population Genetic Diversity of cocoa (*Theobroma cacao* L.) using RAPD markers: The Case of Agroforestry's System in East Kolaka, Indonesia. *Int. J. Emerg. Technol.*, *11*: 887–891.

Tomar, J. M. S., Ahmed, A., Bhat, J. A., Kaushal, R., & Shukla, G. (2021). Potential and Opportunities of Agroforestry Practices in Combating Land Degradation.

Upadhyaya, K. (1997). Diagnostic Survey of Agroforestry Systems in Balh Valley of Himachal Pradesh. College of Forestry Dr. Yashwant Singh Parmar University of Horticulture and Forestry.

How to cite this article: Sharma, J., Sharma, S. D., Sharma, K.' and Sharma, D. (2021). Appraisal of Biological Yield and Economic Returns of Existing Agroforestry Systems in Tehsil Bangana of Una District of Himachal Pradesh, India. *Biological Forum – An International Journal*, *13*(2): 413-419.