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Climate Resilient Alternate Land Use Systems for Sustainable Development in Rainfed Agro-Ecology of Odisha

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ABSTRACT: Rainfed agriculture is being adversely affected by the major problems like land degradation, climatic change, degeneration of bio-diversity due to open grazing and poverty driven over utilization of natural resources. All these problems together lead to increasing challenges for sustainability of rainfed crop production. These problems can be mitigated if the farming community can be mobilized and motivated to adopt improved rainfed technologies. In order to meet the challenges and the vagaries of monsoon, the alternate land use system (ALU) is a suitable technology to minimize such risk and to achieve stability in the dryland areas. In view of the above facts, the on-farm demonstrations were undertaken in two village clusters such as Budhadani and Dadaki of the Kandhamal District of Odisha under All India Coordinated Research Project for Dryland Agriculture (AICRPDA), Odisha University of Agriculture and Technology (OUAT), Phulbani during 2015-16 to 2018-19. Different agri-horti alternate land use systems such as (i) mango + greengram (ii) mango + blackgram (iii) mango + groundnut (iv) mango + turmeric (v) jackfruit + turmeric (vi) papaya + greengram (viii) papaya + cowpea (ix) papaya + groundnut (x) papaya + blackgram (xi) sole mango (xii) sole jackfruit (xiii) sole papaya were taken in both the village clusters out of which, turmeric based systems were fitted in old orchards and all other systems were taken up in newly established orchards. It was found from the investigation that the integration of cropping with fruit components registered higher gross income than the fruit crops alone. The turmeric crop as intercrop recorded higher net income than the other crops. Turmeric, greengram, blackgram and groundnut as intercrops can profitably be grown in rainfed uplands under red lateritic soils of Odisha because of their ability to improve soil fertility and fulfil the nutritional requirement of the farming families.

Key words: Alternate land use system, agri-horti system, rainfed agriculture, sustainable development, on-farm demonstration.

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Introduction

In modern concept, dryland areas are those where the soil moisture balance is always on the deficit side. In other words, annual evapotranspiration exceeds precipitation. In dryland agriculture, consideration of amount of rainfall has little importance over its distribution. The area receives 1400 mm or more rainfall annually also fall in the category of dryland agriculture because the annual potential evaporation is more than the annual rainfall. Thus, the average moisture deficit so created is bound to affect crop production under dryland situation ultimately leading to total or partial crop failure. Accordingly the crop production is either low or extremely uncertain and unstable which are the real problems of dryland. In dryland or rainfed condition, the agri-horti alternate land use system is the most important in terms of economic returns to the farmers and their preferences (Wani *et al.,* 2009; Singh *et al*., 2013; Mynavathi *et al.*, 2017; Gupta *et al.,* 2019).

Aberrant monsoon behaviour under rainfed condition in red and lateritic soil of Odisha results in poor crop yields and makes crop production unstable and uneconomical. Lateritic soils are invariably low in organic matter and poor in N, P and K contents. These soils have low water holding capacity and are prone to erosion. Poor management of marginal lands, particularly the topmost soil layer of the undulating topography results into land degradation. For profitable cultivation, some alternate land use systems are needed to be advocated for these lands. The alternate land use system is a practice when a land is put under an alternative production system in order to match its capability more appropriately to the new land use and achieve more sustainable biological and economic productivity on a long term. It is aimed to optimize the use of resources through recycling, internalize the input production, and reduce the risk and conservation of natural resources. It reduces the erosivity of rainfall and erodibility of soil through dissipation of energy of raindrops by canopy and improves the soil organic matter, physic-chemical and biological properties of soil (Gupta *et al.,* 2019).

Fruit based agri-horti system i.e. fruit trees intercropped with agricultural crops could be an alternate land use system for these lands (Saha *et al.,* 2014; Biswas *et al.,* 2003). Under this system, fruit tree can be grown successfully with pulses such as greengram, blackgram and cowpea; oilseed crops such as groundnut and spices such as turmeric as bonus crops and this system can be an economic and profitable alternative system for marginal and sub marginal lands (Singh, 2006; Giri Rao, 2009). It was also observed that the dry land horticultural fruit trees like mango, papaya and jackfruits integrated with short duration arable crops like legumes, pulses and spices were the most profit oriented among different agri-horti systems. In view of the above facts, the on-farm demonstrations were undertaken in the two village clusters to develop a suitable agri-horti based alternate land use system for rainfed areas with red and lateritic soils of Odisha.

Materials and Methods

The on-farm research was conducted at two village clusters such as Budhadani and Dadaki of the Kandhamal District of Odisha under All India Coordinated Research Project for Dryland Agriculture (AICRPDA), Odisha University of Agriculture and Technology (OUAT), Phulbani during 2015-16, 2016-17, 2017-18 and 2018-19. The AICRPDA, Phulbani initiated its participatory technology development and upscaling in both the village clusters which are located at 20^0 28' N latitude, 84^0 14'E longitude and 736 m above mean sea level (MSL). The villages are located in North Eastern Ghat Zone of Odisha and have a tropical sub-humid climate with average annual rainfall of 1407 mm, concentrated mostly in the month of June to October. The soils of the villages are sandy loam with slightly acidic to neutral in soil reaction and low to medium in fertility status. The available nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) in the soil layer of 0-15 cm were found to be 117.8, 22.8, 237.4 and 23.52 kg/ha, respectively.

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The monsoon onset at right time of normal date of 10^{th} June during 2015, 2017 and 2018 whereas monsoon onset was delayed by 14 days during 2016. The total rainfall during 2015, 2016 and 2017 were found to be 24.6%, 11.2% and 10% less respectively and 18% more during 2018 than the normal rainfall. The total number of dry spells during 2015, 2016, 2017 and 2018 were found to be 5 (75 days), 3 (41 days), 2 (22 days) and 1 (17 days) respectively. The monsoon scenario of both the villages during 2015-18 is given in the Table 1 and weekly rainfall distribution of both the villages during 2015-18 is given in Figure 1.

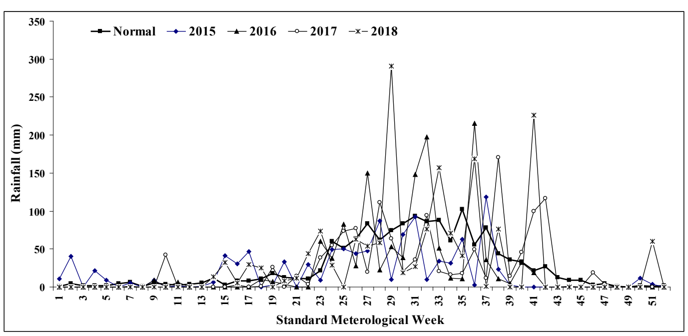

Fig. 1 : Weekly rainfall distribution of the Budhadani and Dadaki village during 2015-18

The outcome of participatory rural appraisal (PRA) revealed that most of the farmers in the villages are small and marginal farmers. Before conducting the demonstration, list of farmer beneficiaries was prepared from group meeting and specific skill training was given to the selected farmers. Selected farmers participated in research interventions from soil sampling to harvesting. Different agri-horti alternate land use systems such as (i) mango + greengram (ii) mango + blackgram (iii) mango + groundnut (iv) mango + turmeric (v) jackfruit + turmeric (vi) papaya + greengram (viii) papaya + cowpea (ix) papaya + groundnut (x) papaya + blackgram (xi) sole mango (xii) sole jackfruit (xiii) sole papaya were taken in both the village clusters out of which, turmeric based systems were fitted in old orchards and all other systems were taken up in newly established orchards. Soil nutrient status of each treatment was recorded before commencement of the experiment and after completion of four cycles of intercropping during *kharif* seasons.

For economic evaluation of the system, prevailing market prices were used. System profitability was calculated by using prevailing market price of inputs and outputs. In order to compute the profitability of different cropping system under different nutrient management practices over years, the net returns and benefit-cost (B:C) ratio were calculated (Maruthi Sankar *et al.*, 2012; Nema *et al.,* 2008). The gross returns (₹/ha) were computed as a product of mean yield of each treatment over years and value of the crop at each location. The net returns (₹/ha) were computed as a difference of gross returns and cost of cultivation (₹/ha) for each treatment. The B:C ratio was derived as a ratio of gross returns and cost of cultivation for each treatment (Barik *et al.,* 2015; Behera *et al.,* 2012). The significant differences among treatments were compared with the critical difference at 5% level of probability (Gomez and Gomez, 1984).

Results and Discussion

Soil nutrient status due to different alternate land use systems

The soil pH, organic carbon (OC), available nitrogen (N), phosphorus (P) and potassium (K) in different alternate land use systems were measured before sowing of the intercrops during 2015-16 and after harvesting of the intercrops during 2018-19 and the results are presented in Table 2. Higher value for organic C, available soil N, P and K were observed in different alternate land use systems as compared to sole orchard treatments at the end of the study that indicated the improvement in soil fertility. Effective recycling of organic residues from different alternate land use systems in the study effectuated this improvement.

The percentage increase in soil pH, organic carbon (OC), available N, P and K due to different alternate land use systems in four years is given in the Figure 2. The organic carbon (OC) was increased by 31-52% after harvesting of the intercrops in four years from the initial condition i.e. before sowing of intercrops in case of different alternate land use system whereas the organic carbon was increased by 9-12.5% in case of sole orchard crops such as mango, jackfruit and papaya in the experiment period

Table 1 : Monsoon scenario of the village Budhadani and Dadaki during 2015 - 18

Description	Normal	2015	2016	2017	2018
Date of onset on monsoon	10th June	12th June	24th June	10th June	9th June
Date of cessation of monsoon	6th October	22nd September	9th October	21st October	14th October
Total rainfall (mm)	1407	1060.6	1248.8	1265.9	1659.8
Number of rainy days	65	60	60	75	67
Dry spell (Nos and total days)		4 (72 days)	3 (41 days)	3 (22 days)	1 (17 days)

Table 2 : Soil pH, organic carbon (OC), available nitrogen (N), phosphorus (P) and potassium (K) in different alternate land use systems after 4 years

Agri-horti based ALU	Before sowing (2015-16)					After harvest (2018-19)				
models	pH	OC	N	P	K	pH	OC	N	P	K
Mango + greengram	5.5	0.32	117.2	22.8	210.5	5.6	0.42	136.8	28.8	236.6
Mango + blackgram	5.4	0.28	119.9	24.2	216.8	5.7	0.40	138.2	29.2	241.2
Mango + groundnut	5.6	0.31	112.2	21.8	220.6	5.7	0.42	134.1	26.2	244.3
Mango + turmeric	5.5	0.26	114.8	23.7	218.8	5.6	0.39	133.2	28.8	247.5
Jackfruit + turmeric	5.4	0.25	110.7	20.6	212.9	5.7	0.38	129.8	25.8	243.2
Papaya + greengram	5.4	0.34	118.8	24.2	220.5	5.6	0.45	136.4	29.4	246.6
Papaya + cowpea	5.6	0.36	116.6	23.8	222.6	5.8	0.48	136.2	28.8	251.8
Papaya + groundnut	5.3	0.30	114.8	22.9	221.2	5.4	0.42	133.8	27.2	252.7
Papaya + blackgram	5.5	0.24	112.6	23.2	219.6	5.7	0.36	132.4	28.4	249.8
Sole mango	5.6	0.22	112.4	20.6	212.3	5.6	0.24	114.2	21.7	215.4
Sole jackfruits	5.5	0.24	116.6	22.2	214.2	5.5	0.27	119.2	23.4	216.5
Sole papaya	5.4	0.25	117.8	23.4	215.7	5.4	0.28	119.2	24.2	217.8

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of four years. Even in exhaustive intercropping of turmeric in fruit plant, the organic carbon content in soil also increased considerably from 0.25 to 0.38 in mango + turmeric and 0.26 to 0.39 in jackfruit + turmeric alternate land use system. The spatial and temporal intensification of cropping and enhanced biomass production per unit area and time invariably increase the organic carbon status of the native soil.

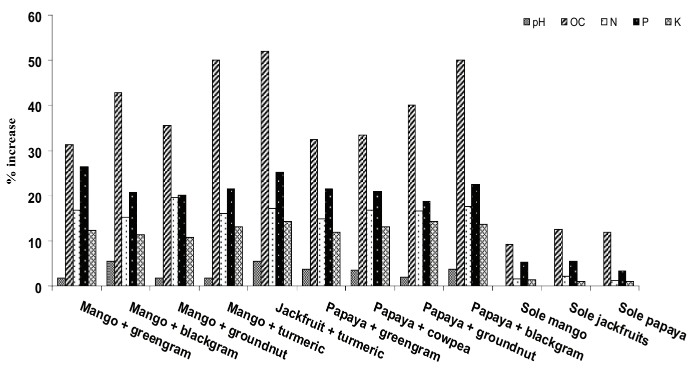

Fig. 2 : The percentage increase in soil pH, organic carbon (OC), available N, P and K due to different alternate land use systems

It may be due to enhanced ecosystem services like proliferation of microbial biomass and crop residue decomposition. Furthermore, application of organic mulch to turmeric crop might have increased the organic carbon content of soil after decomposition. Similarly, the available N, P and K were increased by 14.8-19.5%, 18.8-26.3% and 10.7-14.2%, respectively after harvesting of the intercrops in four years from the initial condition in case of different alternate land use system.

In case of sole orchard crops of mango, jackfruit and papaya, the available N, P and K were increased by only 1.2-2.2%, 3.4-5.4% and 1-1.5%, respectively in four years. The result clearly signifies the improvement in soil fertility due to alternate land use system. The findings are in confirmity with the results of Biswas *et al*. (2003). Effects of integration of different components along with cropping for better utilization of resources were also reported earlier by Rangasamy *et al*. (1994) and Jayanthi *et al.* (2003).

Yield and economics of different alternate land use system

The arable crops were cultivated in the alleys or inter-spaces of the fruit trees such as mango, jackfruit and papaya as compared to sole fruit crops and recorded positive effect of intercropping on tree productivity and overall equivalent yield. The income from crops and fruits and gross income under each treatment during the study for four consecutive years are presented in Table 3.

The intercrop of turmeric was taken up in old orchards and all other intercrops were taken up in newly established orchards. The mongo fruit yield (4400 kg/ha) was found to be more when turmeric was intercropped than the sole mango orchard (4000 kg/ha). Similarly jackfruit yield (8500 kg/ha) was found to be more when turmeric was intercropped than the sole jackfruit orchard (8250 kg/ha). The fruit yield with intercrop was found to be more as compared to the sole crop even in exhaustive intercropping of turmeric with mango and jackfruit plant. In field condition, often it is observed that synergism between component crops

Table 3 : Yield and economics of different agri-horti based alternate land use systems in two village clusters during 2015-19

Agri-horti based ALU systems	Yield (kg/ha)	MEY (kg/ha)	Income from crop (₹/ha)	Income from fruits (₹/ha)	Cost of cultivation (₹/ha)	Gross income (₹/ha)	Net return (₹/ha)	B:C ratio
Mango + greengram	GG - 650	1950	39000	0	20000	39000	19000	1.95
Mango + blackgram	BG - 680	1700	34000	0	18000	34000	16000	1.89
Mango + groundnut	GN - 1240	2480	49600	0	25000	49600	24600	1.98
Mean data		2043			21000	40867	19867	1.95
Mango + turmeric	M - 4400 T- 4800	16400	240000	88000	110000	328000	218000	2.98
Jackfruit + turmeric	J - 8500 T - 4750	16125	237500	85000	110000	322500	212500	2.93
Papaya + greengram	P - 8400 GG - 660	6180	39600	84000	35000	123600	88600	3.53
Papaya + cowpea	P - 8600 CP - 2820	7120	56400	86000	35000	142400	107400	4.06
Papaya + groundnut	P - 8400 GN - 1220	6640	48800	84000	40000	132800	92800	3.32
Papaya + blackgram	P - 8500 BG - 670	5925	33500	85000	33000	118500	85500	3.59
Mean data		9732			60500	194633	134133	3.22
Sole mango	M - 4000	4000	-	80000	0	80000	80000	-
Sole jackfruit	J - 8250	4125	-	82500	0	82500	82500	-
Sole papaya	P - 8250	4125	-	82500	15000	82500	67500	5.5
SE_m (±)		526				1220	860	
CD (P=0.05)		1542				3840	2520	

MEY - Mango equivalent yield; GG - Greengram; BG - Blackgram; GN - Groundnut; CP - Cowpea; T - Turmeric; M - Mango; J - Jackfruit; P - Papaya
Market price (Rs/kg): Greengram - 60/-; Blackgram – 50/-; Groundnut – 40/-; Cowpea – 20/-; Turmeric – 50/-; Mango – 20/-; Jackfruit – 10/-; Papaya – 10/-

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of a system exists. Some of the basic requirements of the crops are compensated by the component crops through root exude and also through differentially associated microbial activities which results in augmented production. The same may be the reason for increase in fruit yield of intercrop compared to the sole crop. The papaya fruit yields were also found to be more when intercropped with greengram, blackgram, cowpea and groundnut than the sole papaya yield. Yield of intercrops grown under different alternate land use systems indicated that early supplementary and/or complementary relation exist between the systems' components implying the presence of synergistic effects among the components. The results of the present experiment are in agreement with the finding of Saha *et al.* (2014).

For comparison among the different agri-horti based alternate land use systems, the system crop yield has been converted to mango equivalent yield (MEY). From the results of 4 years, it was found that the mango equivalent yield of mango + turmeric (16,400 kg/ha) and jackfruit + turmeric (16,125 kg/ha) alternate land use system were significantly higher than sole mango (4,000 kg/ha) and jackfruit (4,125 kg/ha). Among the papaya based alternate land use systems, the mango equivalent yield of the papaya + cowpea (7,120 kg/ha) and papaya + groundnut (6,640 kg/ha) system were found to be significantly higher than the papaya + greengram (6,180 kg/ha) and papaya + blackgram (5,925 kg/ha) alternate land use systems and also than that of sole papaya (4,125 kg/ha). No significant difference in MEY was found between papaya + cowpea and papaya + groundnut alternate land use system. Similarly, no significant difference in MEY was found between papaya + greengram and papaya + blackgram system. From all the fruit yielding alternate land use system, the mean yield, net return and B:C ratio were found to be 9,732 kg/ha, ₹ 1,34,133 per hectare and 3.22 respectively. Whereas from all the newly established mango orchards, the mean yield, net return and B:C ratio were found to be 2,043 kg/ha, ₹ 19,867 per hectare and 1.95 respectively. In the newly established mango orchards, the mango equivalent yield of mango + groundnut (2,480 kg/ha) was significantly higher than the mango + greengram (1,950 kg/ha) and mango + blackgram (1,700 kg/ha) alternate land use system. In this mango based alternate land use systems, the yields were only from the agricultural crops not from the fruit crop. It was found from the yield result that the different agri-horti based alternate land use systems generated higher yield as compared to fruit crops alone.

The results also showed that integration of cropping with fruit components could generate higher gross income than fruit crops alone. The turmeric crop within the interspaces registered higher net income and B:C ratio than the other crops. The net return per hectare from mango + turmeric was found to be ₹ 2,18,000/- followed by jackfruit + turmeric (net return- ₹ 2,12,500/-), papaya + cowpea (net return – ₹ 1,07,400/-) and papaya + groundnut (net return - ₹ 92,800/-). The B:C ratio of papaya + cowpea was found to be maximum as 4.06 followed by papaya + blackgram (3.59), papaya + greengram (3.53), papaya + groundnut (3.32). The B:C ratio of the sole papaya (5.5) is higher as compared to papaya based alternate land use system. However, net return from papaya based alternate land use system is higher as compared to sole papaya. Integration of arable crops with fruit trees resulted in better utilization of resources and hence, improved the soil fertility as well as sustainable gross and net monetary returns of the farming families.

Conclusion

The increased values of organic C, available soil N, P and K in different alternate land use systems as compared to sole orchard crop indicated the improvement in the soil fertility. The improvement in the soil fertility was due to the effective recycling of organic residues from different alternate land use systems. The integration of cropping with fruit components registered higher gross income than fruits crop alone. The turmeric crop within the interspaces recorded higher net income and B:C ratio than the other crops. Turmeric, greengram, blackgram and groundnut as intercrops can profitably be grown in rainfed uplands under red lateritic soils of Odisha because of their ability to improve fertility of soil and nutritional status of the farming families. Under aberrant weather and poor soil conditions, these agri-horti alternate land use systems can ensure sustainable gross monetary returns for predominantly marginal and resource-poor farmers of Odisha. The different alternate land use systems in association with crops holds great promise for contributing to sustainable land use systems which can overcome the problem of land degradation and also provides diversified production and consequently greater food diversity.

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