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Effect of Agronomic Management on Watershed Productivity, Impact Indices, Crop Diversification and Soil Fertility in Eastern Ghats of Orissa

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ABSTRACT

Land degradation, subsistence farming with poor crop harvests and lack of employment opportunities has resulted into poverty in eastern ghats of Orissa. To avert the situation, IWDP and TDET watershed projects were implemented in Kokriguda watershed (area 317.5 ha) which represents the resources position of this tribal region, during 1997 to 2003. Different agronomic practices viz., improved varieties, crop diversification, integrated nutrient management, summer ploughing, use of irrigation facilities developed under the project etc. were taken up to improve the overall productivity, soil fertility, income, and nutrition of the farmers in the watershed.

Area under most of the crops increased substantially. Especially, area under cash crops (vegetables) expanded from 1.25 ha to 18.0 ha at the end of the project. Cropping intensity increased by 33%. Use of irrigation facilities, adoption of high yielding varieties and other improved agronomic practices enhanced crop yields by 33.3 to 111.8%. The overall rice equivalent yield (REY) of entire watershed (arable land only) was estimated to be 46.3q/ha of worth Rs. 26391. REY for this watershed was higher than that of Koraput district and Orissa by 25.26 and 10.83 q/ha, respectively. The corresponding gap for gross returns was Rs. 14398 and Rs. 6156/ha. Additional gross returns from Koraput district and Orissa state as per Kokriguda REY were estimated to be Rs. 4768.2 and 34316.7 millions. Impact indices like cultivated land utilization index, crop fertilization index, crop productivity index, crop diversification index increased by 50, 238.5, 45.39 and 44.12%, respectively. A positive impact of agronomic practice was noticed on soil fertility and ecological sustainability also.

Keywords: Kokriguda watershed, Eastern ghats, Impact indices, Soil fertility, Crop yields, Production gaps

Eastern ghats region of Orissa (area: 4.87 m ha) spreads over ten districts of the state and feed 2.13 million population. This tribal (about 50%) region is confronted with a multitude of resource degradation problems. Due to steep and rugged terrain and non-availability of water, less land is available for cultivation. Hence the farmers extend cultivation to steep hill slopes increasing their vulnerability to erosion. Dass et al. (2008) reported that farmers practice subsistence agriculture with very low input use (fertilizer use 23.4 kg/ha). Shifting cultivation on hills is still in vogue. Due to degraded and low fertility soils coupled with poor management practices, the crop productivity is very low with average rice yield of 10.1 q/ha and ragi.6.3 q/ha. Less intensive and least remunerative cropping systems further weaken the economy of chronically poor tribals. Starvation, malnutrition and poor health are very common in this region. Adoption of integrated watershed approach is recognized widely as appropriate strategy for sustainable and holistic development of the rural areas. Short-tem gain activities hold the key to the overall success of the watershed programmes. Farmers take interest in activities which increase crop yields directly and quickly than the soil conservation works of which the positives effects on crop productivity are visible only after certain years (Sombatpanit et

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al., 1997). Interventions like replacement of seeds, introduction of high yielding varieties and hybrids, crop diversification with remunerative crops, creation and utilization of irrigation facilities, and low cost inputs like bio-fertilizers, green manures which increase crop yields directly and substantially are readily accepted and usher-in the participation of the farmers even in the long-term gain activities. In tribal regions, scarcity of food is the prime concern. Hence agronomical interventions assume greater importance in up-surging the overall crop productivity and thus generating adequate food in the watersheds. Information on agricultural scenario as influenced by implementation of various agronomic interventions in the watershed as a whole is lacking in eastern ghats region. Hence various agronomic technologies were introduced and implemented through IWDP and TDET projects and their impact on crop productivity, income and soil fertility was studied in Kokriguda.

MATERIALS AND METHODS

Study site

Location and social profile

Kokriguda watershed (area 317.5 ha) is located in Semiliguda Block of Koraput district in the state of Orissa, between 820 52' 59'' to 820 54' 03"E longitude and 180 40' 15" to 180 40' 44" N latitude. It represents the general resource position and socio-cultural set up and agro-ecology of eastern ghats region. The village has 78 households of Paraja tribe. About 90% of families are below poverty line. The village is highly backward as revealed from 80% illiteracy. Small family size forces them to divert children to agriculture/ livestock maintenance/ wage earning. Liquor addiction and one day living attitude are the bottlenecks to their development.

Soil properties

Red soil is the dominant soil group in the watershed, with small patches of fine textured black soil in the Jhola land (low land consisting of wide terraced gully beds). Genetically, the soils come under Udic Paleustalfs. Soil texture varies from sandy loam to sandy clay loam. The sand content is about 60%. Soils are acidic with pH ranging from 4.5 to 6.2 and having very low salt content (EC varying from 0.184 to 0.321 dS/m). Soils are low in N, P and organic matter content. Nutrient Value Index for O, C, N, P and K was worked out to be 1.63, 1.2, 1.1, and 2.77, respectively (Patnaik et. al. 2004)

Pre-project agricultural scenario

Cultivated agricultural land was around 167.7 ha out of which 96.4% was rainfed. Small and marginal farmers constituted 85% of land holdings; large size farmers were 9%. About 6% of the villagers were landless. Average land holding size was 2.15 ha. Technology followed was indigenous without any mechanization and with very low level of input use. Crop yields were very low. FYM was the only input to meet the nutritional needs of the crops. Its availability per household was estimated to be 5.4 t/year as against requirement of 11.5 t considering single crop of ragi or rice per year. Although there was shortfall of FYM, yet 40-50 % of it was sold out to the resourceful and progressive farmers of nearby villages.

Approach for implementation

Agronomic practices implemented in the watershed are listed along with area against each in table 1. The following approach was adopted for the successful introduction and spreading of these technologies in the watershed.

Creating awareness and developing desire: Farmers are not always aware of the improvements they could make by using scientific and technological knowledge (Reddy, 1993). Thus first of all, the attention of villagers was directed towards the crop diversification and improved agronomic practices by conducting informal meetings and discussions with them. Their interest was stimulated by explaining them as to how it could contribute towards higher crop yields, income, nutrition, resource conservation and better living. This interest was later transformed in to desire by continuous persuasions and motivation of farmers by Watershed Development Team (WDT) to learn and adopt the technologies.

Assessing farmers' preference: Farmers' problems, needs and preferences were known through Participatory Rural Appraisal (PRA).

Selecting young, educated and progressive partners: The young and little- educated farmers are more receptive and easy to convince. Hence initially, relatively young, aware, enthusiastic and willing farmers were chosen to be made acquainted with the improved agricultural technologies.

Skill transfer: Trainings on field-crop production technology, bio-mass recycling, and improved

vegetable cultivation and processing were conducted.

Demonstrations and trials on crop varieties, and fertilizer, FYM, bio-fertilizer, pesticide application were carried out in the farmers fields for practically showing them the benefits of such technologies.

Exposure visits: Exposure visits of farmers to nearby progressive villages adopted by other developmental agencies/ organizations were also conducted.

Meetings: Regular formal and informal meetings with the farmers' groups and individual farmers' helped in motivating and encouraging the farmers for taking up the improved technologies.

Linkages developmental/ research agencies: Linkage of framers with inputs (seeds, fertilizers, pesticides) supply and farm-machinery supply agencies was established. The farmers were acquainted with nearby CSWCRTI, Research Centre, Koraput, Research Stations of SAU, Collectorate, Block Development Office, Agricultural Department, Horticultural Department etc..

The bio-physical impact indices were computed using following expressions.

1. **Cultivated land utilization index (CLUI)**

$$\mathbf{CLUI} = \sum_{i=1}^{n} ai \,.\, di \,/\, (\mathbf{A \times 365})$$

where, i= 1, 2--------n

ai= Area occupied by the ith crop,

di= Duration of the ith crop

A= Total land area available for cultivation during the 365 days

2. **Crop fertilization index (CFI):** It is the ratio of fertilizers (NPK) applied to the crop and recommended dose of fertilizers (NPK)

3. **Crop productivity index (CPI)**

$$\mathbf{CPI} = \frac{1}{n} \sum_{i=1}^{n} (yi/\, Yi)$$

where, n is the total number of crops grown in the watershed, yi is the average yield of ith crop cultivated in the watershed, and Yi is the yield of ith crop with standard package of practices

4. Crop diversification index (CDI)

$$\mathbf{CDI} = \sum_{i=1}^{n} Pi \log (1/\, Pi)$$

Where, Pi is the proportion of area sown under ith crop to the total cropped area in the watershed and n in the total number of crops grown in the watershed

Values of pre-project and post project periods have been compared. For estimating the over all productivity of different crops, crop samples from 5 m x 5 m area, 4 samples/ha were harvested and threshed separately. Similarly to determine the overall fertility status of soil before and after the project, soil samples were collected from representative sites and analyzed for organic C, N, P and K using wet digestion method (Walkley and Black, 1934); Alkaline KMnO4 method (Subbiah and Asija, 19956); Bray's P-I method (Bray and Kurtz, 1945) and (Hanway and Heidel, 1952), respectively.

To estimate the potential of agronomic interventions in enhancing the yield of Koraput district and entire state of Orissa, the yield of each crop for Kokriguda watershed, Koraput district and Orissa state was converted to rice equivalent yield (REY) taking into account the area, yield, and market support price of each crop.

RESULTS AND DISCUSSION

Crop productivity

There was remarkable improvement in area and yield of crops, with cropping intensity increasing from 78 to 120%. The net sown area in kharif increased from 127.25 to 161.9 ha while that of rabi, from 3.5 to 38.55 ha. Season and crop wise improvement in area and yield is given in table 2. For cereals, area increased by 7.9 - 83.3% and yield by 35.5 - 69.2%. Increase in yield of oilseeds varied from 33.3 - 111.8%. Among vegetables, winter season tomato (Lycopersicon esculentum) the most preferred vegetable crop of tribal farmers, recorded highest increase in yield (110.9%). Varma and Chauhan (1998) also reported 20- 138% increase in productivity of different crops in the watershed of Kalyani (tributary of Gomti river) river. Cropping intensity also reached to 183%. Similar were the findings of Varma and Singhal (1998) who reported 40- 80, 25-50 and 50- 87.5% rise in the yield of cereals, pulses and oilseeds, respectively, from Mansara watershed in Barabanki district. Sharda et al., (2006) also reported that introduction of HYV of wheat and rice led to food security by increasing food productivity by 14% in Sainji watershed (Tehri Garhwal, Uttranchal), and

in Aganpur-Bhagwasi watershed (Patiala, Punjab), dissemination of improved crop production through crop demonstrations increased the yield of most of the crops; maximum yield was recorded in wheat (Triticum aestivum) (82%), blackgram (Phaseolus mungo)(80%) and lentil (Lens culinaris) (56%).

Overall productivity of watershed: ragi equivalent yield

To have better understanding of overall increase in crop productivity, ragi equivalent yield was calculated for whole watershed taking into account the area under individual crop in the whole watershed, average yield and support prices of produce of each crop. Total ragi equivalent yield in the whole watershed was worked out to be 1149.6 q for the year 98 (pre-project), which increased to 3011.7 q in 2001(mid project) and 4396.3 q in 2003 (project completion), thus registering an increase of 162.0 and 282.4%, respectively, over the base year. However on per hectare basis, the ragi equivalent increased by 99.1 and 149.4% for the corresponding period over pre project yield of 8.79 q/ha (Table 3). This high increase in ragi equivalent yield is ascribed to the expansion of area under vegetable crops from 1.25 (1998) to 18.0 ha (2003), which are very remunerative as well as high yielding as compared to the test crop (ragi). Dhyani et. al. (2001) reported the success of commercial cultivation of off-season vegetables (tomato: Lycopersicon esculentum), peas: Pisum sativum, cabbage: Brassica oleracea var. capitata, etc.) and six-folds higher agricultural output than base year of production in Fakot watershed, Tehri Garhwal, Uttaranchal.

Productivity and resources use indices

Index of crop productivity (ICP): Introduction of high yielding varieties, use of chemical fertilizers, bio-fertilizers, composts and manures etc. improved yield of crops tremendously. Because of improvement in the yield of crops, Index of crop productivity increased from 0.33 during pre-project period to 0.48 during post project period, registering an increase of 45.39% (Table 4)

Crop diversification index (CDI)

During pre-project period CDI was worked out be 0.62 and 0.06 for kharif and rabi season, respectively. The overall CDI was 0.68. These low values of CDI particularly for rabi season were because the tribal farmers of Kokriguda were growing only a few crops for home consumption. This indicated a wide scope for diversification of their crops especially during winter/ rabi season. Hence, a number of field crops, pulses, vegetables and spices were introduced in the watershed, and CDI during post project period rose to 0.74, 0.24 and 0.98 for kharif, rabi and overall, respectively. The increase in overall CDI over pre project was 44.12% (Table 4). Sikka et al. (2002) have also reported CDI increase from 0.83 to 0.98 in DPAP (Drought Prone Area Programme) watersheds in Coimbatore district of Tamil Nadu.

Cultivated land utilization Index (CLUI)

CLUI was worked out to be 0.13 for kharif and 0.01 for rabi season and 0.14 as overall during pre-project period. Very low CLUI of Kokriguda watershed indicated inefficient and under utilization of available cultivable land and needed interventions in this regard. Hence during the project implementation phase, a considerable area lying vacant or abandoned was brought under cultivation, and double cropping resulting in the increase in CLUI to 0.17 in kharif, 0.04 in rabi and 0.21 as overall value during post project period (Table 4). A low CLUI value even during post project period is due to the fact that major portion of arable land is rainfed and farmers take only one crop in a year.

Crop Fertilization Index (CFI)

CFI was worked out to be 0.18 and 0.1 for kharif and rabi, respectively, during pre-project period. The value for overall CFI was 0.13.The corresponding values of CFI after completion of project improved to 0.45, 0.39 and 0.44 (Table 4). Although there had been appreciable increase in CFI during post project period, the values of CFI were still low, which indicates that NPK (major nutrient) consumption in the watershed is less than even half of the recommended dose.

Crop diversification through vegetables

Because of the bioclimatic suitability and availability of irrigation water, efforts were made for popularizing vegetable cultivation in the village, which was accomplished through exposure visits, trainings, introduction of high yielding cultivars, supply of inputs and demonstration of package of practices which resulted in number of vegetable growers increasing from 5 in 1998 to 38 in 2003. Persistent efforts resulted in fourteen-fold increase

Table 1. Agronomic practices implemented under project and area under each practice after completion of project

Agronomic practice/ intervention	Area sponsored by the project (ha)				Area under improved practices after completion of project (ha)
	1999	2000	2001	2002	2003
Low land rice varieties (high yielding)	6.5	4.5	2.5	2.5	18.5
Upland rice varieties (high yielding)	1.1	4.5	5.3	1.6	8.5
Boro-rice	1.0	1.5	3.2	4.4	13.8
Ragi varieties (high yielding)	10.5	22.0	15.4	10.3	48.6
Crop diversification (seasonal and off-season vegetables)	1.2	4.1	6.65	5.5	18.5
Double cropping					38.6
Inter cropping	0.4	1.2	1.5	1.6	5.0
INM in rice	1.0	1.4	4.1	2.0	21.8
INM in ragi	2.3	5.7	2.0	1.0	52.6
Pesticide use	2.5	8.5	4.2	1.3	10.5
Summer ploughing	5.4	3.5	2.5	-	37
Irrigation facility	6.0				41 (potential)

Table 2. Area and yield of crops during pre- and post project period

Season	Crop	Area (ha)		Yield (q/ha)		% increase over pre --project	
		Pre-1997-98	Post-2002-03	Pre-1997-98	Post-2002-03	Area	Yield
A. Kharif	Upland paddy	9.5	12.5	7.6	10.3*	31.6	35.5
	Jhola paddy	25	32	11.2	15.4	28.0	37.5
	Ragi	69	74.45	6.7	9.15	7.9	36.6
	Niger	12	15.75	1.5	2	31.3	33.3
	Little millet	3	5.5	1.3	2.2	83.3	69.2
	Ginger	0	0.75	0	68.5	NI*	NI
	Runner beans	0.75	1.5	56	65.4	100.0	16.79
	Ground nut	2.5	6.45	8.5	18	158.0	111.8
	Sweet potato	0.5	2.5	65	80.25	400.0	23.46
	Tomato	0	4	0	168.7	NI	NI
	Miscellaneous	5	6.5	5.5	6	30.0	9.1
	Sub-total (A)	127.25	161.9			27.2	NI
B. Rabi/	Rice	1	13.8	6	9.7	1280	61.67
Summer	Ground nut	0	4.6	0	13.5	NI	NI
	Tomato	0.25	3.7	84.5	178.2	1380.0	110.9
	Cabbage	0	1	0	172.5	NI	NI
	Chilli	0.2	1	31.6	51.5	400.0	61.4
	Brinjal	0	1	0	165.4	NI	NI
	Cauliflower	0	0.2	0	160.3	NI	NI
	Vegetable peas	0	2.6		45.5	NI	NI
	Knolkhol	0	1.2	0	167.9	NI	NI
	Capsicum	0	1	0	54.5	NI	NI
	Bhindi	0	0.2	0	72.7	NI	NI
	Carrot	0	0.3	0	133.8	NI	NI
	French bean	0	0.2	0	54.3	NI	NI
	Cucurbits	0.05	0.25	120	142.6	400.0	18.83
	Miscellaneous	2	7.5	4.5	5.5	275	22.22
	Sub-total (B)	3.5	38.55				
	Grand total (A+B)	130.75	200.45			53.3	
	Cropping intensity	77.9	119.5				

NI = Newly introduced crop * yield of 2001

Table 3. Trends in *ragi* equivalent yield over the project period in the watershed

Year	Ragi equivalent yield (q)		% increase over pre project	
	For whole watershed	Per ha area	Whole watershed	On ha basis
Excluding vegetables				-
1997-98 (pre project)	1076.4	8.2	0.0	0.00
2000-01(Mid project	1630.8	9.5	51.5	15.10
2002-03 (Post project)	2359.8	11.8	119.2	43.00
Including vegetables				
1997-98 (pre project)	1149.6	8.79	0.0	0
2000-01(Mid project	3011.7	17.50	162.0	99.1
2002-03 (Post project)	4396.2	21.93	282.4	149.4

Table 4. Resource use indices in Kokriguda watershed

	Pre project			Post project			% Increase		
	Kharif	Rabi	Overall	Kharif	Rabi	Overall	Kharif	Rabi	Overall
CLUI	0.13	0.01	0.14	0.17	0.04	0.21	30.8	300	50.0
CFI	0.18	0.1	0.13	0.45	0.39	0.44	149.8	290	238.5
CPI	-	-	0.33	-	-	0.48	-	-	45.39
CDI	0.62	0.06	0.68	0.74	0.24	0.98	19.34	300.0	44.12
IWEI	-	-	-	-	-	0.28	-	-	-

CLUI: cultivated land utilization index, CFI: Index of crop productivity, CPI: Crop productivity index, CDI: Index of crop productivity, IWEI: Induced watershed eco-index

Table 5. Manure and fertilizer use in pre and post project period in Kokriguda watershed

Crops	FYM (t/ha)		Urea (kg/ha)		DAP (kg/ha)		MOP (kg/ha)	
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-
Paddy	0.5	4.0	18.3	51.2	13.3	37.41	-	4.5
Ragi	3.8	6.5	18.5	55.1	14.1	29.6	-	-
Vegetables	2.3	9.5	8.0	103.8	-	55.0	-	-
Average	2.2	6.67	14.9	70.03	9.13	40.67		1.5

Table 6. Soil fertility improvement in the watershed

	Pre-project period	Post- project period
O.C (%)	0.46	0.48
N (Kg/ ha)	221.16	236.0
P (Kg/ ha)	6.86	7.62
K (Kg/ ha)	295	313.5

Table 7. Drought analysis during project period for Kokriguda watershed

Year	Drought condition	Onset of effective monsoon	Withdrawal of effective monsoon	Critical dry spells				
				I	II	III	Iv	V
1997	D	14th June	27th Oct	8-25 Oct.	-	-	-	-
1998	N	12th June	21st Oct	13-25th Aug	7-17 Sep	19th Sep-1st Oct		
1999	N	16th June	28th Oct	23rd June-5th July	11-21 Aug	13 -26th Sep	28th Sep-14th Oct-	16-26 Oct
2000	N	27th June	2nd Oct	20th July-9th Aug	-	-	-	-
2001	N	8th June	23rd Sept	15-26 June	25th Aug - 8th Sept	-	-	-
2002	N	17th June	18th Oct	1-14 July	11th Sept-10th Oct	-	-	-
2003	A	18th June	3rd Nov	8-18 Oct.	-	-	-	-

D- Drought year, N- Normal year, A- Abnormal (Excess) year

Table 8. Effect of drought on crop yield in the watershed

Crop	Yield (q/ha)					
	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03
Upland paddy	7.6	7.85	8.25	9.54	10.3	1.5
Jhola paddy	11.2	11.56	13.25	14.52	15.7	15.4
Ragi	6.7	7.5	7.15	7.8	9.4	9.15
Niger	1.5	1.70	1.65	1.75	2.5	2
Groundnut	8.5	9.0	9.45	11.9	12	18
Suan	1.3	1.75	1.6	1.8	1.8	2.2

Table 9. Estimated potential of watershed technologies on yield and return advantage

	Kokriguda	Koraput	Orissa
Cropped area (000′ ha)	0.2005 ha	331.17	5574.52
REY (q/ha)	46.3	21.04	35.47
Returns (Rs/ ha)	26391	11993	20235
Total gross returns from entire crop area (Rs in million)	5.3	3.6972	112705
Gap in REY(q/ha)	-	(-) 25.26	(-) 10.83
Gap in returns (Rs. /ha)	-	(-) 14398	(-) 6156
Additional returns as per REY of Kokriguda watershed (Rs. in million)	-	4768.2	34316.7

in gross area under vegetables, i.e. from 1.25 ha in 1998 to 18.0 ha in 2003.

There is intensification of crops in time scale also. Vegetables are now found in the fields through-out the year. There have been shifts in sowing time of vegetables to exploit better market rates. During initial years of the project, farmers were growing mostly tomato after harvesting their main food crop (ragi and rice). Transplanting was being carried out in December and January months, thus giving vegetable produce in March-April, during which markets for most vegetable would be low resulting in to very low returns. Hence the farmers were advised for crop diversification and change in sowing time, so that higher market rates in the early/late season could be harnessed. The vegetables grown in the watershed include tomato (*Lycopersicon esculentum*), runner bean (*Phaseolus coccineus*), ginger (*Zingiber officinale*), cucumber (*Cucumis sativus*), brinjal (*Solanum melongena*), french bean (*Phaseolus vulgaris*) during Kharif season; pea (*Pisum sativum*), beans (*Phaseolus spp.*), knol khol (*Brassica oleracea var. gongylodes*), cabbage (*Brassica oleracea var. capitata*), Shimla mirch (*Capsicum annuum var. grossum*), chilli (*Capsicum annuum*), carrot (*Daucus carota*), raddish (*Raphanus sativus*) during early winter; tomato (*Lycopersicon esculentum*), brinjal (*Solanum melongena*), pea (*Pisum sativum*), carrot (*Daucus carota*), raddish (*Raphanus sativus*), chilli (*Capsicum annuum* during *rabi* and tomato (*Lycopersicon esculentum*), brinjal (*Solanum melongena*), chilli (*Capsicum annuum*), cabbage (*Brassica oleracea var. capitata*), bhindi (*Abelmoschus esculentus*) during summer.

Employment potential and income from vegetable cultivation

Vegetable cultivation in the watershed generated employment potential of 3762 number of man-days/annum (208 man-days/ha/year), which discouraged male out-migration to the nearby towns. Net returns obtained from vegetables were Rs.15,625/ farmer and Rs.14,245/ha. Some of the villagers opened bank accounts to deposit the savings. Low net profit from vegetables is due to lack of marketing skills of tribal farmers.

Improvement in nutrition

Ragi (Elusine coracana) and rice (Oryza sativa) constituted the major food items before start of this project (1997) with almost negligible consumption of vegetables (15.4 g/capita/day). But because of creation of awareness for improved diet, increased production and availability in the village, per capita consumption of vegetables in Kokriguda reached 36.5 g/day in 2003.

Impact on adoption of some agronomic practices

Manure and fertilizer use

On an average, use of FYM increased by three-folds and urea and DAP by five-folds over pre-project period. During pre-project period, vegetables were receiving relatively very less quantity of FYM and fertilizers but after project implementation, per ha FYM and fertilizer application rose to highest in vegetables (Table 5) as very high remuneration achievable from vegetables have been realized by the tribal farmers of the village.

Summer ploughing

Summer ploughed area expanded from 10 to 37 ha that amounts to 16% of arable land of watershed. The number of farmers practicing summer ploughing increased from 22 to 45. Depth of ploughing was kept about 20 cm. It is done during last week of April - May, making use of and harvesting (in-situ) water of pre-monsoon showers.

Soil fertility changes in the watershed:

A considerable change in the status of available pool of different plant nutrients viz., O.C., N, P and K was observed in the watershed. Organic carbon content increased from 0.46 to 0.48 in 0-30 cm layer. Available N and P also recorded upswing over the pre-project status but remained in low category (Table 6). Available K improved and its status remained high. The improvement in available nutrient status of soil is attributed to enhanced application of FYM, chemical fertilizers, biofertilizer, regeneration of biomass and nutrient recycling.

Impact of drought on crop yield

Month- wise drought analysis during the project period (1997-2003) reveals that in general, June to October, the main growing season, have almost normal months. While 1997 is drought year, 2003 is abnormal (excess) year. Rest all other years are normal years. Week- wise drought analysis indicates that during the year 2002 maximum 52% of the weeks (from 24th to 46th) are drought weeks. However, critical dry spell (CDS) analysis shows that the year 2002 experienced two CDSs of 14 and 30 days duration, respectively

(Table 7). The seedling, flowering and grain formation stages of upland paddy corresponded to these dry spells because of which its yield was reduced by 85%; otherwise like other field crops, the yield of upland paddy was also following an upward trend over the years. Yield of niger (*Guizotia abyssinica*) was reduced by 20% as compared to 2001-02. Negative effect of CDSs during 2002 on the yield of ragi (*Elusine coracana*) and *jhola* land *rice* (*Oryza sativa*) was marginal. Whereas during whole project period, suan (*Panicum sumatrense*) with 2.2 q/ha and groundnut (Arachis hypogaea) with 18 q/ ha recorded highest yield during 2002 (Table 8). This could be due the fact that these crops being of short duration and sown early were able to escape moisture stress period (CDS). On the whole, there was 2.7% loss in the total cereal and millet production of the Kokriguda village due to CDS in the year 2002.

Ecological sustainability

Villagers have got a potential source of income in the form of vegetable growing. Because of the income source, pressure on forests for collecting fuel wood for sale was reduced. This resulted in better natural regeneration in the hillocks imparting a dimension to the sustainability of forest and other farm land vegetation resources.

Extrapolation of Kokriguda productivity in terms of rice equivalent yield (REY) to District and State level.

The overall REY of Kokriguda watershed (considering arable land only) was estimated to be 46.3q/ha which had market value of Rs. 26391/ ha. REY for Koraput district and Orissa was less than Kokriguda, the gap being 25.26 and 10.83 q/ ha, respectively. The corresponding gap for gross returns was Rs. 14398 and Rs. 6156/ha. Additional returns from Koraput district and Orissa state as per Kokriguda REY were estimated to be Rs. 4768.2 and 34316.7 millions (Table 9). This indicates that the pack of agronomic technologies implemented at Kokriguda watershed holds the potentials of enhancing yield and revenue from agricultural lands to a large extent.

REFERENCES

Bray, R.H. and L.T. Kurtz. 1945. Determination of total organic and available forms of phosphorus in soils. Soil Sci. 59, 39- 45.

Dass, Anchal, Sudhishri, S and Dwivedi, V.K. (2008). Enhancing Viability of Tribal Agriculture in Koraput - Bolangir - Kalahandi Region of Orissa through Contract Farming. Journal of Soil and Water Conservation 6(4): 185-193

Dhyani, B.L. Samra, J.S. Babu Ram, Kumar, Nirmal (2001). Environmental payoff of integrated watershed management programme in Garhwal Himalaya- A case study of ORP Fakot. *Journal of Soil and Water Conservation* 45(3 & 4): 141-147

Hanway, J.J. and H. Heidel. (1952). Soil analysis methods as used in Lowa State College Soil Testing Laboratory. *Lowa Agric.* 57, 1-37

Patnaik, U. S., Choudhury, P. R., Sudhishri, S., Dass, A. and Paikaraya, N. K. (2004). *Participatory watershed management for Sustainable Development in Kokriguda Watershed, Koraput, Orissa*, CSWCRTI, Research Center, Sunabeda, Koraput, Orissa. 123 p.

Reddy, A. A. (1993). *Extension Education.* Sree Lakshmi Press, Bapatla, Guntur, p. 28

Sombatpanit, Samaran, Zobisch, M.A., Sanders, D.W. and Cook, M.G. (1997). *Soil Conservation Extension: From Concept to Adoption.* Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi, 488p

Sharda, V.N., Sikka, A.K. and Guyal, G.P. (2006). Participatory Integrated Watershed Management: A Field Manual. CSWCRTI, Dehradun, 366p

Sikka, A.K., Chand, Subhash, Madu, M., Sundarambal, P. and Samara, J.S. (2002). Some measures and indices for evaluating impact of watershed management programme. In: *Resource Conservation and Watershed Management: Technology and and Future Strategies Ed by S.K.Dhyani, K.P. Tripathi, Ratan Singh, A. Raizada, N.K.Sharma, A.S. Mishra, S.S. Shrimali, B.L.Dhyani, A.R. Sharma and O.P.S.Khola.* Indian Assoc. of Soil & Water Conservationists, CSWCRTI, Dehradun: 310-315.

Subbaih, B.V. and I. A. Asija. (1956). A rapid procedure for the determination of available nitrogen in soil. Current Sci. 25, 259- 260.

Varma, V and Chauhan, R.K.S. (1998). Natural development of waterlogged eco-system for sustainable production. Journal of Soil and Water Conservation 42(1&2): 62-67.

Varma, V and Singhal, V.K. (1998). Sustainable development of flood prone watersheds in Gangetic plains. Journal of Soil and Water Conservation 42(1&2): 80-83

Walkley, A. and I. A. Black.1934. An examination of the Degtjareef method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci. 34, 29-38