Indian Journal of Ecology (2022) 49(5) (SI): 1861-1869
DOI: https://doi.org/10.55362/IJE/2022/3748

Manuscript Number: 3748
NAAS Rating: 5.79

Potential of Different Fruit-based Agroforestry Models for Improving Livelihood in Humid and Sub-Tropical Region of India

Suren Murmu, Gayatri Kumari Padhi[1], Paritosh Murmu[2], Debjit Roy and Pratap Kumar Dhara

Bidhan Chandra Krishi Viswavidyalaya, Mohanpur-741 252, Nadia, India
[1]KVK, Piprakothi, East Champaran, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur-848 125, India
[2]KVK, Nabarangpur, Odisha University of Agriculture & Technology, Bhubaneswar-751 003, India
E-mail: murmu.suren@bckv.edu.in

Abstract: In developmental context of rural areas the major constraints lies is lack of family planning, concomitant population growth, extensive deforestation, fragmented land holdings and monocropping. Agroforestry practices helps improving productivity and reduce inputs, trying to mitigate the adverse effect of monocropping and deforestation. So, the scientific community intervenes to harness the positive effects of agroforestry land use systems and address global issues of land degradation, bio diversity conservation, agriculture sustainability and more recently the climate change and food security by providing good returns to the farmers. In this light a research was conducted at Regional Research Station (Bidhan Chandra Krishi Viswavidyalaya), Jhargram, West Bengal, India to find out suitable fruit-based agroforestry model which comprised silvi species gamhar *(Gmelina arborea)*, fruit crop mango (*Mangifera indica*) and five arable crops viz, cowpea, black gram, groundnut, okra and maize cultivated during Kharif and mustard in Rabi season. The all the growth characters of gamhar (*Gmelina arborea*), production of mango and soil health status were at higher side under agroforestry systems as compare to sole cropping. Gamhar + Mango + Groundnut – Mustard agroforestry model gave the highest returns in terms of income and yield of tree and intercrops i.e ₹8,46,420.62 $ha^{-1}yr^{-1}$ in Indian Rupee (INR).

Keywords: Fruit based Agroforestry, Livelihood, Productivity, Red and lateritic zone

According to FAO, India is the first country in the world to adopt the National Agroforestry Policy in 2014, under Ministry of Agriculture and Farmers Welfare with an objective is to expand tree plantation in combination with crops or livestock to improve overall productivity, reducing unemployment, generating additional source of income for marginal growers. This policy highlights that agro forestry could be implemented to meet the domestic and industrial requirements of the country for wood and its products. Around 31 percent of the Earth's land mass, constitute the total forest cover which accounts to an area of over 4 billion ha (FAO 2010). Mono cropping have been a failure to meet the demands of the people, and attaining sustainability for the future generations and is proved to be at rear side in generating additional income. Therefore, diversification of land use systems with agro forestry is a quintessential need for providing variety of products for meeting requirements of the people, insurance against risks caused by weather fluctuations, improving soil health and ensuring sustainable production with a futuristic approach. Agroforestry is the preferred land use management practice for improving livelihood security by increasing the total productivity per unit area of land, to meet the growing demands of the people for food, fruits, fuel wood, timber, fodder, bio-energy and other ecological services (Sarkar 2019a, Sarkar et al 2017c, Sarkar 2019b). Murmu et al (2016) focussed on diversification of agroforestry by selection of appropriate tree species, their quality planting material and remunerative crop combinations for reclaiming the degraded lands of India by increasing their productivity and economic returns by meeting the water and nutrient requirement of the crops, trees and controlling their insect, pest and diseases. Agroforestry systems provide good economic rates of return and also optimize livelihood solution for poor farmers, biodiversity conservation and environmental sustainability. The integration of trees with agricultural crop diversifies the income drive and enforces sustainability for increased social, economic and environmental benefits through agroforestry which is a dynamic, ecologically-based natural resources management system (Msuya and Kideghesho 2012). Agroforestry aims at promoting economical, social and environmental sustainable rural development (Leakey 2012). In India, agroforestry systems are classified as traditional and advanced agroforestry systems (Korwar et al, 2014).

Fruit-based agroforestry system integrates the cultivation of agronomic crops, vegetable crops, fruit trees and silvi component. The integration of forest trees provides all food, fuel, medicines, fodder, building materials and cash income (Fig. 1). Fruit crop-based multi-storied agroforestry models were the most effective in minimizing the risk of sole cropping in upland watersheds of Eastern India. Kumar (2020) opined that inter space between the fruit crops is utilized for growing short duration cash crops which not only sustain the orchardist during the non-fruiting months of the main crop but also add to the fertility of the soil by enhancing the soil health. Intercropping has greater advantages that increases production, fruit quality chemical composition of fruits and reduces the fruit drop. Rahman et al (2015) ascertained that mango based suitable Agri-horti-silvi cropping models have been standardized for rainfed uplands in the watersheds under sub-humid plateau regions of Eastern India. Mango is an important fruit crop to be included in the agro forestry system as the association is believed to optimize the yields, enhance soil fertility and soil moisture, ameliorates the soil, by adding biomass for long term build up of soil organic matter. Crop production on red and laterite soil under rainfed condition is low and unstable. *G. arborea* is one of the indigenous multipurpose tree species grown in eastern region of India and produces one of the best quality timbers. It is a medium to large-sized deciduous tree of up to 40m height, and grows best in areas with a mean annual rainfall from 800 to 2,500mm, and an annual average temperature of 15-36°C and prefers a heavy soil and damp situation. This plant grows best in loamy alluvial soils, but ranges from gravel to sand to clay. There is a recorded mean increment of annual diameter of 3cm. Wood and wood-pulp both account for use in furniture, bent-wood articles, boat-building, panelling, brushes, slate frames, figure and pattern making

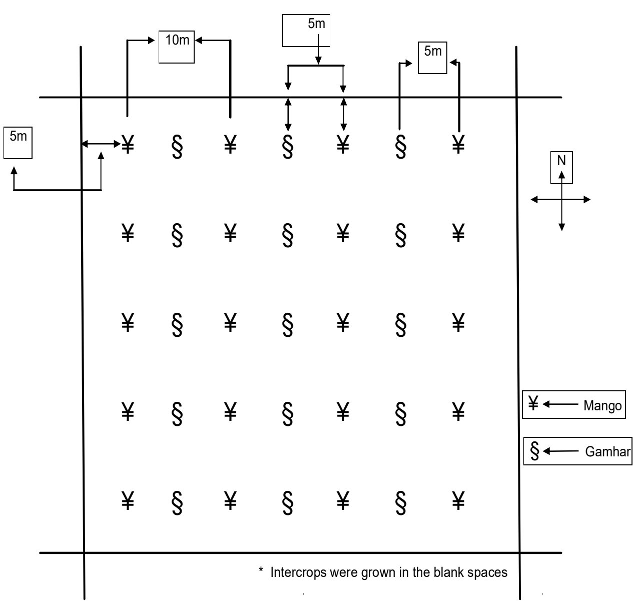

Fig. 1. Layout of experiment

as well as for wrapping, writing and printing papers. It is a well-suited agroforestry tree found in the red and laterite zone of West Bengal (Dhara 2019). Adoption of economically important tree species under agro forestry systems increases the productivity and narrows the gap between demand and supply of wood. (Murmu and Dhara 2022) Mango based agri–horticultural systems constitutes of three main components i.e., main crop, filler crop and inter crops which occupy three different tiers in space of the production system. The intercropping of rainfed arable crops is of immense importance for getting quick returns in the initial years. The integration of short duration arable crops like, pulses, vegetables, groundnut etc. with dry land horticultural fruit trees like, mango, guava etc. is proved to be the most profitable. With areas of 50% of western part of West Bengal being in rainfed condition encounters land degradation and as well as the climate is tropical and humid, hence for enhancement of livelihood a suitable mango-based agroforestry system is needed to be developed for this soil erosion prone zone, where in suitable intercrop integrated with mango-based agroforestry system will provide higher economic return and maintain the sustainability of the environment (Mondal and Dhara 2016).

Keeping in view the prima facia condition of red and laterite zones of West Bengal, a field experiment was undertaken to develop a suitable fruit-based agro-production system for rainfed red and laterite zone of West Bengal.

MATERIAL AND METHODS

Location of the study area: The present study was carried out at Regional Research Station (Red and Laterite Zone) of Bidhan Chandra Krishi Viswavidyalaya at Jhargram, West Bengal, India. The experimental site is located at $22^{0}30”$ N latitude and $87^{0}0”$ E longitude and at an elevation of 78.77 above mean sea level.

Climate and weather: The location of experiment is situated in humid sub-tropical climatic zone and characterized with short winter and long hot summer. The annual precipitation varies between 1100 and 1300mm, about 80% of which are usually precipitated during monsoon period (June-September). Maximum and minimum temperatures during the month of cropping period were found between 25.5-38.8 and 16.4-28.2°C respectively. The detailed meteorological data in respect of air temperature, relative humidity, total rainfall and soil temperature have been collecting from Regional Research Station (Red and Laterite Zone) of Bidhan Chandra Krishi Viswavidyalaya at Jhargram, West Bengal, India.

Soil: The experiment was carried out in upland situation where the soil are coarse texture and acidic (pH 5.5) and poor in organic matter available nitrogen, phosphorus, potassium and lime content and highly susceptible to erosion hazards.

Tree and plant material: Previously established mango (*Mangifera indicia*) trees were used as fruit tree component and Gamhar (*Gmelina arborea*) was used as tree component with six arable crops as intercrops viz. Groundnut (Var. TAG-24), Cowpea (Var. Pusa Barsati), Black gram (var. WBU 109), Maize (var. Kanchan-K-25) and Okra (var. Parvani Kranti).

Experimental design and treatment combination: The experiment initially started in August 2007, with one year old saplings of mango grafts cv. Amrapali (100Nos.) planted along with Gamhar *(Gmelina arborea)* seedlings of about 2months old at 10× 10m spacing. The tree component were planted in between two mango plants and a 5m spacing in between two mango rows and as boundary plantation of the experimental field. The plot size of experiment accompanied with intercrops was 20 × 20m for each treatment. Six arable crops viz. Cowpea (Var. Pusa Barsati), Black gram (var. WBU 109), Groundnut (Var. TAG-24), Okra (var. Parvani Kranti), Groundnut (Var. TAG-24) and Maize (var. Kanchan-K-25). were grown during kharif season (mid-June to Ist October) followed by mustard crop (var. B-9) in rabi season (October to March) of 2015-16 and 2016-17, which was cultivated by using residual soil moisture.

The experiment has been laid out in a randomized block design having 8 treatments (T_1: Gamhar + Mango + Cowpea; T_2: Gamhar + Mango + Black gram followed by Mustard; T_3: Gamhar + Mango + Groundnut followed by Mustard; T_4: Gamhar + Mango + Okra followed by Mustard; T_5: Gamhar + Mango + Maize followed by Mustard; T_6: Gamhar + Mango; T_7: Sole Gamhar; T_8: Sole Mango) with 3 replications. Inter crops were grown with standard agronomic package of practices. Different growth parameters of silvi species and fruit tree (height, DBH, Crown diameter and fruit yield) were recorded.

Land preparation: The experimental land with Gamhar and Mango plants were first ploughed in the month of April. The land preparation was carried out and experimental plots of 20 X 20m were laid out and intercrops were planted accordingly in the kharif season and mustard was grown in the residual moisture.

Application of fertilizer and manures: The recommended doses of cow dung/compost, Urea, SSP and MOP were applied. Full amount of well decomposed cow dung/compost and SSP were incorporated during the final land preparation. The nitrogenous fertilizers were applied in full doses. The recommended doses of fertilizers were applied in all the intercrops grown, as in case of leguminous crops least amount of nitrogenous fertilizer was applied.

Weeding and irrigation: Weeding was done three times in experimental plots to keep the plots weed free. The plots were irrigated by using watering can to supply sufficient soil moisture for the intercrops and mustard was allowed to grow in residual moisture.

Thinning or filling: Emergence of seedlings of intercrops was started after 15days from the date of sowing. Seedlings were thinned out for two to three times at 5days interval from first thinning.

Pest and disease control: No major diseases and pests were observed hence, insecticide and fungicide application was minimal.

Data analysis: Different growth attributes i.e., height, stem girth, crown diameter at breast height and volume yield was recorded.

The basal area of individual Gamhar tree was calculated by using following formula.

$$BA = \pi \times \frac{(DBH)^2}{4}$$

The volume yield calculation (for tree species) was done by quarter girth formula. The volume yield estimates were calculated by the given equation,

$$Y_{vol} = BA \times h_t \times 0.5$$

The commercial biomass of wood of Gamhar was estimated by the help of commercial volume yield and wood density.

Biomass = Volume yield (kg/m^3/ha/yr) × Wood density (kg/m^3)

Data on soil nutrient status had also been taken both prior to commencement of the experiment and after completion of two cycles of inter cropping for calculation of increase or decrease percentage of soil nutrients. The height and yield of mustard was recorded for all the treatments. The yield of mango and intercrops were recorded for all the treatments.

For economic evaluation of the system, the return from tree component, fruit component and the intercrops were calculated by recording the yield of mango and intercrops, along with wood production from different treatments. The return from the tree fruit and intercrops were estimated from the prevailing farm gate prices and were estimated in terms of (Rs/ha/yr). The economics of different treatment was worked out separately by taking into account the yields, existing price of various input and output separately. The investment on fertilizer, labour and power for performing different operations such as ploughing, weeding, irrigation, picking/harvesting (`ha^{-1}) were considered as per market price of Jhargram, West Bengal. The cost of cultivation was taken into account for calculating economics of treatments and to work out return hectare^{-1} (₹ha^{-1}) and benefit cost ratio.

Gross return: Gross returns were obtained by converting the harvest into monetary terms at the prevailing market rate during the course of studies for every treatment.

Net returns: Net return was obtained by subtracting cost of cultivation from gross return.

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

Benefit cost ratio (B: C) : The benefit cost ratio was calculated on the basis of net return per unit cost of cultivation.

$$\text{B : Cratio} = \frac{\text{Net Returns (Rs } h^{-1})}{\text{Cost of Cultivation (Rs } h^{-1})}$$

The data gathered in each observation were statistically analyzed using SPSS version 20 software. The critical differences were calculated to assess the significance of treatment means wherever the 'F' test was found significant at 5% level of probability by means of ANOVA.

RESULTS AND DISCUSSION

Growth parameters of gamhar *(Gmelina arborea)*: The height of the Gamhar tree was recorded to be highest in both the years in treatment (T_3) where Gamhar was intercropped with Mango and Groundnut i.e., 5.78 and 6.67m in 2015 and 2016 respectively (Table 1). This was followed by (T_1) where Gamhar was intercropped with cowpea followed by T_2 (Gamhar + Mango + Black gram – Mustard) and T_5(Gamhar + Mango + Maize – Mustard) and the lowest height recorded in Sole Gamhar i.e., 4.33 and 4.41m in 2015 and 2016 respectively. The DBH and volume yield recorded of Gamhar inferred the same trend as height of the tree, the highest DBH was in T_3 4.71 and 4.89cm, followed by T_1 and T_2. The lowest DBH being recorded from sole Gamhar as 3.44 and 3.58cm respectively in both the years. The increasing age of plant resulted in increasing of growth attributes of the tree (Table 1). The estimates of volume yield of the trees were found to be highest in T_3 0.034 and 0.045 $m^3ha^{-1}yr^{-1}$, followed by T_1. The growth attributing characters were higher in Mango based Agro-production models as compared to sole crop, thus exhibiting a positive effect of mango-based intercropping on tree growth. The growing of legumes as intercrops entrapped positive effect on growth attributes of gamhar as well as on commercial wood biomass of the tree component. The effect of heredity and environment is directed towards growth in diameter and height of tree (Das et al 2017).

All the Mango-based agro forestry systems were significantly different from each other and were found to have increased height and DBH (Diameter at breast height) than the sole crop. The results are in conformity with the findings of Rathore et al (2013). The complementary effect of Mango-based agro-production accompanied with inter-cropping of groundnut on growth and timber volume yield of Silvi species was further elaborated by Das et al (2014) and Sharma et al (2017), where the growth attributes of silvi species (Gamhar) was higher in the mango-based agro forestry model than in sole cropping. The lowest volume yield was in sole crop as 0.015 and 0.016 $m^3ha^{-1}yr^{-1}$ in 2015 and 2016. Swain (2014) opined that yield was higher in mango based agro forestry systems than the sole crop and were significantly different under rainfed situation, fruit tree-based framing system resulted in reduced risk. According to Saravanan (2012) and Fanish & Priya (2013), farmers who are facing problems in practicing unprofitable sole agriculture can raise *G. arborea*. Gamhar is extensively used for timber, industrial wood and fodder production and is grown both on government and private lands in north-east India.

Commercial biomass production & basal area of gamhar : The highest commercial wood mass is 13.73 kg/m^3/ha/yr recorded in the second year (2016) in treatment followed by treatment T_1 (Table 2). There is increase in wood mass in the successive years. The basal area of gamhar also followed

Table 1. Growth attributes of Gamhar tree grown in agroforestry and sole plantation

Mango-based AFS model	Height (m)		DBH (cm)		Volume yield ($m^3ha^{-1}yr^{-1}$)	
	2015	2016	2015	2016	2015	2016
T_1:Gamhar + Mango + Cowpea	5.67	6.63	4.52	4.68	0.034	0.037
T_2:Gamhar + Mango + Black gram – Mustard	5.52	6.55	4.38	4.58	0.029	0.030
T_3:Gamhar + Mango + Groundnut – Mustard	5.78	6.67	4.71	4.89	0.034	0.045
T_4:Gamhar + Mango + Okra – Mustard	5.25	5.56	3.87	4.00	0.020	0.025
T_5:Gamhar + Mango + Maize –Mustard	5.46	5.87	4.22	4.34	0.022	0.031
T_6:Gamhar + Mango	4.84	4.90	3.68	3.84	0.019	0.021
T_7:Sole Gamhar	4.33	4.41	3.44	3.58	0.015	0.016
T_8:Sole Mango	-	-	-	-	-	-
CD (P=0.05)	0.57	0.40	0.42	0.36	0.006	0.005

the same trend as of the growth attributes of gamhar.

Growth attributes of mango under different agroforestry systems: The height, stem girth and crown diameter was found highest in T_3 (6.25 and 7.01m in 2015 and 2016 respectively), followed by T_1 and T_2(Table 3). The least height of mango was recorded in sole cropping of mango i.e., 4.55 and 5.04m in successive years respectively. The maximum stem girth recorded in T_3 was 68.46 and 79.85cm in 2015 and 2016 respectively, followed by T_1. The treatments T_2, $T_5$and T_4 ranked third, fourth and fifth for both height and stem girth. The sole crop of mango recorded lowest stem girth i.e., 48.24 and 53.29 cm in 2015 and 2016 respectively. The same trend was observed in crown diameter of the fruit crop. The crown diameter was highest in T_3 i.e., 5.62 and 6.65cm in both the years followed by T_1 and T_2. The lowest crown diameter 4.77 and 5.60cm was recorded in sole crop of mango. All the treatments were at par from each other.

Production (t/ha) of fruit (mango): The mango yield obtained from T_3 was highest among all treatments in the consecutive years i.e., 6.42 and 9.67t ha^{-1} in 2015 and 2016 respectively, followed by T_1 by T_2, T_4 and T_5respectively (Table 5). The production of mango was more when legume crops were intercropped with mango. The lowest mango yield was obtained in Sole mango crop in consecutive years i.e., 4.54 and 6.09t ha^{-1} in 2015 and 2016 respectively. The mango yield and production of intercrops increased in the year 2016 as compared to year 2015. The increase percent of yield of mango in different AFS models was maximum (50.67%) in T_3-(Gamhar + Mango + Groundnut – Mustard) (Table 5).

Height and yield of intercrops under different agroforestry systems: Yield of intercrops grown under different mango-based agroforestry systems were slightly increased in second year as compared to first year (Table 5). The height of the intercrops was increased by 3.77, 5.71, 11.50, 13.08 and 44.98% in cowpea, groundnut, okra and maize (Fig. 2). The yield of intercrops also increased comparably in 2016 than 2015. The highest increase of yield was recorded in groundnut i.e., 30.47%, followed by cowpea,

Table 2. Commercial biomass production & basal area of Gamhar

AFS model	Wood biomass of Gamhar (kg/m3/ha/yr)			Basal area of Gamhar (m2)		
	2015	2016	Increase (%)	2015	2016	Increase (%)
T_1	10.20	11.20	9.73	0.0117	0.0125	7.35
T_2	8.71	8.98	1.88	0.0109	0.0121	10.51
T_3	10.47	13.73	31.16	0.0126	0.0136	7.41
T_4	6.17	7.66	24.17	0.0083	0.0091	9.22
T_5	6.66	9.53	42.99	0.0101	0.0107	5.45
T_6	5.74	6.26	9.01	0.0078	0.0084	7.22
T_7	4.41	4.88	10.51	0.0067	0.0073	8.48
T_8	-	-	-	-	-	-
CD (p=0.05)	1.83	1.59	-	0.0021	0.0018	-

See Table 1 for treatment details

Table 3. Growth attributes of Mango tree grown in agroforestry and sole plantation

AFS model	Height (m)		Stem girth (cm)		Crown diameter (cm)	
	2015	2016	2015	2016	2015	2016
T_1	6.18	6.85	65.87	75.91	5.57	6.62
T_2	5.99	6.77	61.83	70.39	5.48	6.58
T_3	6.25	7.01	68.46	79.85	5.62	6.65
T_4	5.85	5.86	52.02	62.03	4.98	5.86
T_5	5.90	6.62	55.64	66.01	5.41	5.95
T_6	4.93	5.73	52.21	58.93	4.90	5.91
T_7	-	-	-	-	-	-
T_8	4.55	5.04	48.24	53.29	4.77	5.60
CD (p=0.05)	0.13	0.47	6.05	8.16	0.39	0.75

See Table 1 for treatment details

blackgram, okra and maize with increase of 10.65, 7.91, 3.71 and 0.96% respectively (Fig. 3). The increase in yield in second year was might be due to the addition of nutrients from crop residues from first year and micro flora activity in the rhizosphere. Kaur et al (2017) also observed profitable intercropping in mango plantation.

Height and production of mustard in different agroforestry models: The height of mustard increased in the successive year 2016. The highest height of mustard was recorded in T_5 (Gamhar + Mango + Maize – Mustard) (101.07 and 103.55m in 2015 and 2016 respectively), followed by T_3 (Fig. 4). The yield of mustard was maximum in T_5 (Gamhar +

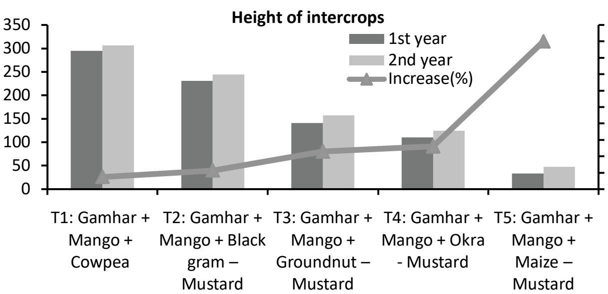

Fig. 2. Height of intercrops in consecutive years in different agroforestry models

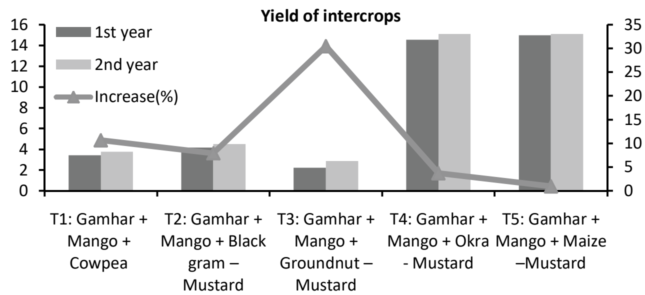

Fig. 3. Yield of intercrops and increase percentage in different agroforestry models

Table 4. Effect of different agroforestry models on soil health status

Treatment	Initial status of nutrient		Final status of nutrient		Increase (%)		Initial status of nutrient			Final status of nutrient			Increase (%)		
	pH	OC	pH	OC	pH	OC	N	P	K	N	P	K	N	P	K
T_1	5.5	0.37	5.7	0.48	3.64	29.73	164.1	17.8	174.1	228.45	24.6	208.32	39.21	38.20	19.66
T_2	5.5	0.36	5.7	0.45	3.64	25.00	169.09	17.5	170.09	231.67	24.13	200.34	37.01	37.89	17.78
T_3	5.4	0.35	5.6	0.43	3.70	22.86	167.37	17.8	177.37	227.32	24.02	207.34	35.82	34.94	16.90
T_4	5.3	0.36	5.5	0.44	3.77	22.22	162.5	19.8	172.5	218.23	26.32	199.32	34.30	32.93	15.55
T_5	5.3	0.33	5.5	0.39	3.77	18.18	173.05	15.1	183.05	224.35	19.21	207.55	29.64	27.22	13.38
T_6	5.1	0.34	5.3	0.39	3.92	14.71	148.2	11.8	158.2	181.34	14.67	182.13	22.36	24.32	15.13
T_7	5.1	0.31	5.3	0.35	3.92	12.90	144.2	11.7	154.2	166.23	14.06	176.34	15.28	20.17	14.36
T_8	5.1	0.29	5.1	0.32	0.00	10.34	140.2	11.7	150.2	158.34	13.9	165.34	12.94	18.80	10.08

See Table 1 for treatment details

Table 5. Economics returns obtained from different AFS models

AFS models	*Production of wood (m3/ha/year)	Yield of mango (t/ha)	Yield of mustard (t/ha)	Production of intercrops (t/ha)	Return from tree (Rs./ha/year)	Return from fruit crops (Mango) (Rs./ha/year)	Return from mustard crop (Rs./ha/year)	Return from intercrop (Rs./ha/year)	Gross returns (Rs./ha/year)	B:C Ratio
T_1	11.20	7.46	-	3.59	335862.69	223900	-	107750	667512.69	1.05
T_2	8.98	7.13	0.94	4.34	269484.08	213850	37600	86700.00	607634.08	1.03
T_3	13.73	8.05	1.01	2.55	412020.62	241400	40200	152800.00	846420.62	1.82
T_4	7.66	6.43	0.87	14.82	229851.88	192950	34600	50933.33	508335.22	0.96
T_5	9.53	6.67	1.16	4.78	285822.33	200100	46400	286800.00	819122.33	1.73
T_6	6.26	5.79	-	-	187814.84	173750	-	-	361564.84	0.81
T_7	4.88	-	-	-	146287.29	-	-	-	146287.29	0.17
T_8	-	5.31	-	-	-	159400	-	-	159400.00	0.59

See Table 1 for treatment details
(*Production of Wood = Volume Yield × No. of plants grown in One ha. Farm gate Price = Gamhar- (Rs 30000/m^3), Mango = Rs 30/kg, Mustard = Rs 40/kg, Pigeon Pea = Rs 50/kg, Black Gram =Rs 40/kg, Bottle Gourd = Rs 15/kg, Okra = Rs 20/kg, Maize = Rs 60/kg)

Mango +Maize – Mustard) in both the years i.e., 0.94 and 1.38t ha^{-1} respectively, followed by T_4, T_2 and T_4. The lower mustard yield was attributed to the residual moisture in which mustard was grown.

Soil health status: The soil nutrient analysis was carried out by measuring the initial nutrient status and end nutrient status after completion of the experiment (Table 4) represents the initial nutrient status and final nutrient status of the soil after completion of two years. After completion of two cycles of cropping, the results increase in percentage of organic carbon, N, P and K was highest in first treatment T_1(Gamhar + Mango + Cowpea) i.e., OC-29.73%, N-39.21%, P-38.20% and K-19.66%), followed by T_2, T_4, T_5 and T_6. The higher increase in soil nutrients is attributed by intercropping with leguminous crops like Cowpea and Black gram. The lower increase in the nutrient status was recorded in the sole cropping T_7 and T_8. The increase of soil pH was observed under all the different agroforestry system as compared with T_8. The findings are in conformity with the results of Misra (2011), Uthapa et al (2015) and Yadav et al, (2011) reported the complimentary effect of edition of different components along with agricultural crops for better utilization of natural resources.

Economic return from different Mango + Gamhar based agroforestry system model: Return from Gamhar were estimated in terms of Rs/ha/yr, by the help of estimation of commercial biomass in the final year of the experiment. The return from fruit tree, intercrops and mustard were calculated based on the mean yield and farm gate prices. T_3 (Gamhar + Mango + Groundnut – Mustard) agroforestry model gave the highest returns in terms of income and yield of tree and intercrops i.e., ₹8.46 lakh $ha^{-1}yr^{-1}$ in Indian Rupee (INR). This was followed by T_5 with total income gained as ₹8.19 lakh $ha^{-1}yr^{-1}$. T_1, T_2 and T_4 ranked third, fourth and fifth (Table 5). The sole cropping of mango and gamhar provides minimal income to the farmers, on the contrary the agro forestry models are enabled to enhance the livelihood of the farmers by combining the complementary effects of the agro-ecosystem. Murmu et al, (2017) also observed the trend of integration of crops with components of tree and fruit gave higher gross income than tree and fruit tree alone (Basanda et al, 2017). Tiwari and Baghel (2014) concluded that higher household income is expected to increase the risk-bearing capacity of smallholder farmers' decision making and the willingness to wait for the returns from long term investment such as trees. This is an incentive to agroforestry adoption and its subsequent impact on the living standards of rural farming households. Similarly, McGinty et al (2008) observed that the average annual income of farmers is important to adopt agroforestry. Sharma et al (2017) observed and the results corroborated that mango + gamhar + groundnut system was more remunerative followed by mango + gamhar + maize, when compared with maize mono-cropping under rainfed condition in West Bengal.

Farmers can increase their income by selling forest, agriculture and livestock products which leads to a sustainable life with improved livelihood. Chakraborty et al (2015) infers that farm size is significantly positively related to farmers' income. Hemrom and Nema (2015) reported that

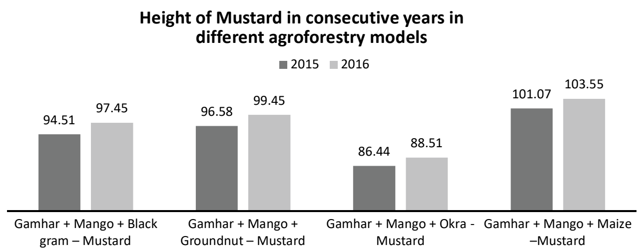

Fig. 4. Height of mustard in consecutive years in different agroforestry models

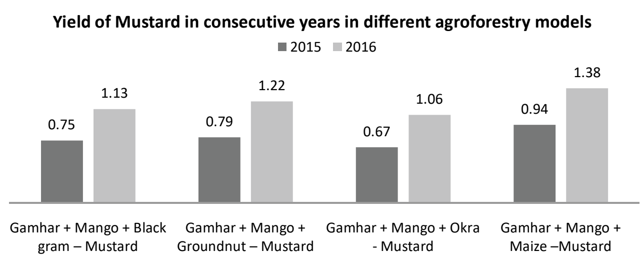

Fig. 5. Yield of mustard in consecutive years in different agroforestry models

Source: https://www.doi.org/10.36.106/gjra

Fig. 6. Maintaining soil health through agroforestry

the Agri-silvicuture system combines trees like *Shorea robusta*, *Tectona grandis, Acacia* spp, *Phoenix Sylvestris* etc and horticultural species like the fruit trees *Cocos nucifera*, *Caraya papaya*, *Musa acuminate*, *Mangifera indica*, *Anacardium ocidentale* and *Embellica officinalis*. *Artocarpu sheterophyllus*, *Azadirachta indica*, *Dalbergia sissoo*, *Gmelina arborea*, *Leucaena leucocephala*, *Melia azadarech*, *Syzygium cumini* and *Tectona grandis* are the tree species and the horticultural tree includes *Artocarpus heterophyllus*, *Litchi chinensis*, *Mangifera indica* and *Syzygium cumini* (Singh et al 2017, Singh and Oraon 2017, Lakra et al 2018). Farmers in the study area are having sufficient farming experience, but few farmers are having adequate knowledge in agroforestry. The contribution of the trees in the farming systems certainly diversifies the dimension by way of income and employment to the farm households besides fulfilling the requirement of wood. Income of households from the sale of agroforestry produce contributes only 2.41 percent to total annual income which indicative of enormous potential of improvement in existing agroforestry practices prevalent in the study area (Kumar et al 2018) Results indicate that agroforestry may not only be an optimal solution for poor farmers, species diversity conservation and environmental sustainability but may also have good economic rates of return.

CONCLUSION

All Mango-based agroforestry systems evaluated were profitable in respect to tree yield, fruit yield, yield of arable crops and soil health improvement compared to sole tree or sole fruit. Gamhar + Mango + Maize followed by Mustard and Gamhar + Mango + Groundnut followed by Mustard can be best models for the farmers to uptake for higher gross income and improvement of soil health leading towards sustainability and improvement of livelihood in rainfed and sub-tropical region of West Bengal. A relatively large percentage of the population lives under the poverty line and is affected by the countries degrading natural resources. The present research assesses the contribution of agroforestry to livelihoods in a tribal rural area of West Bengal. Agroforestry systems are a land management technique that implies a combination of forest trees with crops. The study has led to the conclusion that agroforestry may be considered as one of the major strategies for poverty reduction in rainfed and sub-tropical region of West Bengal, where there minimal scope of conservation of soil and forest, with subsistence requirement of food crop production. This study is a definitive example of how agroforestry systems with local crop, fruit and tree species components can restore the ecosystem services in degraded lands safe guarding farmers livelihood and income. Agroforestry systems not only increases food and fodder but also protects the existing environment and provides opportunities for unemployed and poor rural people. It is therefore, important that the policy makers, NGOs and Government Organizations should promote sustainable tropical agroforestry in developing environment-friendly and cost-effective technologies for poverty reduction in rainfed and sub-tropical region of West Bengal.

ACKNOWLEDGEMENT

The first author is grateful to Ministry of Tribal Affairs, Govt. of India, which provided him National Fellowship for Scheduled Tribe, for pursuing his Ph. D programme.

CONTRIBUTION OF EACH AUTHOR

This work was carried out collectively by all the authors. The first author Suren Murmu designed the study, formulated the protocol, methodology, collected the data resources, formal analysis, investigation, visualization and wrote the first draft of manuscript. The second author Gayatri Kumari Padhi managed the analysis of the data, figures and the tables. The third author Paritosh Murmu and fourth author Debjit Roy managed the visualization, literature resources and reviewed the editing. Author Pratap Kumar Dhara supervised the complete experiment and approved the final manuscript. All authors had read and approved the final manuscript.

REFERENCES

Basanda GM, Dhara PK and Tarafdar PK 2017. Differential responses of arable crops with gamhar (*Gmelina arborea*) and mango (*Mangifera indica*) based agroforestry system in red and lateritic soils of West Bengal, India. *Indian Journal of Agricultural Research* **51**(1): 86-89.

Chakraborty M, Haider MZ and Rahaman M 2015. Socio-economic impact of cropland agroforestry: Evidence from Jessore District of Bangladesh. *International Journal of Research in Agriculture and Forestry* **2**(1): 11-20.

Das B, Dhakar MK, Sarkar PK, Kumar S, Nath V, Dey P, Singh AK and Bhatt BP 2017. Performance of mango (*Mangifera indica*) based agri-horticultural systems under rainfed plateau conditions of Eastern India. *Indian Journal of Agricultural Sciences* **87**(4): 521-527.

Das R, Dhara PK, Mandal AR and Dutta Ray SK 2014. Agri-Silvi-Fruit-Vegetable based agro production system-suitable models for sustainable land use and conservation in Red-Laterite and Semi-Arid Tracks. *Ecology, Environment and Conservation* **20**: S7-S13.

Dhara PK 2019. *Agroforestry Model: Gmelina and Eucalyptus based Agri-silvi-horticultural System.* Successful Agroforestry Models for different Agro-ecological regions of India. Central Agroforestry Research Institute (CAFRI) Jhansi, Uttar Pradesh, India: p 107-112.

Fanish SA and Priya RS 2013. Review on Benefits of agroforestry system. *International Journal of Education and Research* **1**(1): 1-12.

FAO 2010. *Global Forest Resources Assessment*. Food and Agriculture Organization of the United Nations, Rome, Forestry Paper: p 163.

Hemrom A and Nema S 2015. A study on traditional agroforestry practices existing at Bastar region of Chhattisgarh. *International Journal of Multidisciplinary Research and Development* **2**(3): 56-64.

ICAR-AICRPDA 2018*. Annual Reports of Central Research Institute for Dryland Agriculture*, Hyderabad, India: p 67.

Kaur N, Singh B and Gill RI S 2017. Productivity and profitability of intercrops under four tree species throughout their rotation in north-western India. *Indian Journal of Agronomy* **62**(2): 160-169.

Korwar GR, Prasad JVNS, Rao GR, Venkatesh G. Pratibha G and Venkateswarlu BJC 2014. Agroforestry as a strategy for livelihood security in the rainfed areas: Experience and expectations, pp.117-154. In: J.C. Dagar et al. (eds). *Agroforestry Systems in India: Livelihood Security & Ecosystem Services*. Advances in Agroforestry, 10. Springer Publisher, India.

Kumar A, Sah RB, Singh BK and Oraon PR 2018. Socio economic analysis of tribal farmers in the Gumla District of Jharkhand from existing agroforestry practices. *International Journal of Current Microbiology Applied Science* **7**(6): 595-604.

Kumar PN 2020. Effect of intercropping on fruit crops: A review. *International Journal of Current Microbiology and Applied Sciences* **9**(12): 745-755.

Lakra TS, Siddiqui MH, Chakraborty AK, Oraon PR and Malik MS 2018. Agroforestry practices followed in west Singhbhum District, Jharkhand. *Trends in Bioscience* **11**(4): 400-406.

Leakey RB 2012. *Multifunctional agriculture and opportunities for agroforestry: implications of IAASTD,* pp 203-214. In: Nair PK, Ramachandran and Garrity, Dennis (eds). *Agroforestry: the future of global land use*. Advances in Agroforestry, 9. Springer Publishers, New York, USA.

McGinty M, Swisher ME and Alavalapati J 2008. Agroforestry adoption and maintenance: self-efficacy, attitudes and socio-economic factors. *Agroforestry Systems* **73**: 99-108.

Misra PK 2011. Soil fertility management in agroforestry system. *International Journal of Biotechnology and Biochemistry* **7**(5): 637-644.

Mondal U and Dhara PK 2016. System for suitanable agriculture in New Alluvial Zone of West Bengal, India. *Journal of Research Innovation and Management Science* **2**(4): 26-37.

Msuya TS and Kideghesho JR 2012. Main streaming agroforestry policy in Tanzania legal framework. in: Martin Leckson Kaonga (eds). *Agroforestry for biodiversity and ecosystem services–science and practice*. In Tech Publishers, Shanghai, China.

Murmu S and Dhara PK 2022. Effective Food Safety and Land Use Management by Tribal Farmers through Agroforestry Practices, pp 303-308. In: Ghatak A, Vishwakarma Ramanuj, Prakash N and Kumar R (eds). *Crop Protection-driven Food Safety and Security*, Scientific Books Publisher, Delhi, India.

Murmu S, Chowdary KA, Roy D, Patra BC and Dhara PK 2017. Productivity and soil fertility status of mango-based agroforestry system in red and laterite zone of West Bengal. *Current Journal of Applied Science and Technology* **25**(3): 1-8.

Received 22 July, 2022; Accepted 15 September, 2022

Murmu S, Dhara PK and Roy D 2016. Agroforestry: A sustainable agro-technique for red and laterite zone of West Bengal. *Journal of Agroecology and Natural Resource Management* **3**(3): 280-283.

Rahman SA, Foli S, Pavel MA, Mamun MA and Sunderland T 2015. Forest, trees and agroforestry: Better livelihoods and ecosystem services from multifunctional landscapes. *International Journal of Development and Sustainability* **4**(4): 479-491.

Rathore AC, Saroj PL, Lal H, Sharma NK, Jayaprakash J, Chaturvedi OP, Raizada A, Tomar JMS and Dogra P 2013. Performance of mango based agri-horticultural models under rainfed situation of Western Himalaya, India. *Agroforestry Systems* **87**: 1389-1404.

Saralch H and Singh SP 2013. Determining maturity indices for time of seed collection in *Gmelina arborea* under Punjab conditions. *International Journal of Farm Sciences* **3**(2): 90-94.

Saravanan S 2012. Constraints Faced by the farmers in adoption of *Gmelina arborea*: A case study in Tamil Nadu. *Indian Journal of Hill Farming* **25**(1): 13-16.

Sarkar PK 2019a. CO2FIX model: A tool for estimating carbon sequestration potential of any agroforestry system. *Agriculture & Food: e-Newsletter* **1**(3): 61-66.

Sarkar PK 2019b. Improving livelihood through agarwood (*Aquilaria malaccensis* Lam.) based agroforestry systems: An option. *Agriculture & Food: e-Newsletter* **1**(6): 139-147.

Sarkar PK, Das B and Bhatt BP 2017c. Bakain (*Melia azedarach* L.): a promising agroforestry species for improving livelihood to farmers of Eastern plateau and hill region of India. *The Bioscan* **12**(2): 1095-1100.

Sharma B, Tripathi SK, Dhara PK, Kumari P, Meena SK, Kumari R and Kumar A 2017. Comparative study of mango based agroforestry and mono-cropping system under rainfed condition of West Bengal. *International Journal of Plant & Soil Science* **15**(2): 1-7.

Singh BK, Oraon PR, Kumar A and Malik MS 2017. Traditional Agroforestry practices existing at Lohardaga District of Jharkhand. *Trends in Bioscience* **10**(23): 4651-4654.

Swain SC 2014. Performance and profitability study of different mango based intercropping systems in Easternghat high land zone of Odisha. *Journal of Crop and Weed* **10**(2): 170-178.

Tiwari R and Baghel BS 2014. Effect of intercropping on plant and soil of Dashehari mango orchard under low productive environments. *Asian Journal of Horticulture* **9**(2): 439-442.

Uthapa AR, Chavan SB and Handa AK 2015. Trees for soil amelioration: A review. *Global Journal for Research Analysis* **4**(6): 320-322

Verma P, Bijalwan A, Dobriyal MJR, Swamy SL and Thakur TK 2017. A paradigm shift in agroforestry practices in Uttar Pradesh. *Current Science* **112**(3): 509-516.

Yadav RS, Yadav BL, Chhipa BR, Dhyani SK and Munna R 2011. Soil biological properties under different tree based traditional agroforestry systems in a semi-arid region of Rajasthan, India. *Agroforestry System* **81**: 195-202.