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Integrated Approach of Crop Diversification, Soil and Rainwater Management for Enhancing Agricultural Productivity of Rainfed Acidic Land

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(Sponsored by : TIFAC, New Delhi)

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1.0 INTRODUCTION

Soil acidity is one of the limiting factors which affects crop production adversely in many parts of the India. Nearly 40 percent of the cultivated land in India are acidic in nature and contain soil pH in the range of 4.5 to 6.5. A major portion of the acid soils are grouped as red, laterite as well as mixed red and black or ferruginous red and red yellow soils which come under the classification of Alfisol, Oxisol, Ultisol and Inceptisol. These acidic soils are found in the regions receiving high rainfall where leaching losses of bases are very high. The acid soils are produced in the region of acidic parent material. It is also formed due to application of acid forming fertilizers and removal of basic cations through crop cultivation. The North Eastern states like Arunachal Pradesh, Assam, Manipur, Mizoram, Meghalaya, Nagaland, Tripura and Sikkim have almost entire area having acidic reaction (>95%). Acid soils are also dominant in other Eastern Indian states like Orissa, West Bengal, Bihar, Jharkhand and Chhattisgarh. In Kerala, not only high rainfall and temperature have contributed to the development of acid soils, but soils rich in organic deposits resulting in the formation of peats under marshy conditions have also been responsible for soil acidity. Besides, the acid soils are also found in parts of Tamil Nadu, Karnataka, Maharashtra, Andhra Pradesh, hills of Utter Pradesh and Himachal Pradesh. The major acid soil affected states in India along with the area affected is given in the Table-1.

In regard to eastern India, 80% of soils in Orissa (12.5 m ha), 76% in Assam and North Eastern states (20 m ha), 39% in West Bengal (3.5 m ha), 30% in Bihar (5.2 m ha), 20% in eastern M.P. (2.9 m ha) and 10% in eastern U.P. (0.86 m ha) are acidic. In Orissa, out of 15.8 mh a geographical area, 12.8 mha (about 80%) is acidic (pH: 5.0-6.5). Rough estimates show that in Orissa about 12 percent of acid soils are strongly acidic (pH<5.0), 48 percent moderately acidic (pH 5.0-5.5), and 40 percent mildly acidic (pH 5.5-6.5). Agriculturally important districts in Orissa having acid soils pH < 5.5 are Mayurbhanj (80%), Dhenkanal (60%), Angul (60%), Phulbani (60%), Sundargarh (60%) Cuttack, Kendrapada, Jagatsinghpur, Jajpur, Angul, Koraput (33%), Nawarangpur, Khurda, Nayagarh, Puri.

Acid soils are low in bases, deficient in organic matter, nitrogen and phosphorous and deficient in secondary nutrients (Ca, Mg), and micronutrients (Mo, B and Zn). Aluminum toxicity, low water retention capacity, high infiltration are also the characteristics of acid soil. Due to these reasons, the crop productivity in acid soil regions is not optimum and far below than that of the potential.

Hence it is necessary to ameliorate the acid soils with liming materials along with integrated approach of crop diversification and water management to enhance the productivity of acid soil. Liming materials may be like limestone, dolomite etc. which is costlier and may not be affordable by farmers. But these should be less expensive and available within easy reach of farmers' beside suitability. In Orissa, locally available huge amount of paper mill sludge may be used as chief source of liming, which will not only raise agricultural production in the state but also reduce environmental pollution in the surrounding areas of the factory.

Keeping that above points in view, a project sponsored by TIFAC, New Delhi on "Agricultural diversification for enhancing productivity of acidic uplands of eastern India" was executed by Directorate of Water Management, Bhubaneswar from 2006-07 to 2009-10 in representative acid soil areas of Orissa i.e. Rautrapur village of Durgadevi Panchayat of Remuna Block, Balasore district and Bhimda village of Badasahi block of Mayurbhanj district, Orissa where paper mill sludge of nearby Emmami paper factory, Balgopalpur, Balasore was applied to ameliorate soils. In addition to soil amelioration, efforts were also made to diversify cropping system and to conserve rainwater for its recycling to ensure higher and stable agricultural productivity and cropping intensity of rainfed acidic land.

Table-1: Area under acid soils in major soil acidity affected states.

States	Geographical area (GA), mha)	Area under acid soil (mha)	Percent of GA
1. Assam and NEH states	26.22	20.0	76.2
2. West Bengal	8.88	3.5	39.4
3. Bihar	17.39	5.2	30.0
4. Orissa	15.57	12.5	80.0
5. Madhya Pradesh	44.30	8.9	20.0
6. Andhra Pradesh	27.70	5.5	20.0
7. Tamil Nadu	13.00	2.6	20.0
8. Karnatake	19.20	9.6	50.0
9. Kerala	3.90	3.5	90.0
10. Maharashtra	30.80	3.1	10.0
11. Uttar Pradesh	29.40	2.9	10.0
12. Himachal Pradesh	5.60	5.0	90.0
13. Jammu & Kashmir	22.20	15.5	70.0

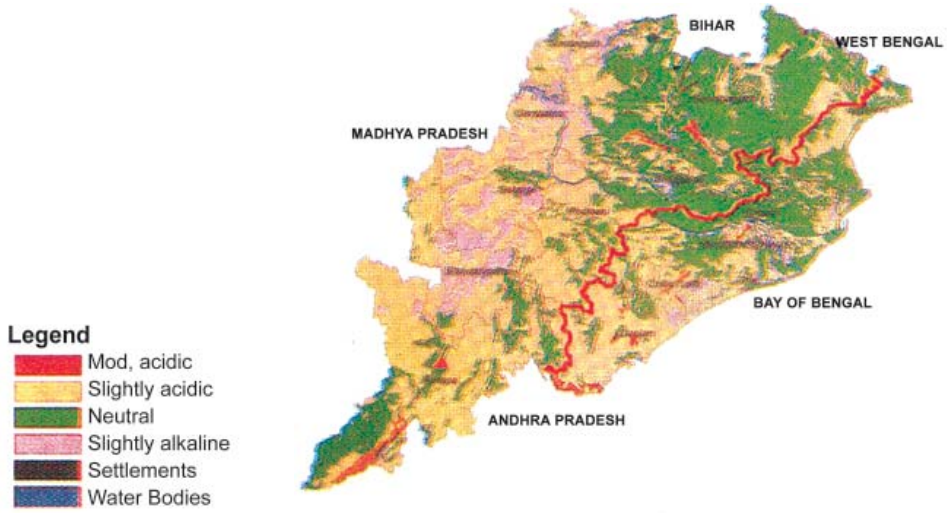


Fig.-1: Soil reaction map of Orissa

2.0 CROP PRODUCTION CONSTRAINTS OF ACID SOILS

A. Related to soil physical properties

- Leaching of bases, fine earth and organic matter due to high rainfall
- Coarse texture soils (high macro pore)
- Low organic matter, Weak soil structure
- High infiltration and permeability rate
- Low moisture holding capacity
- Formation of soil crust, particularly in red and laterite soils (seed germination is affected)
- More susceptible to drought, dry spells
- Poor drainage of peat, marshy and acid sulphate soils (in Kerala)

B. Related to soil chemical and biological properties

- Low P-availability and high P-fixation capacity
- Toxicity of Fe and Mn (Al in some cases)
- Low organic matter status of lateritic and red soils
- Deficiency of secondary nutrients (Ca, Mg), and micronutrients (Mo, B and Zn)
- Leaching losses of nutrients are high and base saturation percentage in low
- Nutrient imbalance, low cation exchange capacity
- Dominance of kaolinite and sesquioxides clay fraction (low water holding capacity)
- Activity and population of Bacteria and Actinomycetes are reduced
- Biological nitrogen fixation and nitrification are adversely affected.

3.0 STUDY AREA

The project was implemented in representative acid soil areas of Orissa i.e. Rautrapur village of Durgadevi Panchayat of Remuna Block, Balasore district and Bhimda village of Badasahi block of Mayurbhanj district, Orissa (Location of the study area is given in Fig.-2). Gross cultivated area of two study villages viz., Routarapur and Bhimda was 45.3 and 127.9 ha, respectively. (Table –2). About 80% of the farm families of the area are marginal/small with an average holding size of less than 2 ha and rest are large farmers' (with > 4 ha of land). Study revealed that, majority of farm families use their own traditional implements. Improved farm machineries and tractors are also not available. The climate of the study area in general is hot and humid. The mean maximum temperatures occur in the month of May with average value of 42 ^{O}C and minimum in December with the value being 8 ^{o}C. The mean annual rainfall of the region is 1650 mm and southwest monsoon normally breaks on 12th June. Paddy is the dominant crop during *kharif* season whereas, pulses (greengram, blackgram, lathyrus) and oilseeds (groundnut, sesamum, mustard and sunflower) are grown during winter. Boro paddy is also grown during winter/summer season where irrigation facilities are available.

The upland acid soils of the area is light textured with low water retention capacity and fertility status and mainly rainfed mono-cropped, dominated by rice with low (<1 t ha^{-1}) and unstable yield. In spite of getting low and unstable yield due to erratic south west monsoon, moisture stress during crop growth period, existence of biological constraints like weeds (*Cyperus rotundus, Echinochloa colona*), diseases (blast, brown spot) and pests (gundhi bug, termite, worms), farmers grow rice traditionally in rainfed upland rice ecosystem. Since in upland, rice productivity is

low and unstable, hence an attempt was made to diversify upland rice ecosystem with the introduction of low water requiring non-rice crops like maize, groundnut, sunflower, blackgram in the rainy season following ridge and furrow methods of sowing. Growing of these non-rice crops on rainfed upland is also agronomically feasible because on such land there was no accumulation of standing water during rainy season.

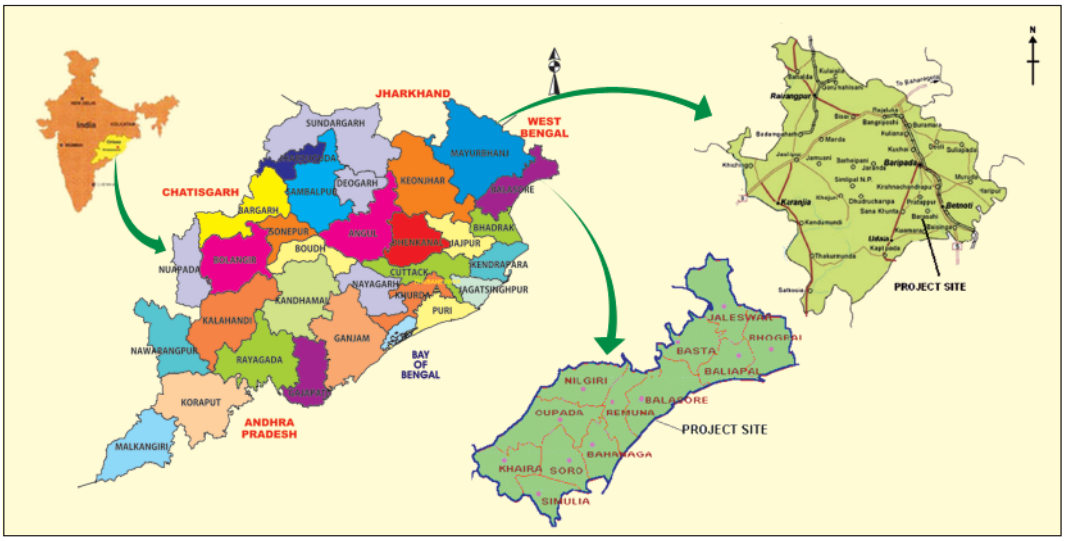


Fig.2: Location of the study area

The productivity (average 2 t/ha) and cropping intensity of rainfed acidic lowland is also low and vast rainfed areas in the eastern region remain fallow after rice. During rainy season, rice is grown on such land with traditional cultivation practices and most of the rice varieties under cultivation are of comparatively longer duration, not harvested at physiological maturity and consequently land does not become available when sufficient residual soil moisture is found in the field (in the November) to grow second crops. To increase cropping intensity of rainfed shallow lowland, second crops like maize, sunflower, groundnut sesamum, were introduced in rainfed lowland rice fallow during winter (*rabi*) season utilizing carry-over residual soil moisture and supplemental irrigation after ameriolating acid soils with paper mill sludge.

Table-2: Cultivable land statistics (ha) of two study villages

Distribution pattern	Routarapur (Balasore)	Bhimda (Mayurbhanj)
Gross Cultivated Area	45.37	127.9
Net cultivated area	39.2	108.20
Up land	8.96	8.12
Medium land	17.36	55.16
Low land	12.88	44.92
Irrigated land	4.42	0.60
Rainfed land	40.90	127.3

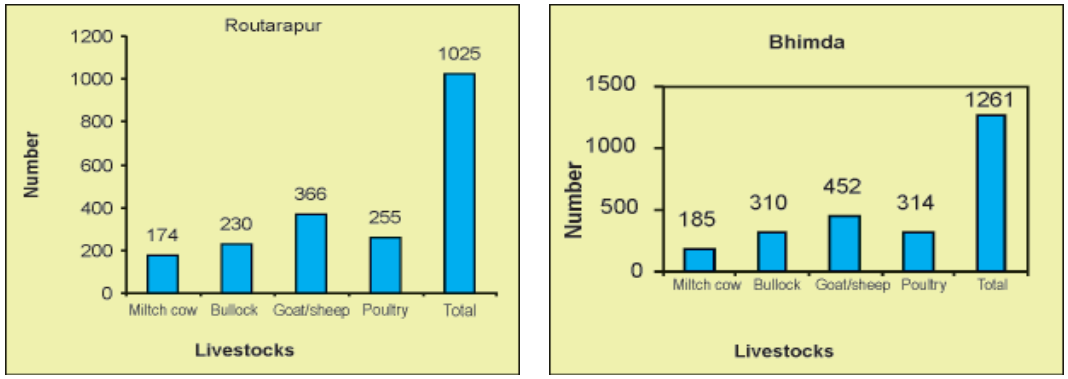


Fig. 3. Available livestocks in study villages (Routrapur and Bhimda)

The Participatory Rural Appraisal (PRA) technique was performed in the study villages to ascertain the agricultural production related constraints through Rank Based Quotient (R.B.Q.) and results are given in Table-3.

$$RB.Q. = \frac{\sum F_i(n+1-i)}{n \times F_i} \times 100$$

F_i = Frequency of key informants for the i^{th} rank
n = Number of rank
N = Number of key informants

Table-3 : Problem identification through Rank Based Quotient (RBQ) technique

Sl. No.	Problems identified	I	II	III	IV	V	VI	R.B.Q.(%)
1.	Lack of suitable soil and water conservation, and improved cultivation practices	6	11	5	4	2	2	71.6
2.	Light textured upland acidic soils with poor water retention where rice productivity is low and unstable	23	7	0	0	0	0	96.1
3.	Water scarcity, erratic monsoon, lack of irrigation facilities	25	3	2	0	0	0	96.1
4.	Fragmentation of holding, labour problem	1	1	0	6	12	10	43.3
5.	Non availability of high yielding varieties of seeds and other agro-inputs at proper time	1	6	3	5	6	9	46.6
6.	Farmers are traditionally rice growers and lack of knowledge about improved cropping system.	4	5	0	5	11	5	50.5

Based on PRA survey, it was revealed that light textured upland acidic soils, water scarcity, erratic monsoon with lack of irrigation facilities were the top most agricultural production related constraints in the region with the R.B.Q. value being 96.1% which were to be addressed through Research and Demonstration..

4.0 AGRO-CLIMATIC CHARACTERISTICS OF THE STUDY AREA

Based on percentage of departure of actual seasonal rainfall from normal, IMD (Indian Meteorological Department) has classified four categories of rainfall situation viz., normal (+19 to -19%), deficit (-19 to 59%), scanty (<-59%) and excess (>=19%). Accordingly, annual rainfall of past 44 years (1960-2003) for Mayurbhanj and Balasore districts of Orissa was categorized and decade wise results are presented in Table-4.

Table-4 : Decade wise distribution of excess, normal and deficit southwest monsoon rainfall

Districts	1970-79			1980-1989			1990-1999			2000-09		
	E	N	D	E	N	D	E	N	D	E	N	D
Balasore	01	06	03	02	04	04	04	05	01	2	6	2
Mayurbhanj	01	04	05	00	08	02	01	07	02	2	6	2

E = Excess; N = Normal; D = Deficit

From normal monthly rainfall (Table-5), distribution in different seasons viz. southwest monsoon (June-September), post monsoon (October-November), winter (December-February) and pre-monsoon (March-May) were computed. Study revealed that about 173.8-192.5 mm rainfall occurs during pre-monsoon period which would be useful for summer ploughing. Summer ploughing will help to recharge the soil profile and to reduce weeds, pests and diseases infestation.

The coefficient of variation of monthly rainfall was computed and results are presented in Table-6. Study revealed that among different months rainfall variability is less during monsoon period (June-September).

Table- 5 : Season wise distribution of rainfall of Balasore and Mayurbhanj districts of Orissa

Seasons	Rainfall (mm)	
	Balasore	Mayurbhanj
Monsoon	1107.7(70.6 %)	1269.6(77.0 %)
Post monsoon	213.3(13.6 %)	140.9(8.5 %)
Winter	54.9(3.5 %)	64.0(3.9 %)
Pre monsoon	192.5(12.3 %)	173.8(10.5 %)

The water requirement (ETc) of major crops in the region was computed by multiplying the crop coefficient (Kc) with reference evapotranspiration (ETo) at different growth stages (Doorenbos and Pruit, 1977, Doorenbos and Kassm, 1979). Computed reference crop evapotranspiration (ETo) and crop water requirements (mm) of major crops using CROPWAT 4.0 model are given in Table 6 and 7, respectively. The ETo values were found to vary from 77-96 mm in January to 192-217 mm in the month of May.

Table- 6 : Rainfall normal (mm), coefficient of variability of rainfall and reference evapo-transpiration of Balasore and Mayurbhanj districts of Orissa

Month	Rainfall normal (mm)		Rainfall variability (%)		Reference ET (mm)	
	Balasore	Mayurbhanj	Balasore	Mayurbhanj	Balasore	Mayurbhanj
January	14.7	10.3	145	209	96	77
February	31.8	28.0	121	143	109	87
March	34.4	40.2	115	102	180	152
April	62.2	52.5	81	72	201	171
May	108.1	101.2	79	63	217	192
June	221.5	265.8	45	28	156	141
July	308.6	337.3	31	31	118	108
August	332.1	359.5	34	45	121	112
September	267.6	262.0	41	45	111	102
October	170.5	114.1	79	101	118	108
November	34.5	21.6	164	203	96	81
December	5.5	7.3	283	234	87	71
Total	**1592.0**	**1601.0**				

Table-7 : Computed crop water requirements (mm) of major crops using CROPWAT 4.0 model

Crop	Balasore	Mayurbhanj		Balasore	Mayurbhanj
Blackgram (K)	345	330	Maize (R)	276	255
Blackgram (R)	291	280	Pigeonpea(K)	468	450
Cowpea	337	308	Sesamum	215	205
Greengram (K)	345	315	Sugarcane	1740	1680
Greengram (R)	291	280	Summer Rice	890	874
Groundnut(K)	414	378	Winter Rice	695	670
Groundnut(R)	401	390	Spring Wheat	412	395
Maize (K)	317	305			

K- Kharif (rainy season), R- Rabi (winter season)

The monthly rainfall at different probabilities using different probability distribution functions (Normal, Lognormal, Log Pearson, Extreme value) was also computed for Balasore and Mayurbhanj districts of Orissa and are given in Table-8 and Table-9, respectively.

Table-8 : Computed and observed (Weibull's method) monthly rainfall (mm) at Balasore district of Orissa

Months	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	17.2	9.8	2.3	-	-	-	-	-	-	14.8	7.5	1.4	10.4	2.6	0.0
Feb	31.6	19.4	7.0	-	-	-	-	-	-	27.7	15.6	5.5	29.3	6.9	0.1
Mar	49.2	31.0	12.0	-	-	-	-	-	-	43.8	25.5	9.7	38.8	22.2	3.5
Apr	72.2	50.7	28.9	-	-	-	-	-	-	65.3	44.0	26.2	60.2	41.2	19.8
May	138.6	98.3	57.2	113.8	71.3	44.3	122.0	80.2	49.0	125.9	85.6	52.2	104.7	81.5	54.1
June	294.0	238.6	182.0	276.5	214.9	166.2	286.1	227.2	174.2	276.3	221.0	175.1	284.0	230.3	164.1

July	317.6	273.2	227.9	308.5	259.6	217.7	313.7	266.4	222.3	303.4	259.2	222.4	302.9	270.1	222.4
Aug	378.9	322.6	265.1	378.0	298.7	234.9	395.9	345.5	277.0	360.9	304.8	258.1	388.2	325.2	266.3
Sept	302.1	248.4	193.6	289.5	224.3	173.0	302.4	242.3	185.2	284.9	231.4	186.9	183.5	244.7	295.9
Oct	217.1	154.0	89.7	176.2	115.0	74.5	184.3	123.2	78.7	196.9	134.1	81.9	154.4	123.1	72.9
Nov	60.0	32.4	4.3	-	-	-	-	-	-	51.2	23.7	0.8	25.8	8.7	1.0
Dec	9.3	3.8	-	-	-	-	-	-	-	7.5	2.0	-	0.0	0.0	0.0

Table-9 : Predicted and observed monthly rainfall (mm) at Mayurbhanj district of Orissa

Months	Normal			Lognormal			Log Pearson			Extreme Value			Weibulls		
	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%	30%	50%	70%
Jan	28.1	13.4	-	-	-	-	-	-	-	23.4	8.8	-	10.4	1.3	0.0
Feb	36.2	20.7	5.0	-	-	-	-	-	-	31.2	15.9	3.1	28.9	10.1	1.8
Mar	11.1	24.3	11.1	-	-	-	-	-	-	33.0	20.2	9.5	31.2	16.4	5.1
Apr	66.9	48.7	30.2	57.0	33.8	19.8	62.1	39.2	22.5	61.1	43.0	28.0	61.9	45.3	24.4
May	109.0	81.1	54.6	94.8	67.5	47.8	96.9	69.7	96.9	100.4	73.5	51.2	91.4	71.3	49.5
June	285.4	275.7	185.0	284.8	209.1	153.5	298.8	257.3	196.5	169.5	220.0	178.8	289.7	227.5	167.5
July	332.4	290.1	246.9	322.5	279.6	241.8	322.4	279.5	241.7	213.9	279.7	241.6	310.9	276.9	253.9
Aug	393.7	338.7	282.6	393.8	316.7	253.7	411.6	361.2	293.6	376.1	321.3	275.7	395.1	345.8	302.2
Sept	331.0	268.1	204.0	308.6	243.6	191.3	315.0	351.2	196.0	310.9	248.3	196.2	328.1	258.5	179.8
Oct	159.5	104.4	48.3	113.4	68.7	41.2	42.1	70.7	42.1	141.9	81.0	41.5	134.2	68.6	45.7
Nov	32.7	15.9	-	-	-	-	-	-	-	27.3	10.6	-	10.8	2.8	0.2
Dec	9.0	4.1	-	-	-	-	-	-	-	7.4	2.5	-	3.2	0.0	0.0

4.1 Actual weather of 3 crop seasons

The actual rainfall of three crop seasons of Balasore and Mayurbhanj districts of Orissa is presented in Table-10(a) and compared with the normal rainfall. In the first crop season 37% and 27% excess annual rainfall occurred in Balasore and Mayurbhanj, respectively. In the later part of the first crop season in August and September when the crop was at reproductive stage, excess rainfall of 30-125% occurred. Proper care was taken to drain out the excess water through furrows from non rice crops. In the second year, excess (151-185%) and incessant rain during sowing and early vegetative periods (June) affected the proper establishment of non-rice crops. The rice crop was performed better in this season. In the third year, -09% to -19% deficit annual rainfall occurred with the highest deviation of 64-66% in the sowing month (June) in two study districts. Deficit rainfall in early part of the monsoon season created sprouting drought in rice as a result rice yield was reduced. On the other hand due to well distributed rainfall, the non-rice crop performed better in this season by overcoming early season dry spell. Monthly average maximum and minimum temperatures of Balasore and Mayurbhanj districts of Orissa were also recorded and are presented in Table-10(b).

Table- 10 (a): Rainfall (mm) of three crop seasons at Balasore and Mayurbhanj districts of Orissa

MONTHS	BALASORE							MAYURBHANJ						
	Normal	2007	Dev. (%)	2008	Dev. (%)	2009	Dev. (%)	Normal	2007	Dev. (%)	2008	Dev. (%)	2009	Dev. (%)
January	14.7	3.2	-78.2	67.2	357.1	21	42.8	10.3	4.5	-56.3	51.7	401.9	12	16.5
February	31.8	92.6	191.1	18.1	-43.0	0	-100	28.0	65.9	135.3	0.9	-96.7	0	-100
March	34.4	0.0	-100	3.8	-88.9	0	-100	40.2	24.6	-38.8	25.4	-36.8	0	-100
April	62.2	19.2	- 69.13	22.7	-63.5	52	-16.3	52.5	53.1	1.1	42.3	-19.4	25	-52.3
May	108.5	96.9	-10.6	98.4	-9.3	132	21.6	101.2	100.9	-0.29	97.2	-3.9	56	-44.6
June	221.5	295.8	33.5	630.8	184.7	75	-66.1	265.8	231.0	-13.0	666.3	150.6	95	-64.2
July	308.6	452.0	46.4	263.5	-14.6	388	25.7	337.3	541.3	60.4	295.1	-12.5	403	19.4
August	332.1	544.0	63.8	286.7	-13.6	275	-17.1	359.5	470.0	30.7	278.8	-22.4	250	-30.4
September	267.6	602.8	125.2	299.5	11.9	298	11.3	262.0	471.0	79.7	281.0	7.2	277	5.7
October	170.5	44.3	-74.0	10.3	-93.9	201	17.6	114.1	24.8	-78.2	202	77.1	173	51.6
November	34.5	35.1	1.7	0.0	-100	0	-100	21.6	50.5	133.7	3.6	-83.3	0	-100
December	5.5	0.0	-100	0.0	-100	0	-100	7.3	0.0	-100	0.0	-100	0	-100
Total	**1592.0**	2186	37.0	**1701**	6.8	1442	-9.2	**1601**	2038	27.3	1763	10.1	1291	-19.3

Source: Orissa Agricultural Statistics, Government of Orissa.

Table- 10 (b): Monthly average maximum and minimum temperatures at Balasore and Mayurbhanj districts of Orissa

MONTHS	BALASORE						MAYURBHANJ			
	2007		2008		2009		2007		208	
	TMAX	TMIN	TMAX	TMIN	TMAX	TMIN	TMAX	TMIN	TMAX	TMIN
January	28	13	28	14	29	12	26	12	27	12
February	30	17	27	16	31	15	29	17	27	14
March	33	21	33	22	32	22	33	20	35	20
April	36	25	35	24	36	24	37	24	34	20
May	36	26	36	25	37	27	37	25	36	21
June	34	26	33	25	35	26	35	25	37	25
July	33	26	32	25	34	24	32	25	33	26
August	32	25	32	26	31	25	32	24	32	36
September	32	25	32	25	32	24	30	24	32	25
October	32	22	32.	23	32	23	31	20	32	22
November	30	19	31	18	29	20	28	17	29	18
December	28	14	28	16	28	15	26	13	27	15

Source: Orissa Agricultural Statistics, Government of Orissa.

4.2 Computation of runoff depth for assessing rainwater harvesting potential in the region

The *kharif*/wet (rainy) season of the region is confined to Southwest Monsoon period (June-September) within which 80% of total annual rainfall occurs. The excess rainfall is not accessed and put into beneficial use before it evaporates or flows into sinks but efficient capture and retention of excess rainfall during the rainy season is essential for creating supplemental irrigation

source to the second crops in rice fallow during dry/*rabi* (winter) season. The SCS runoff curve number method has been employed for computing runoff depth to assess water harvesting potential of the region and result are presented in Table-10(c).

The equation used for computing surface runoff is :

P> 0.2S, where Q = actual direct runoff over the drainage area, P = total storm rainfall, over the drainage area, S = potential maximum retention. P, Q and S are expressed in the same units e.g. centimeters or inches or milimiters

$$S = \frac{2540}{CN} - 25.4$$

In which CN is the runoff curve number (dimensionless) and S is in centimeters.

Study revealed that 472-497 mm runoff occurred at highly assured, (75% probability) level. The runoff was harvested in farm ponds, constructed at two sites and recycled for growing crops in medium and lowlands during winter season.

Table-10(c): Computation of runoff depth (mm) at different probability levels

Months	Balasore			Mayurbhanj		
	10%	50%	75%	10%	50%	75%
June	159.4	103	95.5	140.3	120.4	101
July	161.0	170	130	162.3	171	142
August	205.3	160	145	210.3	165	153
September	143.8	125	101	121.5	109.1	101
Total	669.5	558.0	471.5	634.1	565.5	497.0

5.0 SOIL PROPERTIES

5.1 Soil physical properties of the study area

Study revealed that soils of both the sites were sandy to sandy loam in texture (Table 11a and 11b). The bulk density of the soils varied between 1.45 to 1.55 g/cm$^{3.}$ Due to light textured soils, saturated hydraulic conductivity of soils was very high (1.65 cm/hr) in surface layer (0-35 cm). The available water capacity of soils was also low, ranged between 0.11 to 0.136 cm^3/cm^3 in Balasore and 0.113 to 0.156 cm^3/cm^3 in Mayurbhanj (Table 12 a and 12 b)

5.2 Soil chemical properties /fertility parameters

Important soil chemical/fertility properties of selected farmers' fields of Routarapur, Balasore and Bhimda, Mayurbhanj are given in Fig. 4-9. Study revealed that soils are strong to moderately acidic and pH ranged between 4.68 to 6.17 and electrical conductivity (EC) values ranged between 0.06 to 0.19 dS m^{-1} in two study villages. No salt problem was detected in the soil profile. The organic carbon (%) content of the soil varied from 0.24 to 0.91. In general soil was sandy loam, strong to moderate acidic with low to medium organic carbon, phosphorus and available potassium. Due to strong to moderate acidity, the productivity of crops on such soils are not optimum. Hence it is necessary to ameliorate the soils particularly with cheap liming materials like paper mill sludge, press mud etc, along with integrated approach of crop diversification and water management. Addition of organic matters or integrated nutrient management is also recommended to improve the organic carbon status of the soils.

Table-11(a): Major soil physical properties of experimental site (Bhimda, Mayurbhanj). (Average of six profiles)

Soil depth (cm)	Particle size analysis (%)				Soil Texture	Bulk density (g/cm³)	Ks (cm /hr)
	Coarse sand	Fine sand	Silt	Clay			
0-15	24.5	24.5	34.6	16.4	sl	1.45	1.65
15-30	29.4	23.5	29.0	17.0	ls	1.48	1.52
30-45	24.5	21.6	34.3	19.6	ls	1.50	1.58
45-60	28.8	21.7	27.3	22.2	scl	1.52	0.95

Table-11(b): Major soil physical properties of experimental site (Rautarapur, Balasore). (Average of six profiles)

Soil depth (cm)	Particle size analysis (%)				Soil Texture	Bulk density (g/cm³)	Ks (cm /hr)
	Coarse sand	Fine sand	Silt	Clay			
0-15	30.1	25.2	29.8	14.9	s1	1.50	1.56
15-30	29.8	22.9	25.0	31.0	ls	1.51	1.50
30-45	21.5	24.4	24.6	29.5	sc1	1.53	1.34
45-60	25.8	20.8	25.6	27.5	sc1	1.55	0.88

Table-12(a) : Water retention capacity at different suction values at experimental site (Bhimda, Mayurbhanj). (Average of six profiles)

Soil depth (cm)	(cm^3/cm^3) at 0.01 MPa	(cm^3/cm^3) at 0.033 MPa	(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)
0-15	0.345	0.178	0.068	0.11
15-30	0.356	0.184	0.075	0.109
30-60	0.375	0.224	0.088	0.136

Table-12(b): Water retention capacity at different suction values at experimental site (Rautarapur, Balasore). (Average of six profiles)

Soil depth (cm)	θ (cm^3/cm^3) at 0.01 MPa	(cm^3/cm^3) at 0.033 MPa	(cm^3/cm^3) at 1.5 MPa	Available water content (cm^3/cm^3)
0-15	0.325	0.168	0.055	0.113
15-30	0.349	0.175	0.058	0.117
30-60	0.375	0.216	0.060	0.156

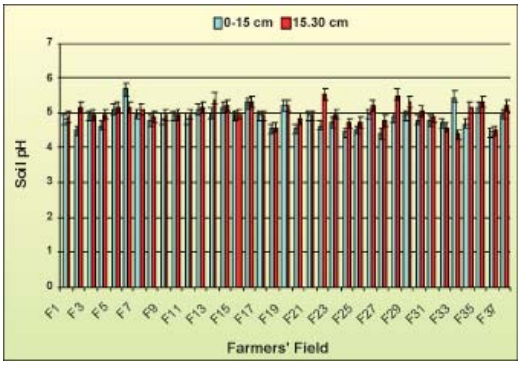


Fig.4: Variation of soil pH in farmers' field

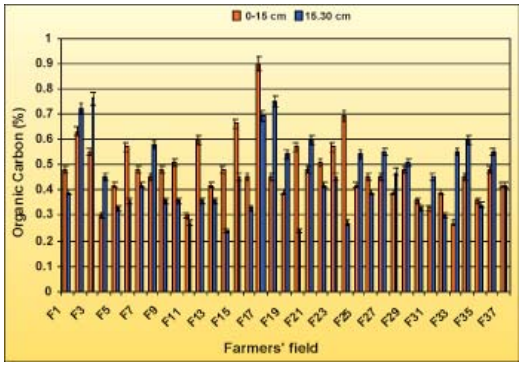


Fig.5: Variation of total organic carbon in farmers' field

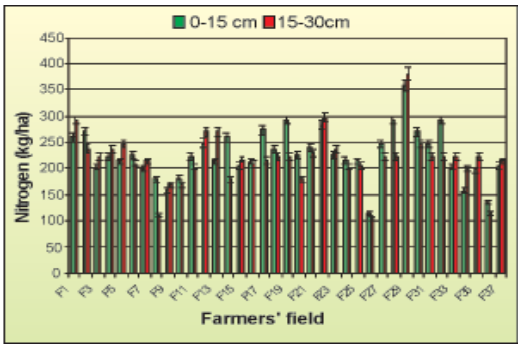


Fig.6: Variation of available nitrogen (kg/ha) in farmers' field

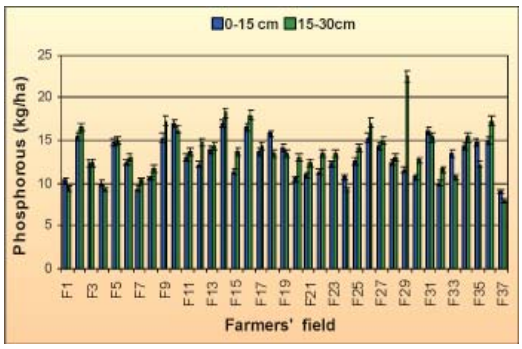


Fig.7: Variation of available phosphorous (kg/ha) in farmers' field

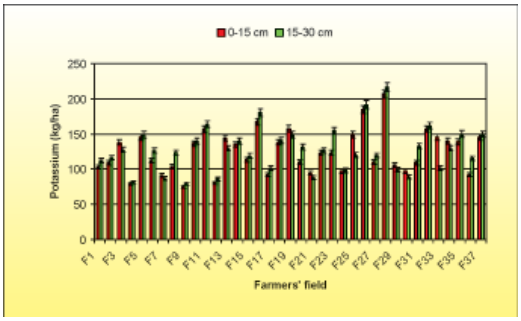


Fig.8: Variation of available potassium (kg/ha) in farmers' field

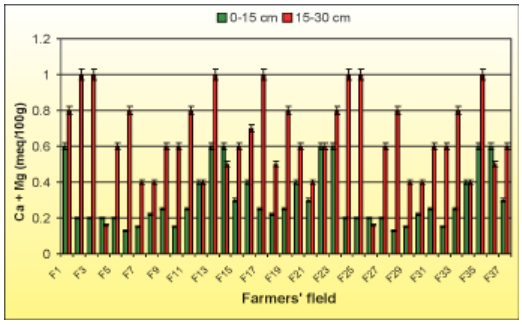


Fig.9: Availability of Ca +Mg (meq/100 g) in farmers' field

5.3 Soil amelioration with low cost liming materials/ paper mill sludge

The quantity of lime required to bring the pH of the soil to a desired level vary according to the nature of the soil. In this study, lime requirement of study soils is determined by the procedure of Shoemaker etal. (1961) which is being widely followed for determination of lime requirement of acid soils less than pH 6.0. To determine lime requirements, 5 g of air dry soil was taken in a dry 50 ml beaker and then 5 ml distilled water and 10 ml of the extractant buffer were added

and stirred intermittently for 20 minutes. The pH of the suspension was determined on the basis of which requirement of lime was read from the standard table. The values are given in tonnes of pure $CaCO_3$ per acre required to bring the soil to the pH indicated and are to be converted to their equivalents in the form of agricultural liming materials to be used (Table - 13).

Liming materials like limestone, dolomite etc. are available in the market but these are costlier and may not be affordable by farmers. So lime should be less expensive and available within easy reach of farmers' beside suitability. In Orissa, locally available paper mill sludge is the chief source of liming which is the solid by-product of paper mills containing fibers and some chemical constituents depending upon the nature of manufacturing processes. The application of paper mill sludge will not only raise agricultural production but also reduce environmental pollution in the surrounding areas of the factory. Keeping that point in view, paper mill sludge of Emmami paper mill, Balgopalpur, Balasore was selected as a liming material to ameriolate acid soil since this factory is located nearby.

The chemical and physical properties of the paper mill sludge vary according to nature of manufacturing processes. In this study proprieties of Emami paper mill, Balasore were analysed which had pH (1:2.5): 8.23 ; EC : 0.20 dSm^{-1} ; Average Ca and Mg : 7.2 meq/100g soil ; $CaCo_3$ equivalent : 30.00% ; Water holding capacity : 119.0% ; Organic carbon : 25.00% ; Nitrogen (Total) : 0.87% ; Phosphorous : 0.20% ; Potassium (Total) : 0.14% ; Sodium (water extract): 0.10%.

The dose of applied liming materials depends on the $CaCO_3$ equivalent of the liming materials, soil texture and its cation exchange capacity (CEC), existing soil pH and desired soil pH to

Collection and application of paper mill sludge in the field (4-6 weeks before sowing)

bring after soil amelioration. Since full lime requirements are very high, 20 - 25 % of full lime through paper mill sludge has been recommended to apply every year in plough layer. The cost of cultivation to grow annual crops in 1 ha of land after soil ameriolation with paper mill sludge is given in Table - 14.

Table-13 : Requirement of lime (t/ha) required to raise pH to 6.5

Sl. No.	Initial soil pH Range	Soil Type				
		Sandy	Sandy loam	Loam	Silt loam	Clay & loamy clay
1.	**A ; 4.5-5.0**					
	For pure CaCo3	4.25	7.25	10.75	15.00	20.00
	Equivalent quantity of Emmami PMS	14.1	23.9	35.4	49.5	66.6
	Average PMS required in soils (sandy, sandy loam and loam) of study areas is 25 t/ha					
2.	**B 5.1-5.5**					
	(Pure CaCo3)	2.5	4.25	6.25	8.50	11.3
	Equivalent quantity of Emmami PMS	8.25	14.02	20.6	28.1	37.3
	Average PMS required in soils (sandy, sandy loam and loam) of study areas is 14 t/ha					
3.	**C 5.6-6.0**					
	(pure CaCo3)	1.0	1.8	2.5	3.5	5.0
	Equivalent quantity of Emmami PMS	3.3	7.6	8.3	11.6	16.5
	Average PMS required in soils (sandy, sandy loam and loam) of study areas is 6.3 t/ha					

Soil having pH less than 4.5 may not be treated. PMS = Paper Mill Sludge

Table-14 : Cost of cultivation to grow annual crops in 1 hectare of land after soil amelioration with Paper Mill Sludge

Item	Quantity/ha	Rate (Rs.)	Amount (Rs.)
A. pH Range 4.5-5.0			
1. Cost of paper mill sludge including transportation charges	25 ton 0.25 LR = 6.25	220/ton 220/ton	5500 1375
2. Spreading charges	15 man days	Rs. 100/man days	1500
3. Cost of Soil Testing		250	250
4. Raising of annual crops (Average cost)		12000	12000
Total cost/ha (Full Lime Requirement)			19250/-
Cost/ha (0.25 Lime Requirement)			15125/-
B. pH Range 5.1 to 5.5			
1. Cost of paper mill sludge including transportation charges	14 ton 0.25 LR = 3.5	220/ton 220/ton	3,400 770/-
2. Spreading charges	15 man days	Rs. 100/man days	1500

3. Cost of Soil Testing	-	250	250
4. Raising of Annual crops (Average Cost)	-	12000	12000
Total cost/ha (Full Lime Requirement)			17150/-
Cost/ha (0.25 Lime Requirement)			14520/-
C. pH Range 5.6 to 6.0			
1. Cost of paper mill sludge including transportation charges	6.3 ton 0.25 LR = 1.57	220/ton 220/ton	1,400 347/-
2. Spreading charges	15 man days	Rs. 100/man days	200
3. Cost of Soil Testing	-	250	250
4. Raising of Annual crops (Average cost)	-	12000	12000
Total cost/ha (Full Lime Requirement)			13850/-
Cost/ha (0.25 Lime Requirement)			12797/-

6.0 EFFECTS OF SOIL AMELIORATION WITH PAPER MILL SLUDGE ON CROP PRODUCTIVITY

Experiments were conducted from 2006-07 to 2009-10 to study the effects of paper mill sludge on productivity of groundnut, sunflower, maize, blackgram and rice during rainy season and on groundnut, sunflower, maize, sesamum and rice during winter season. The soils of the field are acidic. Initial soil samples had pH in the range of 4.96 to 5.3, total carbon 0.65-0.83 %, total nitrogen 0.062 to 0.085% and C: N 9.9 to 10.3. Five treatments viz., T_1: (farmers' practice), 50% NPK; T_2: 100% NPK + 0.2 LR; T_3: 100% NPK + 0.3 LR; T_4: 100% NPK + 0.4 LR and T_5: 100%NPK + 0.5 LR were imposed in 3 farmers' field during both *kharif* and *rabi* seasons (LR= Full lime requirements i.e. 8.3 t/ha pure $CaCo_3$ for sandy loamy soil). Lime in the form of paper mill sludge (PMS) was applied every year in ploughed layer, 4-6 weeks before sowing.

The non-rice crops (maize, groundnut, sunflower, blackgam) were grown during *kharif*/ rainy season in rainfed upland (no surface accumulation of water) following standard package of practices. The productivity and rainwater use efficiency of non-rice rainfed crops were compared with upland rainfed rice. On the other hand, during winter season five crops like maize, groundnut, sunflower, sesamum and rice were grown in rainfed shallow lowland utilizing supplemental irrigation from constructed ponds or other available irrigation sources. For comparison purpose, productivity of all the crop converted into rice equivalent yield.

$$\text{Rainwater efficiency (Crop per rain drop)} = \frac{\text{Crop Productivity in terms of rice equivalent yield (kg/ha)}}{\text{Amount of rainwater received(mm) during crop growth peried}}$$

The experiments were conducted in split plot design with crops in the mainplots and lime application in subplots. The individual plot size was 4 m x 5 m.

Table-15 : Rice equivalent yield *(q ha^{-1}) of rainy season crops in rainfed acidic upland, under different lime and nutrients management

Treatments	Groundnut			Maize			Sunflower			Blackgram			Rice		
	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009
T_1: (farmers' practice 50% NPK	15.3	15	19.6	17.5	12.6	13.8	14.1	14.5	15.2	13.7	9.8	16.2	8.5	10.6	8.8
T_2: 100% NPK + 0.2 LR	26.7	23.2	27.8	21.5	21.5	23.4	33.4	24.8	30.8	34.7	26.5	30.4	20.8	22.6	17.3
T_3: 100% NPK + 0.3 LR	30	25.7	31.7	23.8	18.9	23.8	26	30.8	38.1	26.5	19.7	28.7	15.5	18.1	15.1
T_4: 100% NPK + 0.4 LR	37.1	31.7	38.5	32.9	29.5	33.2	38.1	36.8	39	45.5	38.5	42.7	26.7	27.3	20.8
T_5: 100% NPK + 0.5 LR	43.2	37.5	42.2	38.7	35.8	38.1	51	43.2	51.8	48.4	39.4	47.5	28.3	30.5	23.8

**Average of 3 farmers (one farmer is one replication)*

LSD (0.05): Crop-2.02 Lime: 2.39 Crop x Lime: 3.01

Groundnut at 45 DAS with paper mill sludge (0.2 LR)

Groundnut at 45 DAS with paper mill sludge (0.5LR)

Crop diversification trial with paper mill sludge

Sunflower with paper mill sludge (0.5 LR)

Sunflower with paper mill sludge (0.2 LR)

Table-16 : Net returns (Rs./ha) from rainy season crops in rainfed acidic upland, under different lime and nutrients management

Treatments	Groundnut			Maize			Sunflower			Blackgram			Rice		
	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009
T_1: (farmers practice) 50% NPK	4710	4500	7720	6250	2820	3660	3870	4150	4640	3590	1860	5340	500	1420	860
T_2:100%NPK + 0.2 LR	7690	5240	8460	4050	4050	5380	12380	6360	10560	13290	7550	10280	3560	4820	1110
T_3: 100% NPK+0.3 LR	11000	7990	12190	6660	3230	6660	8200	11560	16670	8550	3790	10090	850	2670	570
T_4: 100% NPK+0.4 LR	13970	10190	14950	11030	8650	11240	14670	13760	15300	19850	14950	17890	6690	7110	2560
T_5: 100% NPK+0.5 LR	17740	13750	17040	14590	12560	14170	23200	17740	23760	21380	15080	20750	7310	8850	4160

Experiemntal field of non-rice and rice crops

Study revealed that all the crops recorded highest rice equivalent yield under T_5 treatment. Higher net returns and rainwater use efficeency were also obtained when crops were grown with 100% NPK + 0.5 LR during both *Kharif* and *Rabi* seasons.

It might be due to correction of soil pH and increase of available nutrients in this treatment. After intoducing non-rice crops, the productivity and rainwater uses efficiency (in terms of rice equivalent yield) were increased (Table 15-17). It was found that under best treatment (T_5) from rice in upland only Rs. 4160 to 8850/- per hectre profit was obtained. Where as through crop diversification proiftability was much higher. The net returns of Rs. 13750-17740, Rs. 14560-14590, Rs. 17740-23760, Rs. 15080-21380 per hectare were obtained from groundnut, maize, sunflower and blckgram, respectively under the same treatment (Table-16).

Under farmers' practice (Ti; Control), only Rs. 500-1420/- net returns & per hectare was obtained from rice. The net returns of Rs. 4500 - 7720, Rs. 2820 - 6250, Rs. 3870 - 4640, Rs. 1860 - 5340 per ha were obtained from groundnut, maize, sunflower, blackgram, respectively.

Table-17 : Effect of paper mill sludge on rainwater use efficiency (kg/ha-mm) of rainy season crops in rainfed acidic upland.

Treatments	Groundnut			Maize			Sunflower			Blackgram			Rice		
	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009
T_1: (farmers practice) 50% NPK	0.86	1.27	1.58	0.98	1.06	1.12	0.79	1.22	1.23	0.77	0.83	1.31	0.48	0.90	0.71
T_2: 100% NPK + 0.2 LR	1.49	1.96	2.25	1.20	1.82	1.89	1.87	2.09	2.49	1.94	2.24	2.46	1.16	1.91	1.40
T_3: 100% NPK+ 0.3 LR	1.68	2.17	2.56	1.33	1.60	1.92	1.45	2.60	3.08	1.48	1.66	2.32	0.87	1.53	1.22
T_4: 100% NPK+ 0.4 LR	2.07	2.68	3.11	1.84	2.49	2.68	2.13	3.11	3.15	2.54	3.25	3.45	1.49	2.31	1.68
T_5: 100% NPK+ 0.5 LR	2.42	3.17	3.41	2.16	3.02	3.08	2.85	3.65	4.19	2.71	3.33	3.84	1.58	2.58	1.92
T_6: 100% NPK	1.72	2.30	2.56	2.06	2.60	2.71	2.30	2.42	2.71	2.20	2.60	3.25	1.49	2.15	1.76

In winter season, four non-rice crops viz., groundnut, maize, sunflower, sesamum were grown in shallow low land utilizing supplemental irrigation. Profitability and water use efficiency were compared with rice crop under different lime and nutrient management practices.

During winter *(rabi)* season also the productivity of all the crops were converted into rice equivalent yield (kg/ha) for comparison purpose. Crop water was efficiency was computed as the ratio of productivity of all the crops in terms of rice equivalent yield (kg/ha) to the amount (mm) of soil moisture utilized.

Table-18 : Effect of paper mill sludge on rice equivalent yield (q/ha) of different crops during winter season

Treatments	Groundnut			Maize			Sunflower			Sesamum			Rice		
	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009
T_1: (farmers' practice) 50% NPK	22.1	24.8	22.9	19.2	22.2	21.4	22.5	23.5	28.5	14	13.9	16.5	17.9	18.7	21.2
T_2: 100% NPK+ 0.2 LR	35.4	32.5	32.5	38.9	38.4	40.3	46	50.5	46.5	28.9	25.3	26.9	38.1	37.2	42.4
T_3: 100% NPK+ 0.3 LR	35	35.8	37	26.6	27.5	34.6	42.5	46	45	26	26.4	25.6	27.3	29.3	32.1
T_4: 100% NPK+ 0.4 LR	48.3	53.3	42.4	50.3	52.3	51.3	62.5	54.5	65	34.1	37	36.6	39.1	40.2	44.2
T_5: 100% NPK+ 0.5 LR	57.9	59.7	53.3	57.2	57.2	58.2	72	67	72	45.1	43.6	44	47.4	47.5	48.5

LSD (0.05): Crop-3.5 Lime - 4.1; Crop x Lime - 6.05

Study revealed that rice equivalent yields of all the crops were higher when 100% NPK was supplied with paper mill sludge (0.5 LR) (T_5 treatment). Under that treatment lowest rice equivalent yield (43.6 to 45.1 q/ha) was obtained in sesamum and highest (72-82) q/ha) was achieved from sunflower crop (Table-18).

Highest net returns per hectare (Rs. 31,400 - Rs. 34,900/-) was obtained from sunflower crop where as from winter rice Rs. 15480-16450 per hectare net return was obtained under T_5 treatment (Table-19). Crop water use efficiency (in terms of rice equivalent yield) was also the highest (16.6 to 19.3 kg/ha -mm) in sunflower crop under T_5 treatment, (Table-20).

Table-19 : Effect of paper mill sludge on net return (Rs./ha) from winter crops

Treatments	Groundnut			Maize			Sunflower			Sesamum			Rice		
	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009
T_1: (farmers' practice) 50% NPK	6470	8350	7030	4440	6540	5980	6750	7450	10950	800	730	2550	4530	5090	6840
T_2: 100% NPK+ 0.2 LR	11780	9750	9750	12830	13880	15210	19200	22350	19550	7230	4710	5830	13670	13040	16680
T_3: 100% NPK + 0.3 LR	11500	12060	12900	5620	6250	11220	16750	19200	18500	5200	5480	4920	6110	7510	9470
T_4: 100% NPK+ 0.4 LR	18810	22310	14680	20210	21610	20910	28750	23150	30500	8870	10900	10620	12370	13140	15940
T_5: 100% NPK+ 0.5 LR	25030	26290	21810	24540	24540	25240	34900	31400	34900	16070	15020	15300	15480	15750	16450

**Average of 3 farmers (one farmer is one replication)*

Rice without paper mill sludge (farmers' practice)

Rice with paper mill sludge (0.5 LR)

Groundnut without paper mill sludge (farmers' practice)

Groundnut with paper mill sludge (0.5 LR)

Maize without paper mill sludge

Maize with paper mill sludge (0.5 LR)

Sunflower with paper mill sludge (0.2 LR)

Sunflower with paper mill sludge (0.5 LR)

Table-20 : Effect of paper mill sludge on water use efficiency in terms of rice equivalent yield (kg/ha-mm) of winter crops

Treatments	Groundnut			Maize			Sunflower			Blackgram			Rice		
	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009	2007	2008	2009
T_1:(farmers practice) 50% NPK	5.46	7.66	6.03	5.55	6.17	5.86	5.92	6.18	7.36	4.88	4.48	6.40	2.56	2.69	2.70
T_2: 100% NPK+ 0.2 LR	8.37	7.74	8.55	9.71	11.10	10.10	12.27	12.98	11.07	9.63	8.38	9.12	5.00	4.96	5.71
T_3: 100% NPK+ 0.3 LR	8.33	9.02	9.37	7.60	7.86	9.11	11.49	11.65	11.84	9.00	8.66	8.68	3.73	3.90	4.54
T_4: 100% NPK+ 0.4 LR	12.14	12.54	10.34	13.41	15.16	12.76	16.23	13.46	15.78	12.40	13.31	12.62	5.21	5.42	5.88
T_5: 100% NPK+ 0.5 LR	14.40	14.56	12.84	15.25	16.34	14.37	19.30	16.34	16.55	15.99	14.63	15.71	6.41	6.21	6.46

**Average of 3 farmers (one farmer is one replication)*

Effects of application of paper mill sludge on soil properties

The change in soil pH and exchangable Al^{3+} after different days of incubation of soil with paper mill sludge was observed and results are presented for two soil samples in Fig. 10 and 11, respectively. Initial soil pH values were 5.1 and 4.95 for two soil samples, respectively. Initial exchangable Al^{3+} for two respective soil samples were 0.53 and 0.59 [c mole (P^+)/kg.

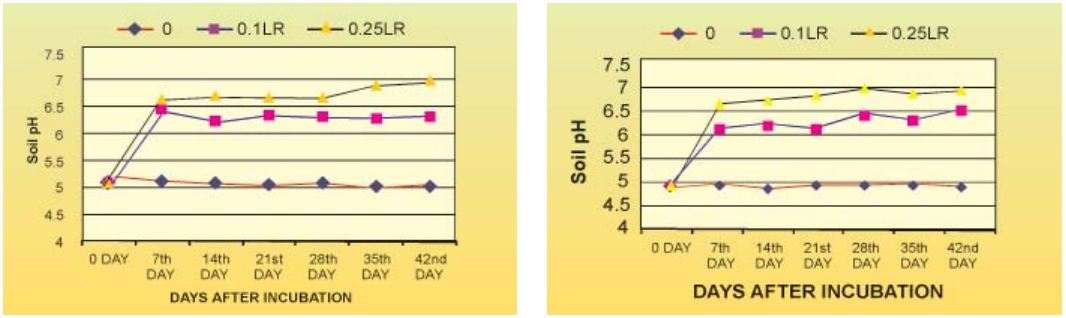


Fig. 10: Change in Soil pH after incubation with paper mill sludge

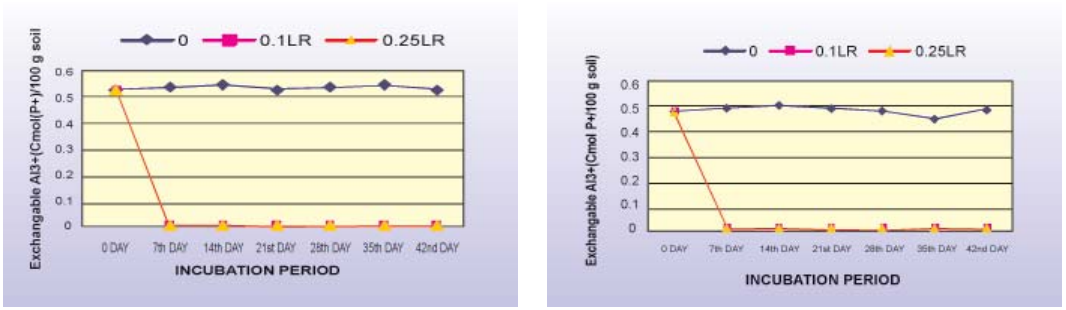


Fig. 11: Change in exchangable Al^{3+} after incubation with paper mill sludge

7.0 IMPACT OF TECHNOLOGY ON PRODUCTIVITY OF CROPS IN FARMERS' FIELD

A. *KHARIF SEASON*

7.1 Effects of application of paper mill sludge on groundnut crops during *kharif seasons* in different farmer' field

The effect of paper mill sludge on groundnut and rice productivity were extensively studied in different farmers' field of Mayurbhanj and Balasore districts, Orissa and the results on groundnut are presented in Table 21, 22 and 23, for the rainy seasons 2007, 2008 and 2009, respectively.

In *Kharif* 2007 average 10.33 q/ha pod yield was obtained with paper mill sludge (@ 0.30 LR) whereas without paper mill sludge average of 6.08 q/ha pod yield was obtained (Table-21)

During *kharif* 2008 (Table-22), incessant rain during early part of the southwest monsoon (June-July) and seepage from upland forest areas affected performance of *kharif* groundnut. It was found that mean yield of 7.64 q/ha was obtained with paper mill sludge with the highest productivity of 8.16 q/ha, whereas, mean yield of 4.6 q/ha yield was obtained when groundnut was grown without paper mill sludge. In this study, 53-73% higher yield was obtained in sludge treated groundnut than that of non-sludge plots. In 2009 *Kharif* 32-58% higher pod yield was obtained in sludge treated plots than that of non-sludge plots (Table-23).

Table-21: Effects of application of Paper Mill Sludge on groundnut crop in *Kharif* 2007

Name of farmers	Sowing date	Plant height (cm)		No. of pods/m2		Average pod length (cm)		Yield (q/ha)		% increase in yield in T1 over T2
		T1	T2	T1	T2	T1	T2	T1	T2	
1. Prasanna Jena	27.06.07	56	48	552	355	2.4	2.1	11.4	7.3	56.16
2. Sundar M. Jena	28.06.07	62	50	615	406	2.3	1.9	12.2	6.4	90.62
3. Kanhu Mahalik	27.06.07	58	51	520	378	2.3	2.0	9.5	6.7	41.79
4. Mahitab Khan	22.06.07	53	49	636	428	2.4	2.2	11.6	7.2	61.11
5. Jatia Singh	22.07.07	60	51	624	388	2.5	2.1	12.7	6.4	98.43
6. Santosh Jena	22.07.07	57	49	526	364	2.2	1.9	9.8	5.4	81.48
7. Praffulla Mahalic	25.07.07	55	50	546	392	2.3	2.1	9.7	5.5	76.36
8. Kati Jena	25.07.07	50	45	540	380	2.3	2.0	9.6	5.8	65.51
9. Arun Jena	28.06.07	54	50	597	382	2.4	2.1	10.5	5.5	90.90
10. Sundar Jena	28.06.07	58	47	605	378	2.4	2.2	11.5	7.1	61.97
11. L. Mahalik	24.07.07	54	49	526	390	2.0	1.8	7.5	4.5	66.66
12. Sarat Singh	22.07.07	56	46	520	392	2.3	2.0	9.2	5.7	61.40
13. Ananta Jena	26.06.07	52	45	515	368	2.1	1.9	9.1	5.6	62.50

T_1 = with paper mill sludge; T_2 = without paper mill sludge

Table-22 : Effects of application of Paper Mill Sludge on groundnut crop in *Kharif* 2008 (T_1 = with paper mill sludge ; T_2 = without paper mill sludge)

Name of farmers	Sowing date	Plant height(cm)		No. of pods/m^2		Average pod length (cm)		Yield (q/ha)		% increase in yield in T1 over T2
		T1	T2	T1	T2	T1	T2	T1	T2	
1. Prasanna Jena	22.06.08	54	46	572	348	2.3	2.0	8.16	4.94	65.1
2. Sundar Mohan Jena	24.06.08	55	45	532	358	2.2	1.9	7.06	4.20	68.1
3. Jatia Singh	21.06.08	58	46	548	370	2.4	2.0	7.9	4.68	68.8
4. Prafulla Mahallik	23.06.08	57	48	508	379	2.4	2.1	7.5	4.90	53.1
5. Sania Dalei	22.06.08	58	50	528	385	2.3	1.9	7.56	4.40	71.8

Groundnut pods with sludge

Groundnut pods without sludge

Table-23 : Effects of application of Paper Mill Sludge (PMS) on groundnut crop in *Kharif* 2009 in different farmers' field (T_1 = with paper mill sludge ; T_2 = without paper mill sludge)

Name of farmers	Sowing date	Plant height (cm)		No. of pods/m²		Average pod length (cm)		Yield (q/ha)		% increase in yield in T1 over T²
		T1	T2	T1	T2	T1	T2	T1	T2	
1. Jatia Singh	12.06.09	56	46	615	405	2.4	2.0	11.0	7.6	44.7
2. Prafulla Mahallik	11.06.09	60	50	550	378	2.5	2.1	9.5	6.5	46.2
3. Prasanna Jena	12.06.09	58	48	618	388	2.3	2.0	11.2	7.8	43.6
4. Sashidhar Mahallik	13.06.09	61	51	575	375	2.4	2.0	10.4	6.6	57.6
5. Sundar Mohan Jena	24.08.09	59	49	570	380	2.5	1.9	9.1	6.5	40.0
6. Kanhu Mahallik	18.06.09	64	50	578	370	2.4	2.0	10.4	7.5	38.7
7. Gura Singh	17.06.09	61	51	525	390	2.4	1.9	10.5	7.5	40.0

7.2 Effects of application of paper mill sludge on rice crops during *kharif seasons* in different farmer' field

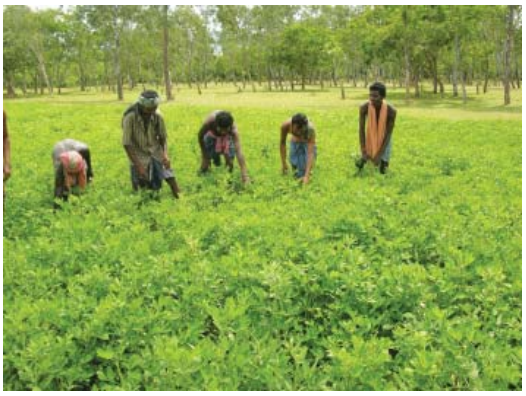
The effects of paper mill sludge on rice productivity are presented in Table 24,25 and 26 for the years 2007, 2008 and 2009, respectively. In *Kharif* 2007, 13-43% higher yield was obtained in sludge treated paddy plots than that of the non-sludged one.

During *kharif* 2008 paddy was grown in rainfed medium and lowlands in 20 acres (10.8 acres in Rautrapur, Balasore and 9.2 acres in Bhimda, Mayurbhanj). The productivity of paddy in sludge and non-sludged plots was compared and study found that on an average 4.68 t/ha grain yield was obtained in Rautarpur, Balasore with paper mill sludge which was 41% higher than mean yield under non-sludged plots (Table-25). In Bhimda, Mayurbhanj, paddy recorded the average grain yield of 3.32 t/ha without paper mill sludge. Whereas, under sludged treated plots, 4.68 t/ha yield was obtained, 17- 43 % higher than non-sludged plots in different farmers' field (Table-25). In *Kharif* 2009 also, Paddy was grown in medium and lowlands in 20 acres (Table-

Table-24 : Effects of application of Paper Mill Sludge (PMS) on rice crop in different farmers' field in *Kharif* 2007 (T_1 = with paper mill sludge ; T_2 = without paper mill sludge)

Name of farmers	Date of Trans-planting	Plant height (cm)		No. of panicles /m²		Average Panicle length (cm)		Test weight (g)		Dry biomass (g/m²)		Yield (q/ha)		%increase in yield in T1 over T2
		T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	
1. Santosh Jena	8.08.07	73	65	285	230	23.5	21.4	22.1	20.12	1438	1225	40.4	28.5	41.7
2. Mani Mandal	8.08.07	75	67	309	254	24.6	21.6	21.8	19.23	1525	1342	35.5	25.1	41.4
3. Gour Mandal	9.08.07	82	58	269	198	24.8	22.2	21.7	19.74	1478	1266	37.5	31.5	19.0
4. Sashidhar Mahalik	10.08.07	76	55	292	216	25.2	22.7	22.7	20.32	1445	1183	38.5	30.4	26.6
5. Hiran Jena	9.08.07	75	61	283	223	23.6	22.5	22.6	19.33	1489	1177	42	29	44.8
6. Damodar Sahoo	8.08.07	82	57	288	241	25.2	21.0	22.7	19.92	1413	1221	40.2	27.6	45.6
7. Jogeswar Rout	10.08.07	76	64	277	213	23.8	21.5	22.5	20.48	1477	1231	37	32.8	12.8
8. Purusottam Patra	09.08.07	78	63	295	207	24.5	23.2	21.9	20.24	1426	1246	41	31.4	30.5
9. Bimbadhar Jena	8.08.07	82	71	272	187	24.8	20.8	22.6	19.15	1388	1145	38	26.5	43.3
10. Prafulla Mahalik	10.08.07	79	68	287	222	23.9	21.6	22.0	20.35	1381	1065	39	30.2	29.1

26). With paper mill sludge, paddy recorded the yield of 4.08-5.20 t/ha in different farmers' field, which was 13-38% higher than that of non-sludge treated plots.



Kharif groundnut with paper mill sludge

Kharif groundnut without paper mill sludge

Table 25 : Effects of application of Paper Mill Sludge (PMS) on rice crop in different farmers' field in *Kharif* 2008 (T_2 = with paper mill sludge ; T_1 = without paper mill sludge)

Location: Rautrapur, Balasore			Location: Bhimda, Mayurbhanj		
Name of farmers	**T_1**	**T_2**	**Name of farmers**	**T_2**	**T_1**
1. Sukura Singh	3.73	4.95	1. Sundar Mohan Jena	3.12	5.14
2. Baidhar Singh	3.75	4.84	2. Kanhu Mahallik	3.24	4.60
3. Chema Biswal	3.68	5.05	3. Jatia Singh	3.45	4.95
4. Gopinath Biswal	3.04	4.35	4. Santosh Jena	3.15	4.95
5. Keshab Maharana	3.45	4.33	5. Prafulla Mahallik	3.05	4.80
6. Banka Singh	3.16	5.13	6. Kati Jena	3.55	4.60
7. Arjun Pradhan	2.68	4.55	7. Arun Jena	3.35	5.05
8. Prafulla Bindhani	3.39	4.45	8. Laxmidhar Mahallik	3.05	4.83
9. Lal Mohan Singh	3.05	4.34	9. Sarat Singh	3.38	5.30
10. Padia Singh	3.17	4.85	10. Ananta Jena	3.05	4.45
11. Budu Singh	3.04	4.45	11. Hiran Jena	3.17	4.65
12. Mangala Singh	2.78	4.53	12. Sania Dalei	3.85	4.89
13. Tofan Singh	3.44	4.85	13. Meram Singh	3.19	4.72
14. Banu Singh	3.45	4.5	14. Mani Mandal	3.06	4.64
15. Bania Singh	3.7	4.84	15. Gour Mandal	3.45	4.45
16. Makuru Singh	3.43	4.74	16. Sashidhar Mahallik	3.15	4.35
17. Bhaskar Ojha	3.2	4.78	17. Prafulla Mahapatra	2.83	4.00
18. Nabin Ojha	3.7	4.85	18. Babula Singh	3.35	4.45
19. Uday Ku Dey	3.73	4.95	19. Rathia Singh	3.56	4.54
			20. Danardan Mandal	2.75	4.75
			21. Kalia Rana	3.12	4.65
			22. Parshu Nayak	2.55	4.55
			23. Ganeswar Maharana	3.08	4.80
Mean	3.32	4.68	**Mean**	3.32	4.68

Table-26 : Effects of application of Paper Mill Sludge (PMS) on rice crop in different farmers' field in *Kharif* 2009 (T_1 = with paper mill sludge ; T_2 = without paper mill sludge)

Sl. No.	Name of the farmers	Date of sowing	Yield (q/ha)	
			T1	T2
1.	Jatia Singh	25.06.09	4.51	3.15
2.	Sasidhar Mahalik	12.07.09	4.34	2.65
3.	Kanhu Mahalik	28.07.09	4.75	3.46
4.	Sukura Sing	12.06.09	4.51	3.29
5.	Raghunath Sing	16.06.09	4.23	3.40
6.	Baidhar Sing	22.06.09	4.55	3.05
7.	Lalmohan Sing	22.06.09	4.08	3.55
8.	Budu Sing	22.06.09	4.85	3.05
9.	Banshidhar Dhinda	24.06.09	4.20	3.35
10.	G. Maharnna	28.06.09	4.50	3.55
11.	Mangulu Mandal	25.06.09	4.00	3.45
12.	Purastam Maharnna	24.06.09	5.20	3.65
13.	Sidheswar Sahu	01.07.09	4.45	3.75
14.	Dibakar Sing	28.07.09	4.25	3.45
		Average	4.45	3.34

B. *RABI SEASON*

7.3 Effects of application of Paper Mill Sludge on productivity of winter (rabi) crops under farmers' management practices.

The impact of paper mill sludge application on *rabi* crops was also studied in different farmers' field. During *rabi* seasons also average 2.5 ton/acres, paper mill sludge was applied to different crops, 4-5 weeks before sowing in ploughed layer and productivity was recorded. Groundnut pod yield varied from 8.33 to 14.50 q/ha with the maximum return of Rs. 21,792 per ha was obtained when soil was ameliorated with paper mill sludge (Table-27). From vegetable cultivation, the maximum net return was Rs 26,875 per hectare from tomato crop and Rs. 18812 per hectare from watermelon (Table-29). The maximum net returns were found to be Rs 5375 to 9800 per ha from *rabi* sesamum (Table 30 & 31).

Table-27 : Effects of application of Paper Mill Sludge on groundnut crop in *rabi* 2007-08 in different farmer's' field.

Sl. No.	Name of the Farmer	Productivity (q/ha)	GrossReturn (Rs/ha)	Cost of cultivation (Rs/ha)	Net Return (Rs/ha)
1	Mangala Singh	9.38	20625	9234	11391
2	Lalmohan Singh	10.11	23250	8826	14424
3	Padia Singh	14.14	32523	11555	20969
4	Makuru Singh	9.58	22042	9688	12354
5	Sukura Singh	11.51	24180	11264	12916
6	Tofan Singh	8.56	17979	9846	8134
7	Baidhara Singh	13.13	28875	10563	18313
8	Banu Singh	13.64	28636	11667	16970
9	Bania Singh	8.75	19250	10646	8604
10	Nabin Ojha	10.42	23958	11329	12629
11	Bhaskar Ojha	9.17	21083	10729	10354
12	Tapan Ojha	8.96	20604	10854	9750
13	Jatin Ojha	9.38	22500	10896	11604
14	Budu Singh	14.50	31900	10108	21792
15	Gopinath Biswal	9.79	22521	9104	13417
16	Chema Biswal	8.54	19646	8979	10667
17	Kesab Maharna	8.33	18333	8313	10021
18	Karunakar Ojha	9.17	21083	8313	12771
19	Gura Singh	9.05	19005	10490	8515
20	Prafulla Bindhani	11.10	24420	9980	14440
21	Banka Singh	8.46	18608	8313	10296
22	Jatia Singh	10.5	22050	8175	13875
23	Sashidhar Mahalik	10.6	21250	8513	12737
24	Musha Singh	10.8	21750	8025	13725
25	Chunu Singh	10.4	22781	8250	14531
26	Rathia Singh	10.75	23650	8250	15400

Rabi groundnut with paper mill sludge

Table 28 : Yield of *rabi* groundnut (2008-09) in sludge treated plots (0.25 LR) at Routrapur project site

Sl.No.	Name of the Farmer	Area (acre)	Productivity (q/ha)	Cost of Cultivation (Rs./ha)	Gross Return (Rs./ha)	Net Return (Rs./ha)
1	Sukura Singh	4	14.05	10525	30800	20275
2	Budu Singh	0.5	13.90	10315	30580	20265
3	Makuru Singh	0.6	13.75	10050	29138	19088
4	Deba Singh	0.6	12.85	10171	26863	16692
5	Baidhara Singh	0.6	11.56	10004	25392	15388
6	Bania Singh	0.6	11.32	10754	25408	14654
7	Tofan Singh	0.6	11.62	10746	24325	13579
8	Singira Singh	0.2	10.55	10500	23625	13125
9	Chema Biswal	1.2	13.91	10750	30617	19867
10	Prafulla Bindhani	0.6	10.97	10750	25204	14454
11	Lal Mohan Singh	0.6	11.00	10746	25300	14554
12	Parikshita Bindhani	0.6	12.41	10346	27225	16879
13	Padia Singh	0.6	12.58	10625	28221	17596
14	Mangala Singh	0.6	11.15	10342	24475	14133
15	Hemanta Kamila	1.2	10.18	10500	22875	12375
16	Sudhakar Dwivedi	1.2	9.75	10469	21938	11469
17	Nityananda Sahu	0.6	11.39	10492	23888	13396
18	Gour Behera	0.6	12.11	10325	25375	15050
19	Purna Behera	1.2	13.00	10800	29250	18450
20	Kartik Prusti	0.6	11.25	10254	23625	13371
21	Ganga Ghadei	0.6	10.2	10500	22458	11958
22	Narayana Sahu	2.1	12.13	10325	25475	15150

Table 29: Productivity of *rabi* vegetables in 2008-09 in sludge treated farmers' field (0.25 LR) at Routrapur, Balasore.

Sl.No.	Name of the Farmer	Name of Vegetable	Productivity (q/ha)	Gross Return (Rs./ha)	Net Return (Rs./ha)
1	Sukura Singh	Tomato	200	43150	26875
		Watermelon	104.0	36325	18825
		Cucumber	87.5	43750	22500
2	Chema Biswal	Tomato	195	38,854	24,583
		Watermelon	103.0	36000	18812
		Cucumber	88	44000	22500

Table-30 : Productivity of Sesamum in *rabi* 2007-08 in sludge (0.25 LR) treated farmers' field of project sites.

SlNo	Name of the Farmer	Productivity (q/ha)	Gross Return (Rs/ha)	Cost of cultivation (Rs/ha)	NetReturn (Rs/ha)
RAUTARAPUR					
1	Makuru singh	7.19	12938	6794	6144
2	Banu Singh	7.20	13656	6875	6781
3	Bania Singh	6.88	12375	5850	6525
4	Budu Singh	6.00	11250	5875	5375
BHIMDA					
1	Sashidhar Mahalik	7.00	12550	6750	5800
2	Prafulla Mahalik	6.87	12718	7075	5643

Table: 31 : Productivity (q/ha) of sesamum during *rabi* 2008-09 in sludge treated (0.25 LR) farmers' field of Routrapur, Balasore.

Sl. No.	Name of the Farmer	Productivity (q/ha)	Gross Return (Rs./ha)	Net Return (Rs./ha)
1	Sukura Singh	6.2	12400	9050
2	Makuru Singh	7.0	13300	9800
3	Chema Biswal	6.5	11700	8170
4	Parikshita Bindhani	6.4	12160	8685
5	Sisin Sahu	6.1	11070	7440
6	Bapun Dhinda	6.0	11400	7940

7.4 Contingency crop planning (growing of crops during pre-*rabi* season).

The contigency crop planning was developed and implemented in farmers' field when main non-rice *kharif* crops were damaged. In the *kharif* 2008, the main crop, groundnut was damaged due to incessant rain during initial growth of the crop. That land was utilized by growing mustard and horsegram during pre-rabi period (October-December) utilizing residual soil moisture, supplemental irrigation and paper mill sludge. Mustard crop recorded 13.75-14.38 q/ha grain yield in Routrapur, Balasore and 11.5-12.5 q/ha in Bhimda, Mahurbhanj (Table-32).

Horsegram recorded 10-12 q/ha grain yield in two study villages (Table-33). Study revealed that horsegram and mustard can be grown as contingent crop or as catch crop when main crop (non-rice) will be failed to grow during rainy season due to abberent weather. From soil sustainability point of view horsegram is recommended because being a leguminous crop it will fix atmospheric N_2 to the soils.

Table: 32 : Productivity of mustard crop during pre-*rabi* 2008-200 in sludge treated (0.25 LR) under farmers' management practices

A. At Routrapur, Balasore

Name of farmers	Area (acre)	Yield (q) from the plot	Gross Return from the plot (Rs.)	Net Return (Rs.) from the plot	Gross Return (Rs/ha.)	Net Return (Rs/ha.)	Yield (q/ ha)
1. Sukura Singh	2.00	11.0	23100	16560	28875	20700	13.7
2. Chema Biswal	1.00	5.71	12075	8825	30188	22063	14.3
3. Prasant Kamila	1.50	8.4	16800	11860	28000	19767	14.0

B. At Bhimda, Mayurbhanj

Name of farmers	Area (acre)	Yield(q) from the plot	Gross Return (Rs.) from the plot	Net Return (Rs.) from the plot	Gross Return (Rs/ha.)	Net Return (Rs/ha.)	Yield (q/ ha)
1. Sundar Mohan Jena	0.50	2.3	4830	3180	24,150	15,900	11.5
2. Jatia Singh	1.00	5.0	10,000	6730	25,000	16,825	12.5

Table-33 : Productivity of horsegram during pre-rabi 2008-2009 in sludge treated (0.25 LR) under farmers' management practices

A. At Routrapur, Balasore.

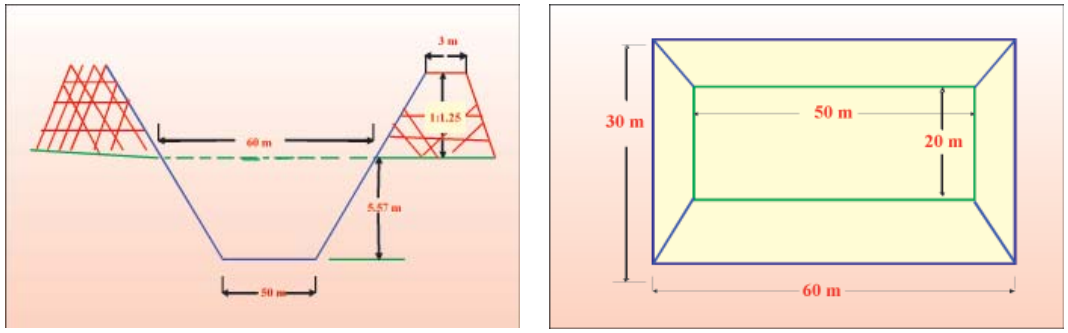
Name of farmers	Area (acre)	Yield(q) from the plot	Gross Return (Rs.) from the plot	Net Return (Rs.)from the plot	Gross Return (Rs/ha.)	Net Return (Rs/ha.)	Yield (q/ ha)
Chema Biswal	0.50	2.4	3840	2582	19200	12910	12.0
Arjun Pradhan	0.50	2.1	3150	1890	15750	9450	10.5

B. At Bhimda, Mayurbhanj

Name of farmers	Area (acre)	Yield(q) from the plot	Gross Return (Rs.) from the plot	Net Return (Rs.) from the plot	Gross Return (Rs/ha.)	Net Return (Rs/ha.)	Yield (q/ ha)
Sundar Mohan Jena	0.50	2.1	3570	2305	17850	11525	10.50
Jatia Singh	2.00	9.0	14400	9370	18000	11712	11.20
Sania Mahapatra	1.50	6.7	10720	6940	17867	11567	11.1

8.0 DESIGN OF WATER HARVESTING STRUCTURES AND DEVELOPMENT OF POND BASED FARMING SYSTEM

Pond based farming system was designed and implemented in two study villages viz., Rautrapur, Balasore and Bhimda, Mayurbhanj. The surface dimension of the each pond was 60m × 30m with 1:1 slope and depth of 5.57 m. Dyke height of 2 m was maintained



Design of pond for developing pond based farming system.

around the pond with the top width of 1.75m. The hydrological parameters like runoff, saturated hydraulic conductivity of the selected sites and water balance of two constructed ponds of study areas were recorded. Water balance of the constructed ponds are presented in Table 34 and 35 for Bhimda, Mayurbhanj and Rautrapur, Balasore study sites, respectively.

Table: 34 : Water balance of the pond constructed at Bhimda, Mayurbhanj

Month	Harvested Water depth (m)	Total volume (m^3) of harvested rainwater	Seepage (m^3)	Evaporation (m^3)	Water utilization for irrigation (m^3)
November, 08	3.4	4675	80.5	154	212
December, 08	3.10	4215	78	169	221
January,09	2.84	3740	81	171	275
February'09	2.4	3210	200	123	865
March'09	1.5	1660	212	198	1050
April'09	1.5	472	215	272	120
May'09	0.45	185	245	334	—-
June'09	1.36	1870	190	257	335
July'09	3.36	4620	120	199	—-
August'09	3.92	5600	105	195	—-
September.09	4.70	5125	95	192	—-
October.09	3.89	4665	82	187	204
November,09	3.5	3982	80.5	169	212
December,09	3.46	4664	78	159	445
January, 10	3.12	3982	81	165	545

Table: 35 : Water balance of the pond constructed at Rautarapur, Balasore

Month	Harvested Water depth (m)	Total volume (m^3) of harvested rainwater	Seepage (m^3)	Evaporation (m^3)	Water utilization for irrigation (m^3)
November, 08	3.8	5225	74.5	154	345
December, 08	3.55	4651	73	169	235
January,09	2.78	4174	75	171	290
February'09	2.55	3678	182	123	1455
March'09	2.05	1918	213	198	1070
April'09	1.89	437	215	272	—-
May'09	0.95	—	276	334	—-
June'09	1.95	2681	164	257	— —
July'09	2.95	4056	172	199	—-
August'09	4.11	5651	134	195	—-
September.09	5.5	7562	95	192	— —
October.09	4.65	6393	57	187	465
November,09	3.45	5681	78.9	169	575
December,09	2.95	4681	75	159	1025
January, 10	2.55	3602	77	165	1235

** Evaporation of two ponds was considered same because these are located within 1 km.*


Harvested rainwater in farm pond

To enhance the productivity and profitability from harvested water, it was utilized for both consumptive and non-consumptive purpose. Fresh water Indian major fish species (Catla, Rohi, Mrigal) of 3 to 4 unit size @10,000/ha were released into the pond during August. The stored water of the pond was also utilized for providing supplemental irrigations to grow *rabi* crops like groundnut, sesamum, mustard, sunflower, vegetables (cucumber, watermelon, okra and ridge gourd). The vegetables like tomato, cauliflower, brinjal, bottle gourd were also grown on the pond bund with the help of harvested water. Short duration fruit crops like papaya, banana were grown on the pond bund. Total of 0.74ha acre in *kharif*, 2.2ha acre in pre-*rabi*, 0.06 ha acre in dyke, 2.85 ha acre in *rabi* and 0.2 ha acre under pond areas were under crops in pond based farming system in Routrapur site, Balasore. On the other hand, total of 1.54 ha acre in *kharif*, 2.2 acre in pre-*rabi*, 0.06 ha acre in *rabi* and 0.2 ha acre in dyke were covered under pond based farming in Bhimda, Mayurbhanj site. From the pond based farming system Rs. 29,250/ha and

Table-36 : Net returns from pond based farming system, 2008-09

Pond	Gross pond based farming area (ha)	Gross Income (Rs) from					Total income (Rs)	Total exp. (Rs) of cultiv-ation	Net returns (Rs) from the land	Net returns (Rs/ha)
		Kharif	*Pre-Rabi*	*Rabi*	Fish	Dyke				
1.Rautarapur	6.08	28,696	58,965	1,02,088	34,575	24,273	2,54,674	76,836	1,77,838	29,250
2. Bhimda	4.0	37,155	43,520	5600	32,000	24,168	1,39,943	44,160	95,783	23,946

Table-37 : Net returns from pond based farming system, 2009-10

Pond	Gross pond based farming area (acre)	Gross Income (Rs) from					Total income (Rs)	Total exp. (Rs) of cultiv-ation	Net returns (Rs) from the land	Net returns (Rs/ha)
		Kharif	Pre-*Rabi*	*Rabi*	Fish	Dyke				
1. Rautarapur	6.08	29110	54550	1,10,200	59,000	32,540	285400	80230	205170	34,195
2. Bhimda	4.0	35,550	5500	40,350	35,000	28,550	144900	49550	95350	23,837

Rs. 23,946/ha net retunes were obtained at 2008-10 in Rautrapur and Bhimda, respectively (Table-36). In 2009-10, Rs. 34,195/ha and Rs. 23,837/ha net retunes were obtained in respective two villages from the same pond based farming system (Table-37). After adoption of pond based farming system, farmers' net returns were found to be higher by 3-4 times than that of earlier.

Components of pond based farming

9.0 TECHNOLOGY DISSEMINATION

- Three trainings/technology demonstration programmes were organized in which different soil and water management technologies/interventions like acid soil amelioration, micro level water resource development, soil and water resources characterization, crop diversification, pond based integrated farming system, multiple use of harvested water, rice-fish integrated system, disease and pest management of major rainfed crops were discussed and demonstrated.
- One week long farmers' training programme on "Scaling up Water Productivity in Agriculture for livelihoods", sponsored by Ministry of Agriculture, Govt. of India was organized from 16th to 22nd Dec., 2008 at Rautrapur, Balasore. In that training programme 72 farmers were trained on different aspects of acid soil management. Success stories were also screened during training programme with the help of video films. Certificates were given to participated farmers on successful completion of the training.





- One field training was organized on 6.11.2007 on 'Enhancing productivity of upland acid soils' at Mayurbhanj, Orissa.
- Under the Capacity Building training Course on Watershed Common Guidelines 2008, 154 officials from Orissa Watershed Development Mission were trained on crop diversification, acid soil management and pond based integrated farming system.
- Efforts were also made to disseminate technologies in different exhibitions, organized by different government and non-government organizations.
- Rainwater harvesting system and agricultural diversification model (on-dyke horticulture, fisheries, cultivation of diversified field crops, short term fruits, floriculture with harvested rainwater) were popularized. The detailed cost estimates, investment, man days generation, production potential, potential gross income generation per year, potential man days generation due to asset created through pond based integrated farming system have been computed to include the technology under 'National Rural Employment Guarantee Act (NREGA) for implementing in watersheds of eastern Indian states

The acid soil management technologies were also disseminated through TV talks, and print media.

Table-38(a) : Radio Talks / TV shows

Title	Date
1. Scaling up Water Productivity in Agriculture in acid soil region. (ETV Oriya, Regional Doordarshan)	22nd December, 2008
2. Improving productivity of acid soils (ETV Oriya, regional Doordarshan)	8th October, 2009

Table-38 (b) : The coverage of farmers' training/meeting/awareness programme in print media

Sl.No.	Headline of the News	Date of published	Name of the News Papers
1.	"Contingency crop planning is need of the hour"	30.07.2008	The Indian Express
2.	"Space tech for better land use"	11.01.2008	The Indian Express.
3.	" Paper mill waste can enhance soil productivity "	08.10.2007	The Indian Express.
4.	"Soil testing a must for proper crops"	12.11.2006	The Statesman
5.	"Crop diversification on watershed basis"	26.11.2006	The Indian Express.
6.	"Expert stress micro-approach to watershed management"	21.11.2006	The Indian Express.

Table-38 (c) : The coverage of success stories and adoption of technology in print media.

Sl.No.	Headline of the News	Date of published	Name of the NewsPapers
1.	"Govt. plans to improve acid soils"	23.04.2008	The Indian Express.
2.	"Crop diversification boosts output"	23.12.2008	The Indian Express.
3.	"Paper mill waste can enhance soil productivity"	08.10.2007	The Indian Express.
4.	"They made fertile patch of green out of barren land"	14.08.2007	The Indian Express.

10. IMPACT OF THE TECHNOLOGY ON LIVELIHOODS OF FARMERS

The assessment of impact of the technology on farming situation and livelihood of farmers was carried out covering a sample of 17 farmers of Bhimda village of Badsahi block in Mayurbhanj district and 12 farmers of Rautrapur village of Remuna block in Balasore district adopting the paper mill sludge application in acidic land.

The farmers of Bhimda village in Mayurbhanj district are having marginal land holding with average 1.03 acre. The yield of paddy increased from 2.6 to 4.4 t/ha after application of paper

mill sludge to reclaim the acid soils. The reclamation of acid soils also prompted the farmers to grow cash crops like groundnut during *kharif* and pulses, vegetables and oilseeds during *rabi* season. Vegetables and oilseeds are dominant crops after paddy. It was found that farmers could diversify the cropping after amelioration of acidic condition through paper mill sludge application. The productivity of vegetables increased by 2 t/ha, while the productivity of oilseeds and pulses were found to be more than one ton per hectare, Many farmers have kept cattle and small ruminants which provided additional income. Few farmers also started to fetch income from poultry and fish. After adoption of acid soil management technologies, the productivity and profitability of farmers were increased.

Table- 39 : Assessment of Impact technology on acreage, production and income of farmers in Bhimda, Mayurbhanj

Name of the Farmers	Farm size (acre)	Farming situation before adoption					Farming situation after adoption				
		Particular	Area (acre)	Produ-ction(t)	Cost of cultiv-ation (Rs.)	Gross Income (Rs.)	Particular	Area (acre)	Prod ucti on(t)	Cost of culti vation (Rs.)	Gross Income
Gour Mandal	1.25	Paddy Goat	0.5	0.5	1250 120	1450 1720	Paddy Mustard Tomato Poultry	0.5 0.5 0.25	1 0.2 2	3500 1650 1600 8500	10800 6450 5600 24750
Ganeswar Maharana	0.3	Paddy	0.2	0.2	500	1300	Paddy Tomato Goat	0.2 0.1	0.4 0.8	1200 650 900	4000 2370 2400
Kanhu Mahallick	0.45	Paddy	0.25	0.275	625	1725	Paddy Cauliflower Bullock	0.25 0.2 ------	0.425 0.9 ------	1500 1470 1000	4500 4870 3200
Sasidhar Mahallick	5.5	Paddy Brinjal Bullock	4.5 0.2	4.5 0.8	11450 1800 1700	31700 4300 4550	paddy Blackgram Groundnut Vegetable Fish Bullock Goat	1.2 0.5 2 1.35 0.45 ------ ------	1.5 0.15 0.9 5 0.45 ------- -------	7000 2600 9300 6300 3500 5600 9000	15000 7100 29100 23400 19500 17900 29000
Jatia Singh	4.5	Paddy Bullock	4 -------	4.2 --------	10000 1600	28900 4400	Paddy Groundnut Mustard	1 0.5 1	1.8 0.15 0.5	6000 1500 3500	18000 5500 13500
Arun Jena	0.35	Paddy	0.25	0.275	640	1880	paddy Cabbage goat	0.25 0.1 -----	0.4 0.3 -----	1200 336 800	3700 1136 2300
Kati Jena	0.25	Paddy	0.25	0.25	625	1750	paddy Cow	0.25	0.5	1650 3400	5350 11700
Banula Singh	0.5	Paddy	0.5	0.55	1300	3775	paddy cow	0.5 -----	1 -----	3500 3300	10500 11500
Mani Mandal	0.675	Paddy Bullock	0.5 -----	0.55 -----	1200 960	3400 2360	paddy cucumber Tomato Goat	0.5 0.05 0.12 -----	1 0.175 1 -----	3000 425 685 1560	10000 1300 2550 4310
Kalia Rana	0.35	Paddy	0.25	0.25	620	1620	paddy Tomato Goat	0.25 0.1 -----	0.4 0.8 -----	1500 650 850	4000 2350 2350
Sania Dalei	0.5	Paddy	0.5	0.5	1300	3300	paddy Cow	0.5	0.1	3500 3400	10000 12500

Danardan Mandal	0.2	Paddy Bullock	0.16 -----	0.4 -----	1000 1100	2600 2660	paddy Bullock	0.2 -----	0.4 -----	1600 3300	4100 10500
Sarat Singh	0.2	Paddy	0.2	0.24	500	1580	Paddy Goat	0.2	0.49	1270 2000	4700 5000
Anant Jena	0.35	Paddy	0.25	0.25	625	1525	Paddy Brinjal Cow	0.25 0.1 -----	0.53 0.4 -----	1300 335 3300	5000 1650 11600
Meram Singh	0.5	Paddy	0.5	0.5	1250	3250	Paddy Goat	0.5	1.025	3500 1800	10675 4800

The sampled farmers of Rautrapur village in Balasore district have also adopted the paper mill sludge application to reclaim the acid soils. The yield of paddy has increased from 2.7 to 4.5 t/ha after paper mill sludge application. Farmers preferred to grow groundnut in *kharif* during post-adoption period as the average area under paddy decreased from 0.94 to 0.51 acre. Growing of oilseeds and vegetables by most of the farmers have diversified the cropping pattern and enhanced the production and income of the farmers. Keeping animals for many farmers provided additional income. The overall income of all the farmers increased during post-adoption period (Table 40).

Table-40 : Assessment of Impact technology on acreage, production and income of farmers in Rautrapur, Balasore

Name of the Farmers	Farm size (acre)	Farming situation before adoption					Farming situation after adoption				
		Particular	Area (acre)	Production (t)	Cost of cultivation (Rs.)	Gross Income (Rs.)	Particular	Area (acre)	Production(t)	Cost of cultivation (Rs.)	Gross Income (Rs.)
Arjuna Pradhan	0.7	Paddy	0.5	0.5	1250	3250	Paddy Tomato Poultry	0.5 0.2 --	1 1.6 --	3000 1300 4300	10000 3950 12450
Gopinath Biswal	2.1	Paddy	0.5	0.55	1250	3450	Paddy Mustard Knolkhol	0.5 1.5 0.1	0.9 0.6 0.38	3200 5000 1270	9500 21800 3400
Keshab Maharana	1.625	Paddy Goat	0.5 -----	0.5 -----	1260 600	3260 1400	Paddy Watermelon Cucumber Poultry	0.5 0.1 0.05 100	1 2.15 0.176 0.25	3000 2000 450 8600	10000 10000 1350 24850
Baidhar Singh	0.75	Paddy Goat	0.5	0.5	1250 900	3250 2100	Paddy Cabbage Goat	0.5 0.25	0.8 1.05	3000 1500 1800	8300 5350 4800
Prafulla Bindhani	1.1	Paddy	1	1.1	2700	7100	Paddy Groundnut Tomato Bullock	0.25 0.6 0.25	0.45 0.2 2.1	1500 2500 1650 1000	4650 7500 6150 3200
Sukumar Singh	8	Paddy Brinjal Bullock	5 0.5 -----	5 2.5 -----	15500 4500 850	40500 10750 2250	Paddy Groundnut Mustard Sesamum Vegetable Fish Bullock	1 4 2 1 0.25 0.45 -----	1.5 2 1.1 0.25 1.5 0.59 -----	7000 16000 6500 1300 1770 3800 11300	15000 66000 29600 6300 5820 23800 31800
Banu Singh	0.6	Paddy Cow	0.5 -----	0.5 -----	1300 2800	3550 8650	Paddy Knolkhol Goat	0.5 0.1 -----	0.9 0.38 -----	3000 1200 1800	9000 3400 4800
Mangala Singh	0.5	Paddy Goat	0.4 -----	0.44 -----	960 600	2710 1400	Paddy Brinjal Cow	0.25 0.25 -----	0.79 1.2 -----	1500 1500 3400	4390 6000 11600

Lal Mohan Singh	1.6	Paddy Bullock	0.5 -----	0.5 -----	1200 980	3200 2380	Paddy Groundnut Blackgram Cow	0.5 0.6 0.5 -----	1.075 0.25 0.16 -----	3500 2500 2000 7000	11000 8500 6000 23400
Chema Biswal	3.45	Paddy Brinjal Bullock	3 0.2 -----	3.15 0.8 -----	7500 1800 800	20100 4300 2000	Paddy Mustard Horsegram Groundnut Vegetable Cow Goat	0.5 1 0.5 1.2 0.25 ----- -----	1 0.25 0.22 0.65 1.45 ----- -----	3300 2500 1000 5200 1590 6480 9000	10300 9500 2000 19500 5390 17280 29000
Banka Singh	0.7	Paddy Bullock	0.5 -----	0.6 -----	1250 1000	2650 2600	Paddy Watermelon	0.6 0.1	0.85 1.415	4300 1700	8800 6700
Bania Singh	1.2	Paddy	0.25	0.25	630	1630	Paddy Groundnut Tomato Poultry	0.5 0.6 0.1 -----	0.8 0.271 0.8 -----	3000 2500 650 4300	8000 8500 2350 13050

The increase in physical assets holding is maximum (increased more than 90%) in case of the sampled farm families of both Mayurbhanj and Balasore districts followed by the financial assets gain (67-68%). Maximum improvement in physical and financial assets indicates the betterment in living condition as well as economic condition. Increase in human assets of the farmers at both places is about 60%. However, social assets gain is 57% and 63% for the farmers of Mayurbhanj and Balasore, respectively. The increase in natural assets is 53% and 43% for the farmers of two respectively districts. Assets holdings of all the sampled farmers increased , Physical social and human assets of the farmers in Balasore have come above the average level. While social and human assets of the sampled farmers in Mayurbhanj district are more than the average level. It implies the fact of recognitions of the farmers in the society on adoption of paper mill sludge application to reclaim acid sois with better farming and increased production. The increased income on adoption of technology has motivated the farmers to invest and intervene further like keeping animals, poultry and fish farming leading to the betterment of income and living standard.

11. SUCCESS STORY AND PRINT MEDIA COVERAGE

After inspiring the technological interventions of Directorate of Water Management, one farmer of Rautrapur village, Shri Sukura Singh bought a power tiller plus some other equipments at a cost of Rs. 1.39 lakhs in 2008-09. In 2009 he adopted the integrated technology of acid soil management in his entire area of 5 acres. Now with the farm mechanization he is able to prepare the fields in time and as a result land and water productivity were increased. Presently he has shifted his house near the farm and now the farm supervision and farm operations are very easy for him. He is earning now Rs. 30,000-35,000/ha, 3-4 times than that of earlier.

- After ameliorating acid soils with paper mill sludge and with the help of harvested rainwater, it is now possible to grow diversified crops (groundnut, maize, blackram, pigeonpea, sunflower, sesamum, rice) throughout the year and farmers are earning net returns of Rs. 23000-34000 per hectare, 3-4 times higher than that of earlier income. Paper mill sludge could ameliorate acidic soils and increased the yield of different crops by 34-68%.
- The acid soil amelioration with low cost liming materials and crop diversification were widely disseminated by organising farmers' fair, training/awareness programme. During rabi 2008-09, the IFFCO, Bhubaneswar adopted the technology of paper mill sludge application in 120 acres of land to grow groundnut crop where 223 farmers were involved.

- The Department of Agriculture, Government of Orissa has chalked out massive plan to ameliorate acidic soils of 2.4 lakh hectares of cultivable land in 2008 by supplying Paper Mill Sludge to farmers. ('The Indian Express on 23.4.2008'). From the year 2008-09, State government of Orissa has started supply of paper mill sludge at subsidized rate (Rs 10/- for 50 kg bag) to all the blocks of Orissa after purchasing the sludge from different paper mills of Orissa.

COVERAGE OF SUCCESS STORY IN PRINT MEDIA

Orissa PLUS

The Statesman on 12.11.2006

Soil testing a must for proper crops

The Indian Express on 8.10.2007

MANAGING ACIDIC SOIL

Paper mill waste can enhance soil productivity

The Indian Express on 14.08.2007

They made fertile patch of green out of barren land

ACIDIC SOIL

The Indian Express on 33.04.2008

Govt plans to improve soil condition

The Agriculture Department has chalked out a massive plan to ameliorate acidic soil of 2.4 lakh hectares of cultivable land this year by supplying lime sludge waste of paper mills to farmers

- Mayurbhanj, Keonjhar, Sundaragarh and Gajapati dists have high acidic soil
- Of 61 lakh hectares of agricultural land, 41 lakh hectares are acidic soil
- 13 lakh hectares are highly acidic