ANSF
APPLIED AND NATURAL SCIENCE FOUNDATION

Journal of Applied and Natural Science
11(3): 743- 751 (2019)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

Productivity and economic evaluation of Willow (*Salix alba* L.) based silvopastoral agroforestry system in Kashmir valley

G.M. Bhat
Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Benhama, Ganderbal-191201 (J&K), India
M.A. Islam*
Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Benhama, Ganderbal-191201 (J&K), India
A.R. Malik
Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Benhama, Ganderbal-191201 (J&K), India
T.A. Rather
Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Benhama, Ganderbal-191201 (J&K), India
F.A. Shah Khan
Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Benhama, Ganderbal-191201 (J&K), India
A.H. Mir
Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Benhama, Ganderbal-191201 (J&K), India

*Corresponding author. E-mail: ajaztata@gmail.com

Article Info
https://doi.org/10.31018/jans.v11i3.2104
Received: May 14, 2019
Revised: September 7, 2019
Accepted: September 9, 2019

How to Cite
Bhat, G.M. *et al.* (2019). Productivity and economic evaluation of Willow (*Salix alba* L.) based silvopastoral agroforestry system in Kashmir valley. *Journal of Applied and Natural Science*, 11(3): 743- 751 https://doi.org/10.31018/jans.v11i3.2104

Abstract
Performance of two fodder crops namely, sorghum (*Sorghum vulgare* L.) and maize (*Zea mays* L.) was investigated with Willow (*Salix alba* L.) to evaluate productivity and economics of the silvopastoral agroforestry system in Kashmir valley. The experiment was laid out by planting two year old willows at 2.0m × 2.0m spacing and dividing the main plot into sub-plots of size 8m × 2m each with 5 replications in randomized block design (RDB). The intercrops of sorghum and maize were maintained at 20cm × 10 cm spacing and supplied with recommended doses of fertilizers. The economics of the willow plantation intercropped with fodder crops was compared with sole willow farming by the benefit-cost ratio and net present worth. The study revealed the differential behaviour of *Salix alba* regarding growth parameters (height, diameter and girth) by different intercrops and various fodder intercrops with respect to yield, above ground biomass, dry matter production and soil nutrient status (pH, organic carbon, available nitrogen, phosphorus and potassium). The willow based silvopastoral system was estimated to have benefit-cost ratio of 2.71 with maize and 2.68 with sorghum, while as sole crop the willows accrued a benefit-cost ratio of 2.66. The study is useful in discovering growth of willows, productivity of fodder crops and soil nutrient status under various silvopastoral agroforestry systems for maximizing economic gains. The findings envisaged evidences in favour of adopting willow based silvopastoral agroforestry instead of sole tree farming and the knowledge of interactions will be helpful in proper management of the system for sustained multiple productions.

Keywords: Agroforestry, Biomass, Economics, Fodder crops, Silvopastoral, *Salix alba*, Soil nutrients

INTRODUCTION

Agroforestry is a sustainable land management system where woody perennials are integrated with agriculture and pastoral operations in farm and rangeland to maximize production, diversify local products and economies, secure food and livelihood security, improve landscape and micro-climate, sustain socioeconomic and cultural stability and strengthen environmental benefits (Leakey, 1996; Brown *et al.*, 2018; Dar *et al.*, 2018). Agroforestry is a sustainable land-use system that combines trees and/or shrubs deliberately with crops and/or livestock into an intensive production system to optimize the benefits (Nautiyal *et al.*, 1998; Moula, 2005; Schaffer *et al.*, 2019). The practice of agroforestry is done taking into consideration many benefits it can offer to a farmer in a large or small scale such as (i) financial outcomes including capital investment, increased family income, creating employment opportunities, migration reduction, increased livestock production, supplementary income, decreased farm expenditure, utilization of unproductive lands, enhancement of property values, *etc*. (ii) environmental outcomes including increase in biomass production, decreased land degradation, groundwater recharge, reduction in dependency on natural forests, reduction in incidence of pest and diseases, climate change mitigation, modification of micro-climate, carbon sequestration, pollution reduction, biodiversity conservation and protection of wildlife habitat, *etc*. (iii) agricultural outcomes including soil improvement, enhanced production of food grains, providing shade and shelter, weed control, multiple forest products like fuel, fodder, timber and other NTFPs, *etc*. (iv) cultural outcomes including maintenance of cultural heritage, recreation opportunities, preservation of spirituals, values, beliefs, customary rituals, habits, totems, festivals, taboos, folklore, traditional recipes *etc*. (Thomas 1990; Nair 1991; Swinkels and Scherr, 1991; Current *et al.,* 1995; Blanc *et al*., 2019; Hanisch *et al*., 2019; Musa *et al*., 2019). These benefits of agroforestry add up to a substantial improvement of the economic and resource sustainability of agriculture (Islam *et al*., 2015; Quli and Islam, 2017; Yadav *et al*., 2019). In fact, combining the woody trees and shrubs with agricultural and pastoral operations, the agroforestry ensures sustainable multifunctional integrated production system for generations (Quli *et al*., 2017; Chará *et al*., 2019; Jose and Dollinger, 2019). Agroforestry is today even more relevant in the context of growing human and livestock population especially in developing countries like India (Dagar, 2012; Bhat and Islam, 2017). In fact silvoarable agroforestry has recently been proposed as an alternative land-use system for Europe (Reisner *et al*., 2007). The scope to increase the land area under cultivation to solve the problem of acute shortages of food, fuel wood, fodder, timber and other NTFPs is very limited. Presently, there is huge dearth of fuel wood (77%), timber (55%), green fodder (77%) and dry fodder (51%) (Roy, 1999).

Consequently, we require to increase the production from the land already under cultivation by adopting systems which are capable of producing the daily human needs *i.e.* food, fodder, timber and fuel wood from marginal areas by increasing productivity and also maintaining and improving the quality of environment (Kareemulla *et al*., 2009). Agroforestry is the only viable alternative which is capable of meeting the present challenges (Islam *et al*., 2016; Bhaskar *et al*., 2019). The agroforestry landscape spreads over 20% of the total geographic region of the Himalayan setting of India and the agroforestry network is distributed in the surroundings of forests covering 52% area (Anon., 2017). Hence, land development planning in the region needs to be based on an integrated consideration of agroforestry and forestry systems rather than considering the two systems as independent or alternative land uses (Islam *et al*., 2017a). In general, very few studies are available focussing on agroforestry economic analyses. The reviews (Swinkels and Scherr, 1991) shown that majority of the economic analyses done for any specific agroforestry practices so far have focused mainly on financial profits only. Although a number of studies (Mughal and Bhattacharya, 2000; Mughal and Bhattacharya, 2002; Sood, 2006; Banyal *et al*., 2011; Islam *et al*., 2012; Islam *et al*., 2015; Ahmad *et al*., 2017; Islam *et al*., 2017; Maqbool *et al*., 2017) on Himalayan agroforestry systems exist, but little work has been done in this regard in the Kashmir Himalayan region (Mir and Khan, 2008; Islam *et al*., 2017b). The aim of this article is to study the interaction of the components of an agroforestry system and to construct the projected economic analysis based on the benefit-cost ratio of the system. Therefore, the present study analysed the projected economic analysis, dry matter production and nutrients status of soil in a silvopastoral agroforestry involving willow (*S. alba* L.) plantation and fodder crops of sorghum (*Sorghum vulgare*) and maize (*Zea mays* L.).

MATERIALS AND METHODS

The silvopastoral experiment was laid out at farmer's field in randomized block design (RDB) at Shalimar, Srinagar, J&K, India. The site extends within 34°05' N latitude and 74°89' E longitude at an altitude of 1560 meters above mean sea level. The two year old willow plants were planted at the beginning of our experiment. The main plot was divided into sub-plots of size 8m × 2m each in which four willow trees were at a spacing of 2m × 2m. The experiment was laid out with 5 replications. The interspaces maintained under 20cm × 10cm spacing were intercropped with sorghum and maize and the fertilizers doses already recommended were applied. The climate is general of typical temperate type; the winters are severe extending from December to March and the temperature goes below freezing point. Most of the precipitation is received from December to April in the form of snow or rain. The summers are moderate with temperatures ranging from 25°C to 33°C from April to September. The autumn season extends from October to November with temperature between 18 °C to 25 °C.

The tree height (m) was measured from the ground to the tip of the main shoot with the help of the graduated wooden scale. The girth (cm) of the trees was measured at breast height (1.37 m) with the help of measuring tape. The diameter (cm) of the trees was measured at breast height using caliper, in both the directions analogous to the axes of the tree bole opposite to each other and the average of the two measurements was worked out to obtain diameter with minimum error. The samples of the soil were collected from 0-25 cm depth using posthole augur, air dried, passed through sieve and analyzed for various chemical characters. The yields were recorded by randomly selecting 25 plots in each treatment and weight on fresh weight basis, which was converted into average yield (q/ha) in terms of usable or edible portion.

The data obtained on the economical analysis were subjected to statistical analysis (Snedecor and Cochran, 1967); the significant effects of the treatments were exhibited by calculating the least significance difference (LSD) at 5% probability level. Projected benefit-cost ratio of sole tree crop (of same dimensions as that of tree + crop) and combination (tree + crop) was computed by taking the net present benefits as numerator and the net present costs as denominator. Conversely, the net present worth was estimated by the subtraction of the net present benefits with net present costs as described in our previous paper (Mir and Khan, 2008).

$B = N_1/N_2$

where, B = benefit/cost ratio,

N_1 = net present benefits, and

N_2 = net present costs.

$W = N_1 - N_2$

where, W = net present worth (NPW).

The benefit/cost ratio and the net present worth (NPW) of the agroforestry systems were analysed on per hectare basis. Inputs like fertilizers were given to the fodder crops on per hectare basis as as per the recommendations suggested in the package and practices of the fodder crops (Table 1) and the cost of fertilizers were estimated as per the current local market prices of fertilizers. The quantity of planting materials *viz*., maize seeds, sorghum seeds, two-year old willow seedlings required to be planted at a spacing of 2m ´ 2m in a hectare were first estimated (Table 2), then the costs of these planting materials were calculated as per the local market rate. The labour costs for the agroforestry plantation establishment, maintenance, intercropping, harvesting *etc.* required during the experimentation and throughout the rotation of willow were calculated as per the local labour rates (Table 3). Rapid market survey were conducted to ascertain the sale rate of the agroforestry products namely, grasses, tree fodder, fuel wood and timber for cricket bat clefts *etc.* (Table 4).

The cash flow was negative in the initial years because the costs invested were more mainly due to land preparation, pit digging, fencing, implements, *etc*. while the cash flow was positive in the subsequent years because the benefits earned were more due to harvesting of grasses, tree fodder, fuel wood *etc*. However, the social and environmental benefits accrued from agroforestry systems were not included in the benefit/cost ratio analysis. Basically, the development of agroforestry plantation is a long-gestation enterprise, where huge costs are invested in early years and the financial benefits are generally accrued after many years. Hence, the costs and benefits of agroforestry plantation are calculated in advance considering all the factors at the commencement of the venture (Feldhake *et al*., 1985; Nair, 1998; Leakey, 2012; Musokwa *et al*., 2018). It was planned that the harvesting of the agroforestry tree crop will be carried out at the rotation of 16 years and all the products will be marketed in the local market at firsthand purchasers by the farmers. The benefit-cost analysis of the agroforestry plantation was computed assuming the rate of return @ 12%. To ensure best growth and development of the agroforestry plantation, gain better earlier returns from the usufructs and get maximum net timber yield, the pre-commercial thinnings to be practiced were presumed at the age of 8, 10 and 12 years. The intercropping of fodder crops *viz*., sorghum and maize in the interspaces of agroforestry plantations in the succeeding years was assumed till the years when the tree canopy becomes denser and growth and production of the crops is reduced.

Valuation of benefits: Fuel wood: Since fuel wood is sold in village markets, hence, its value was estimated at prevailing market prices.

Tree leaf fodder: It was estimated on the present average market prices for the trees of specific size and age and was sold on weight basis i.e. ₹/ ton.

Timber: The trees left upon rotation age were presumed to have been cut for timber (Cricket bat clefts) and valued as per market prices.

Fodder Crops: The fodder crops (sorghum and maize) were sold as per the prevailing market and the yield of these intercrops in the subsequent years was presumed to have been drastically reduced due to closing of the tree canopy and not taken into consideration.

RESULTS AND DISCUSSION

Growth of *Salix alba* as affected by intercrops: The average tree height were; initial, 4.65 m; final, 5.18 m *i.e*. 11.40% increase in height and girth were; initial; 13.92 cm; final, 14.80 cm *i.e*. 6.35% increase in girth under *S. alba* + maize. Similarly, the average height of trees were; initial, 4.00 m; final, 4.42 m *i.e*. 10.72 % increase in height and average girth of trees were; initial, 12.66 cm; final, 13.64 cm i.e. 7.78 % increase in girth for *S. alba* + sorghum. *S. alba* alone performed average tree heights; initial, 5.0 m; final, 5.70 m *i.e.* 14.02% increase in height and average girths; initial, 14.82 cm; final, 16.02 cm *i.e.* 8.06 % increase in girth (Table 5). The growth data for *S. alba* trees as influenced by intercropping of maize and sorghum was recorded for height and girth at two stages *i.e.* before sowing intercrops and at the end of the growing season. The results indicated that per cent increase in height and girth was recorded largest in *S. alba* alone. However, significant per cent increase in growth and girth of *S. alba* was also recorded with intercrops. The maximum growth when raised without intercrops (control)

Table 1. Fertilizer cost for silvopastoral agroforestry plantation.

Variable	Quantity (Kg ha^{-1})			Rate (₹)*			Total Amount (₹)
	Urea	DAP	MOP	Urea	DAP	MOP	
Sorghum	190	110	64	1140	1375	384	2899
Maize	171	132	32	1026	1650	192	2868

*@ ₹ 600, 1250 and 600 for one quintal each of urea, DAP and MOP respectively

Table 2. Cost of planting materials for silvopastoral agroforestry plantation.

Variable	Quantity	Rate (₹)	Amount (₹)
Willow trees (Seedling)	2500	10	25000
Sorghum (kg)	30kg	30	900
Maize (kg)	50kg	10	500

Table 3. Labour costs for silvopastoral agroforestry plantation.

Variable	Year/ Amount (₹)*						
	1	2	3	4	5	6-15	16
Willow	11620	3500	7000	10500	14000	358320	5040
Sorghum	18000	16000	7000	10500	14000	358320	5040
Maize	18000	16000	7000	10500	14000	358320	5040

Table 4. Market prices of agricultural and tree produces of silvopastoral agroforestry plantation.

Item	Price (₹)
Sorghum (ton)	3000
Maize (Fodder) (ton)	2500
Fuel wood (ton)	3000
Tree fodder (ton)	750
Timber (Cricket bat clefts)	100

was obviously due to absence of any competition for growth resources (Ahmad *et al*., 2017; Bhaskar *et al*., 2019). The tree growth information provided an indication of better production values per unit area under agroforestry which is in consistent with the previous workers (Anusha *et al*., 2015; Blanc *et al*., 2019; Brown *et al*., 2018).

Yield of intercrops as affected by *Salix alba:* The fodder crop's average yield was; 199.60 q/ha; 35.68% reduction in yield over control under *S. alba* + maize. Similarly, the average yield of agricultural crops was 156.55 q/ha; 48.69% reduction in yield over control for *S. alba* + sorghum. The average yield of maize alone was 310 q/ha and the average yield of sorghum alone was 305.12 q/ha (Table 5). The yield was considerably higher when agricultural crops were grown as sole crops than the crops grown as intercrops with *S. alba*. While comparing the yield of sole crops with their corresponding intercrops, highest reduction in yield was recorded in *S. alba* + sorghum followed by *S. alba* + maize. The reduction in yield of intercrops grown in association with *S. alba* reflected the competition for growth resources such as, moisture, nutrients, and radiant energy (Feldhake *et al*., 2008; Dar *et al*., 2018). The reduction in the yield of intercrops with *S. alba* as compared to

Table 5. Tree height, girth, crop yield, yield reduction and crop dry weight under willow (*Salix alba* L.) based silvopastoral agroforestry system.

Treatment	Tree height (m)			Tree girth (cm)			Crop yield (q/ha)	Yield reduction (%)	Dry weight (q/ha)		
	Initial	Final	Increase (%)	Initial	Final	Increase (%)			35 days	70 days	105 days
S. alba + maize	4.65	5.18	11.40	13.92	14.80	6.35	199.60	35.68	0.42	6.58	18.70
S. alba + sorghum	4.00	4.42	10.72	12.66	13.64	7.78	156.55	48.69	0.18	4.23	14.97
S. alba alone	5.00	5.70	14.02	14.82	16.02	8.06	-	-	-	-	-
Maize	-	-	-	-	-	-	310.37	-	1.70	16.76	30.35
Sorghum	-	-	-	-	-	-	305.12	-	1.40	14.01	28.91

Table 6. Nutrient status of soil before and after sowing of crops under willow (*Salix alba* L.) based silvopastoral agroforestry system.

Treatment	Before sowing					After sowing				
	pH	Organic carbon (%)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)	pH	Organic carbon (%)	Available nitrogen (kg/ha)	Available phosphorus (kg/ha)	Available potassium (kg/ha)
S. alba + maize	6.35	0.94	304.08	17.66	260.50	6.27	0.99	306.00	18.00	274.54
S. alba + sorghum	6.40	0.91	295.00	19.50	302.40	6.23	0.97	297.31	20.00	310.28
Maize	6.61	0.73	277.37	15.73	266.20	6.29	0.75	277.50	15.80	265.90
Sorghum	6.67	0.79	279.00	16.06	228.80	6.60	0.80	279.30	16.25	230.10

Table 7. Net present worth (NPW) and benefit-cost (BC) of *Salix alba* + Maize based silvipastoral agroforestry plantation (₹/ha).

Particular	Year							
	1st	2nd	3rd	4th	5th	6th-15th	16th	Total
Costs:								
Depreciation on fixed cost (₹ 56000) @10% & land rental	23600	23040	22536	22082	21674	201537	19153	333622
Plantation & harvesting costs (Tree)	38420	5300	8800	12300	15800	376320	156840	613780
Cultivation & harvesting costs (Maize)	22436	20336	--	--	--	--	--	42772
Interest*	5244	1538	2049	2228	2411	36183	10703	61911
Total cost	**89700**	**50214**	**33385**	**36610**	**39885**	**614040**	**186696**	**1052085**
Benefits:								
Fuel wood & fodder	--	15000	30000	45000	60000	2669400	21600	2841000
Timber (Cricket bat clefts)	--	--	--	--	--	--	900000	900000
Maize	49900	15517	--	--	--	--	--	65417
Total benefits	**49900**	**30517**	**30000**	**45000**	**60000**	**2669400**	**921600**	**3806417**
Discounted costs @ 12% pa.	89700	44690	26374	25993	25128	206932	29871	448688
Discounted benefits @ 12% pa.	49900	27160	23700	31950	37800	899586	147456	1217552

NPW= ₹ 1217552 – ₹ 448688 = ₹ 768864; B/C ratio = ₹ 1217552/ ₹ 448688 = 2.71, Fixed cost include costs of fencing, irrigation, repairs, implements *etc.*; Plantation/Cultivation costs include costs of planting material, seed, fertilizer, labour etc. and 5% miscellaneous charges.* Represents interest on fixed cost @ 6.75% and on variable cost @ 6%.

Table 8. Net present worth (NPW) and benefit-cost (BC) of *Salix alba* + Sorghum based silvipastoral agroforestry plantation (₹/ha).

Particular	Year							
	1st	2nd	3rd	4th	5th	6th-15th	16th	Total
Costs:								
Depreciation on fixed cost (₹ 56000) @10% & land rental	23600	23040	22536	22082	21674	201537	19153	333622
Plantation & harvesting costs (Tree)	38420	5300	8800	12300	15800	376320	156840	613780
Cultivation & harvesting costs (Sorghum)	22831	20731	--	--	--	--	--	43562
Interest*	5268	1562	2049	2228	2411	36183	10703	60404
Total cost	**90119**	**50633**	**33385**	**36610**	**39885**	**614040**	**186696**	**1051368**
Benefits:								
Fuel wood & fodder	--	15000	30000	45000	60000	2669400	21600	2841000
Timber (Cricket bat clefts)	--	--	--	--	--	--	900000	900000
Sorghum	46965	9150	--	--	--	--	--	46762
Total benefits	**39137**	**24150**	**30000**	**45000**	**60000**	**2669400**	**921600**	**3787762**
Discounted costs @ 12% pa.	90119	45063	26374	25993	25128	206932	29871	449480
Discounted benefits @ 12% pa.	46965	21493	23700	31950	37800	899586	147456	1208950

NPW= ₹ 1208950 – ₹ 449480 = ₹ 759470; B/C ratio = ₹ 1208950/ ₹ 449480 = 2.68, Fixed costs include costs of fencing, irrigation, repairs, implements etc., Plantation/Cultivation costs include costs of planting material, seed, fertilizer, labour etc. and 5% miscellaneous charges., * Represents interest on fixed cost @ 6.75% and on variable cost @ 6%.

their sole crops can be explained as per observations of (Ong *et al*., 1996; Jose and Dollinger, 2019), who stated that the main source of radiation in understory crop is diffuse radiation which has previously been intercepted and transmitted. This process is known to deplete significant amount of photo-synthetically active radiation (PAR) before it reaches understory crop (Edje, 2014; Musokwa *et al*., 2018).

Dry matter production of intercrops as affected by *Salix alba*: The dry matter production of intercrop were; after 30 days (0.42 q/ha), after 70

Table 9. Net present worth (NPW) and benefit-cost (BC) of *Salix alba* plantation (₹/ha).

Particular	Year							
	1st	2nd	3rd	4th	5th	6th-15th	16th	Total
Costs:								
Depreciation on fixed cost (₹ 56000) @10% & land rental	23600	23040	22536	22082	21674	201537	19153	333622
Plantation & harvesting costs (Tree)	38420	5300	8800	12300	15800	376320	156840	613780
Interest*	3898	1873	2049	2228	2411	36183	10703	59345
Total cost	**65918**	**30213**	**33385**	**36610**	**39885**	**614040**	**186696**	**1006747**
Benefits:								
Fuel wood & fodder	--	15000	30000	45000	60000	2669400	21600	2841000
Timber (Cricket bat clefts)	--	--	--	--	--	--	900000	900000
Total benefits	**--**	**15000**	**30000**	**45000**	**60000**	**2669400**	**921600**	**3741000**
Discounted costs @ 12% pa.	65918	26889	26374	25993	25128	206932	29871	433479
Discounted benefits @ 12% pa.	--	13350	23700	31950	37800	899586	147456	1153842

NPW= ₹ 1153842 – ₹ 433479 = ₹ 720363; B/C ratio = ₹ 1153842/ ₹ 433479 = 2.66; Fixed costs include costs of fencing, irrigation, repairs, implements etc.; Plantation cost includes costs of planting material, fertilizer, labour etc. and 5% miscellaneous charges; * Represents interest on fixed cost @ 6.75% and on variable cost @ 6%.

days (6.58 q/ha) and after 105 days (18.70 q/ha) under *S. alba* + maize. Similarly, the dry matter production of intercrop were; after 30 days (0.18 q/ha), after 70 days (4.23 q/ha) and after 105 days (14.97 q/ha) for *S. alba* + sorghum. The dry matter production of maize alone was recorded as follows; after 30 days (1.70 q/ha), after 70 days (16.76 q/ha) and after 105 days (30.35 q/ha). The dry matter production of sorghum alone was recorded as follows; after 30 days (1.40 q/ha), after 70 days (14.01 q/ha) and after 105 days (28.91 q/ha) (Table 5). Dry matter production of agricultural crops was recorded at three different stages at an interval of 35 days from the date of sowing. The results showed significant differences in dry matter production at all three stages, when intercrops are compared with their corresponding sole crops. It was observed that the variation of dry matter production between sole crop and their respective intercrops reduced as these crops advanced to maturity. This may be attributed to the fact that in the agroforestry system the crops were not able to utilize resources (light, nutrients, moisture) efficiently (Schaffer *et al*., 2019; Yadav *et al*., 2019). Here, the diffuse radiations have previously been intercepted and transmitted, perhaps several times by the foliage of the tree. Therefore, this process depletes a significant amount of photosynthetically active light (PAL) before it reaches the understory crop (Bhaskar *et al*., 2019; Chará *et al.*, 2019) and this interception of PAL may be responsible for decrease in the photosynthetic production in crops grown as intercrops (Brown *et al*., 2018; Hanisch *et al*., 2019) and consequently decrease in dry matter production was observed.

Nutrient status of soil: Before sowing the nutrient status of soil was recorded as; pH (6.35), organic carbon (0.94), available nitrogen (304.08 kg/ha), available phosphorus (17.66 kg/ha), available potassium (260.50 kg/ha) under *S. alba* + maize. Similarly, the nutrient status of soil was found to be; pH (6.40), organic carbon (0.91), available nitrogen (295.00 kg/ha), available phosphorus (19.50 kg/ha), available potassium (302.40 kg/ha) for *S. alba* + sorghum. The soil nutrient status for maize only was; pH (6.61), organic carbon (0.73), available nitrogen (277.37 kg/ha), available phosphorus (15.73 kg/ha), available potassium (266.20 kg/ha). The soil nutrient status for sorghum only was; pH (6.67), organic carbon (0.79), available nitrogen (279.00 kg/ha), available phosphorus (16.06 kg/ha), available potassium (228.80 kg/ha). After sowing the nutrient status of soil was recorded as; pH (6.27), organic carbon (0.99), available nitrogen (306.00 kg/ha), available phosphorus (18.00 kg/ha), available potassium (274.54 kg/ha) under *S. alba* + maize. Similarly, the nutrient status of soil was found to be; pH (6.23), organic carbon (0.97), available nitrogen (297.31 kg/ha), available phosphorus (20.00 kg/ha), available potassium (310.28 kg/ha) for *S. alba* + sorghum. The soil nutrient status for maize only was; pH (6.29), organic carbon (0.75), available nitrogen (277.50 kg/ha), available phosphorus (15.80 kg/ha), available potassium (265.90 kg/ha). The soil nutrient status for sorghum only was; pH (6.60), organic carbon (0.80), available nitrogen (279.30 kg/ha), available phosphorus (16.25 kg/ha), available potassium (230.10 kg/ha) (Table 6).

Soil samples for analysis of pH, organic carbon and available NPK were collected from each of the five replications among treatments before the layout of the experiment and also after the end of the growing season and analyzed as per standard procedure. It was observed that initially the soil reaction was slightly acidic and available NPK and organic carbon was observed to be in the medium range. From these examinations, it was assumed that the soil was fit for cultivation of agricultural crops. Analysis of soil after harvesting the intercrops, it was observed that pH of the soil decreased slightly. This decrease in pH after harvesting the intercrops as compared to initial pH can be attributed to greater uptake of cation nutrients by the tree and crops and resultant excretion of H^+ ions into the soil (Maqbool *et al*., 2017). Also lowering of pH can be explained on the basis that organic acids were produced during the decomposition of organic matter (Dar *et al*., 2018). Lowering of pH in agroforestry system was also reported by Parthiban and Rai (1994).

Furthermore, organic carbon per cent showed increase after the harvest of the crops as compared to nutrient status before layout of experiment. The increase in organic carbon per cent can be explained from the fact that the major avenue for addition of organic matter to the soil is through litter-fall and increase in organic carbon after harvesting can be attributed to decomposed roots, fallen leaves (Fettweis *et al*., 2005; Musokwa *et al*., 2018). The soil samples after harvesting showed the increased amount of available NPK in comparison to initially analyzed samples. The increase in nitrogen content and available phosphorus may be attributed primarily to its restitution to soil through fall (Bhaskar *et al*., 2019). The available phosphorus might also have increased due to organic acids released during microbial decomposition of organic matter enhancing thereby solubility of native phosphates and increase in available phosphorus (Anusha *et al*., 2015). The increase in available potassium may also be attributed to litter fall (Edje, 2014).

Economic analysis: The results (Tables 7-9) on the projected benefit/cost ratio, depicted that there is considerable enhancement in the financial profits by raising sorghum and maize (fodder crops) in combination with willow trees in agroforestry compared with sole willow plantation. The NPW of sorghum, maize and willow (as sole crops) were ₹ 759470, ₹ 768864 and ₹ 720363 per hectare, respectively. The projected benefit-cost ratio analysis indicated that the silvopastoral agroforestry plantation of willow + sorghum and willow + maize generated a benefit/cost (BC) ratio of 2.68 and 2.71 respectively, while the sole willow plantation accrued a BC ratio of 2.66. The silvopastoral practice is one of the most benefiting practices of agroforestry in terms of economic returns and environmental benefits (Chará *et al*., 2019; Hanisch *et al*., 2019; Jose and Dollinger, 2019). The cost components in the silvopastoral experiment were land preparation, pit digging, planting material, fencing for the experimental area, fertilizers, labour for planting, inter-culture harvesting and land rental *etc*. The items of return include fodder crops (sorghum and maize), fuel wood, tree leaf fodder and timber (cricket bat clefts). The study (Mir and Khan, 2008) with willow intercropping with some vegetable crops, it was observed that intercropping also generated higher BC ratio. The results are encouraging and support the fact that there is an increase in the levels of farm income while adopting agroforestry system as stated by earlier workers (Jain *et al.,* 1999; Bhaskar *et al*., 2019; Blanc *et al*., 2019). Karemulla *et al.* (2002) has reported a higher gross as well as net return from silvopastoral system over single crop which is in line with the present results. The earlier studies (Reddy and Korwar, 1985; Pathak, 1991; Yadav *et al*., 2019) on evaluation of comparative economics of silvopastoral agroforestry systems under dry land conditions used the similar methods and results were in consistent with the present findings of silvopastoral plantation. The results of this study provided circumstantial evidence in favour of adopting agroforestry over sole forestry (Ahmad *et al*., 2017; Musa *et al*., 2019).

Conclusion

The study demonstrated that the interaction of plant species (tree + crop) showed significant influence of one component of a system on the performance of the other component as well as a whole system. Agroforestry increases the farm income in a number of ways like, the total productivity per unit area through tree/crop association is more than any sole component only and the new products add to the financial diversity and flexibility of the farming enterprise. In the present circumstances, depletion of grazing fields in forests and increase in the livestock production emphasize an escalating necessity for sustainable land-management systems, able to fast transformation in socio-economic and ecological situations and simultaneously, sustaining our natural forests. The present study showed that fodder crops like maize and sorghum are compatible with the willow farming. The economics revealed that maize grown as intercrop with willow generates a return of 2.71 followed by sorghum 2.68. The benefit cost ratio of mono-cropping 2.66 being comparatively much lesser therefore strongly favours the adoption agroforestry practices instead of sole farming. This practice has several indirect benefits especially enriching soil, improving microclimate and storing carbon.

ACKNOWLEDGEMENTS

This research was conducted under the aegis of Faculty of Forestry, SKUAST-K Shalimar, which is gratefully acknowledged. Sincere thanks are due to SKUAST-K for the assistance to carry out this work. The authors thank the farmer for providing his land during the course of this study.

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