Research Bulletin 66

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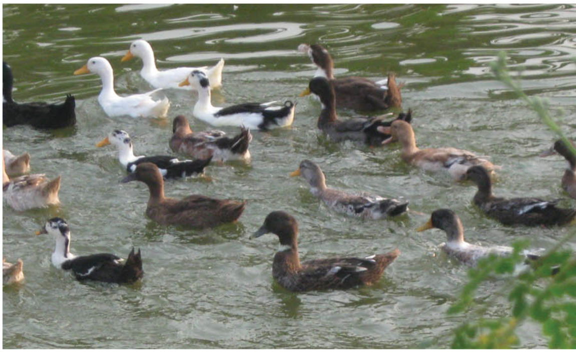

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PREFACE

Agriculture the largest user of the world's freshwater resources, consuming around 70 percent of this vital resource. With increased population and higher living standard, water scarcity is becoming an important issue worldwide. Against the backdrop of global environmental and societal changes, water scarcity looms large in many parts of the world. Changes in water availability may heighten water conflicts between users at different scales, from the local to the transnational level. Water resource development and management therefore, plays a pivotal role in enhancing agricultural productivity through optimum use of water resources and seeks to allocate water on an equitable basis to satisfy all agricultural uses and demands. As agricultural production needs to be increased but water is in limited supply, there is also a strong demand to increase agri-aquacultural water productivity.

Application of better water management practices through intensification of existing agri-aquaculture systems with emphasis on integrated farming system is therefore, the main approach for improving the production performance. Understanding the principles of water resource management and integrated farming system with an effort to optimize, integrate and disseminate such a combined methodology is needed towards a sustainable agri-aquacultural production system. In the present study, water harvesting based integrated farming system models have been developed and economic analysis has been done. The impact analysis of the technological interventions on the livelihood of farmers has been studied.

We sincerely hope that our effort in bringing out this research bulletin based on on-farm field trial will be helpful for all those engaged in agricultural water resource development and its management. This will also serve as a source of information to farmers, policy makers, entrepreneurs, researchers and extension workers.

Authors

CONTENTS

1. Introduction

Agriculture is the mainstay for livelihood of two-third population in India. Eastern region of the country is blessed with plenty of rainfall, out of which about 80% occurs during the monsoon period (July to October). However, because of erratic onset, distribution and withdrawal of rains, rainfed ecosystems (upland, medium and low lands) have problem of uncertain moisture supply that results in monocropping of rice with its lower production and productivity. The rice-fallow area which is about 12-16 million ha is a concern and remain unutilized after harvesting of kharif rice due to lack of proper water resource management. Increasing agricultural production by bringing more area under cultivation and at the same time increasing productivity and cropping intensity would help to a large extent in improving the livelihood of rainfed farmers.

The plateau region of eastern India, has been classified as Agro Ecological Region (AER) No 12 by National Bureau of Soil Survey and Land Use Planning (ICAR), Nagpur, India. This agro-ecological region comprises north-western and western districts of Odisha, Chhatishgarh, Jharkhand and southern districts of West Bengal; and is characterized by hot moist sub-humid type of climate with dry summers and mild winters. Agriculture is the major source of livelihood of the people in this region. However, agricultural productivity in the region is very poor due to lack of water resources coupled with appropriate technical knowledge and inaccessibility to quality planting materials. Therefore the habitats of the region are one of the poorest in India. In view of this, a 'National Agriculture Innovation Project (NAIP)' was initiated in the Dhenkanal district of Odisha, which is located in the eastern region of the country. In the project, technological inputs were provided to the farmers and its impact on the livelihood was studied. The present study also focuses on economic analyses of multiple use of water due to construction of water harvesting structures, pond-based integrated farming system models involving different system components and impact analysis of technological interventions on livelihood of rainfed farmers.

2. Study area

The study was carried out in three villages viz. Khallibandha, Nuagaon and Mandapala) under the Dhenkanal sadar block and three villages (Gunadei, Belpada and Kaunriapala) under Odapada block of the Dhenkanal district, Odisha, respectively (Fig. 1 and Fig. 2). The study villages are situated on the bank of River Brahmani which is a major river of Odisha state in eastern India. The total area of Khallibandha, Nuagaon and Mandapala villages are 247.26, 448.19 and 58.92 ha, respectively. These three villages belong to two watersheds viz. Tarava and Nuagaon watershed (Fig. 1). The total area of Gunadei, Belpada and Kaunriapala villages are 436.82, 191.34 and 239.40 ha, respectively, which are under two watersheds viz. Gunadei and Kaunriapala watershed (Fig. 2). The total area of Tarava, Nuagaon, Gunadei and Kauriapala watersheds are 469.48, 540.76, 788.44 and 1066.73 ha, respectively.

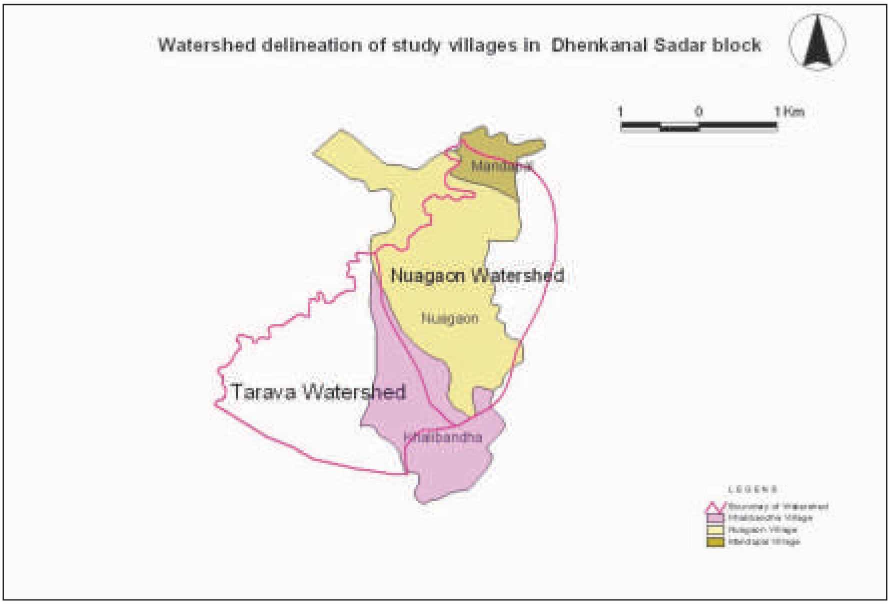


Fig. 1- Watershed delineation in the study villages in Dhenkanal sadar block

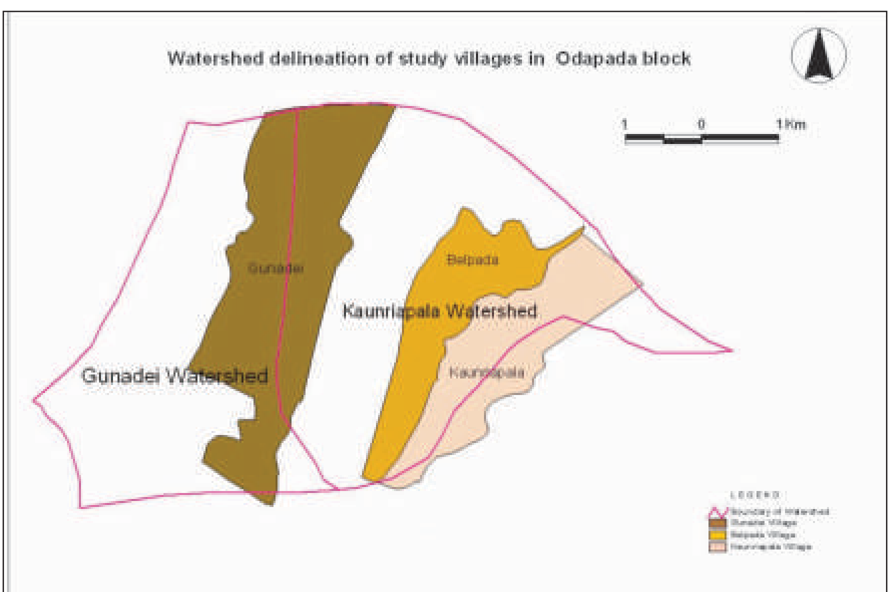


Fig.2 – Watershed delineation in the study villages in Odapada block

3. Rainfall characteristics of the study area

Daily rainfall data of 35 years (1976 to 2010) of Dhenkanal sadar block and Odapada block was collected from the district agricultural office and analyzed. Annual average rainfall of Dhenkanal sadar block was found to be 1435.6 mm (with s.d. of 327.7 mm), whereas the annual rainfall of Odapada block was found to be 1264.3 mm (s.d. of 284.2 mm). There was notable variation in average monthly rainfall in both Dhenkanal Sadar block and Odapada block (Fig. 3 & 4). The probability analysis of rainfall for both Dhenkanal Sadar block and Odapada block was done and rainfall at 10 to 90% probability was found out (Table 1 & 2).

Average monthly and annual rainfall in Dhenkanal sadar block have been observed to be slightly higher that Odapada block. In both the blocks, most of the rainfall occurred in 5 rainy months i.e from June to October. In the Dhenkanal sadar block, the average rainfall in 5 rainy months was 1246.4 mm which was 86.8% of the average annual rainfall. In the Odapada block, the average annual rainfall in 5 rainy months was 1111.9 mm which was 87.9% of the average annual rainfall. In Dhenkanal Sadar block, maximum rainfall was received in the month of August (348.6 mm) followed by July (334.8 mm) and June (229.5 mm). Similarly, in Odapada block, maximum rainfall was received in the month of August (329.5 mm) followed by July (312.8 mm) and June (202 mm). The standard deviation values varied from 84.86 to 139.69 mm in Dhenkanal Sadar block and 95.1 to 152.16 mm in Odapada block during monsoon

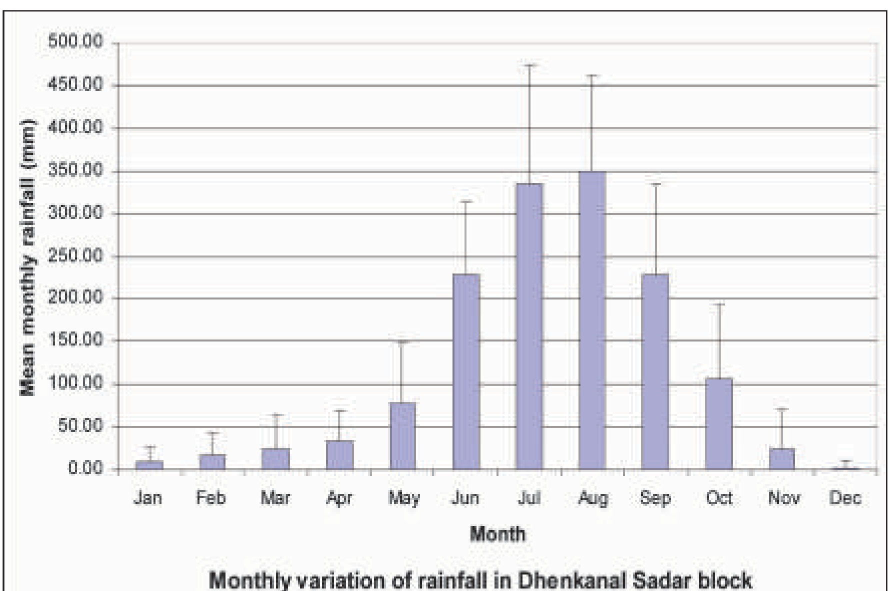


Fig. 3- Monthly variation of rainfall in Dhenkanal sadar block

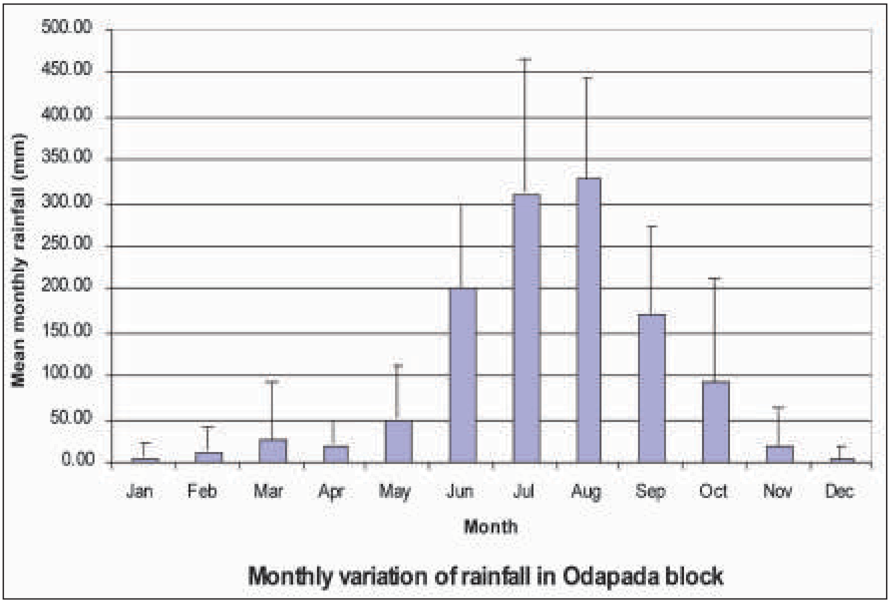


Fig. 4- Monthly variation of rainfall in Odapada block

months. During non-monsoon months, the standard deviation values varied from 9.39 to 70.48 mm in Dhenkanal Sadar block and 4.72 to 52.0 mm in Odapada block. The standard deviation values were generally higher in the monsoon season. But the coefficient of variation was higher for non-monsoon season.

The rainfall occurrence at 20, 50 and 80% probability level can be considered as rainfall occurrence in wet, normal and dry year respectively. The annual rainfall in Dhenkanal Sadar block at 20, 50 and 80% probability are 1613.6, 1388 and 1136.5 mm whereas, the annual rainfall in Odapada block at 20, 50 and 80% probability are 1576.5, 1374 and 1080.4 mm, respectively. At 20% probability level, maximum rainfall was received in Dhenkanal Sadar block in the month of August (473 mm), followed by July (462 mm) and September (313 mm); and in Odapada block, maximum rainfall was received in the month of July (473 mm), followed by August (444 mm) and June (279 mm). At 50% probability level in Dhenkanal Sadar block, maximum rainfall was received in the month of July (312.1 mm), followed by August (291 mm) and June (215.5 mm); and in Odapada block, maximum rainfall was received in the month of July (346 mm), followed by August (305 mm) and June (204 mm). At 80% probability level in Dhenkanal Sadar block, maximum rainfall was received in the month of August (229 mm), followed by July (220.7 mm) and June (156 mm); and in Odapada block, maximum rainfall ~~is~~ was received in the month of August (238 mm), followed by July (225 mm) and June (119 mm).

Table 1- Probability of rainfall occurrence in different months at Dhenkanal Sadar

Probability	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
10	43.5	64	47.5	98.3	167	336.3	537.2	514.5	382.5	278.2	109	5.5	1938.0
20	19	30	33	83	122	276	462	473	313	172	55	0	1613.6
30	10	19.5	17	49.5	97.5	255.5	412	368	257.5	132	23.5	0	1565.0
40	0	8	9	40	74	233	364	336	205	119	13	0	1548.6
50	0	2.5	7.5	20.5	43.1	215.5	312.1	291	188	106	10	0	1388.0
60	0	0	2	13	34.5	208	291	269	163	90	0	0	1306.0
70	0	0	0.5	3	32	178.5	256	259.5	150.5	58.5	0	0	1197.0
80	0	0	0	0	15	156	220.7	229	118	37	0	0	1136.5
90	0	0	0	0	11.5	119.7	180.1	210	77	8	0	0	928.0
Average rainfall	**8.4**	**17.5**	**24.8**	**33.9**	**77.7**	**229.5**	**334.8**	**348.6**	**227.7**	**105.8**	**25.0**	**1.9**	**1435.6**

Table 2- Probability of rainfall occurrence in different months at Odapada

Probability	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
10	41.5	53	55.5	73.5	96.5	312.5	609	534	316.7	293.5	113.5	40	1734.0
20	18	30	41	37	81	279	473	444	262	240	70	0	1576.5
30	15.5	12	31.5	19.5	67.5	252.7	417.5	382.7	246.3	120	10.5	0	1462.5
40	0	2	7	15	53	213	382	321	192	69	4	0	1409.1
50	0	0	0	11	43	204	346	305	174.5	45	0	0	1374.0
60	0	0	0	3	20	181	318	295	153	37	0	0	1284.0
70	0	0	0	0	17.5	147.5	276	266.5	130	22.2	0	0	1232.5
80	0	0	0	0	10	119	225	238	96	10	0	0	1080.4
90	0	0	0	0	3	84	183.5	170.5	48.3	0	0	0	831.5
Average rainfall	**8.3**	**15.3**	**28.7**	**23.1**	**52.0**	**202.0**	**312.8**	**329.5**	**173.7**	**93.9**	**20.3**	**4.7**	**1264.3**

4. Land use map and soil map of the study area

The land use map and soil map of the study areas were prepared based on the digital data obtained from Orissa Space Application Centre (ORSAC), Bhubaneswar. Land use and soil map of the watersheds viz. Tarava, Nuagaon, Gunadei and Kaunriapala are presented in Fig. 5 through 8. The land use/land cover variation and distribution of soil types in Tarava watershed is presented in Tables 3 and 4. Total area of the Tarava watershed is 469.48 ha. Maximum land use is covered under the category 'Agricultural land-crop land kharif crop' (275.09 ha) followed by 'Built up rural area' (41.08 ha). Maximum soil type is covered under the category 'Fine loamy, Fluventic ustochrepts' (298.62 ha) followed by 'Clayey skeletal, Typic Haplustalfs' (77.48 ha).

Table 3: Land use/ land cover in Tarava watershed

Land use	Area (ha)
Agricultural land-crop land kharif crop	275.09
Agricultural land-crop land two crop area	36.41
Agricultural land-plantation-agricultural plantation	14.30
Built up rural area	41.08
Forest-evergreen/ semi evergreen	12.17
Tree clad area	30.24
Wastelands-scrub land - open scrub	36.69
Wastelands-scrub land-dense scrub	18.63
Waterbodies-lakes/ ponds-perennial	0.06
Waterbodies-reservoir/tanks-perennial	4.80
Total	**469.48**

Table 4: Soil types and soil orders in Tarava watershed

Soil types and soil orders	Area (ha)
Clayee Clayey skeletal, Typic Haplustalfs	77.48
Coarse loamy, Typic Ustifluvents	2.33
Fine loamy, Fluventic Ustochrepts	298.62
Fine loamy, Udifluventic Ustochrepts	26.34
Loamy skeletal, fluventic Ustochrepts	14.77
Loamy skeletal, Typic Ustochrepts	49.94
Total	**469.48**

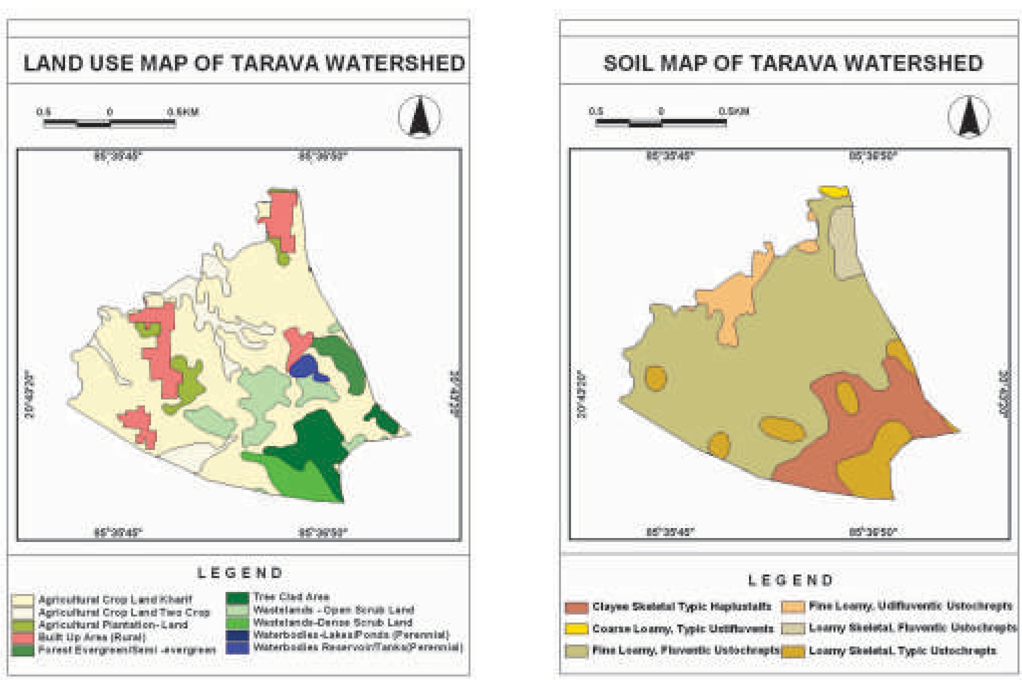


Fig.5- Land use map and soil map of Tarava watershed

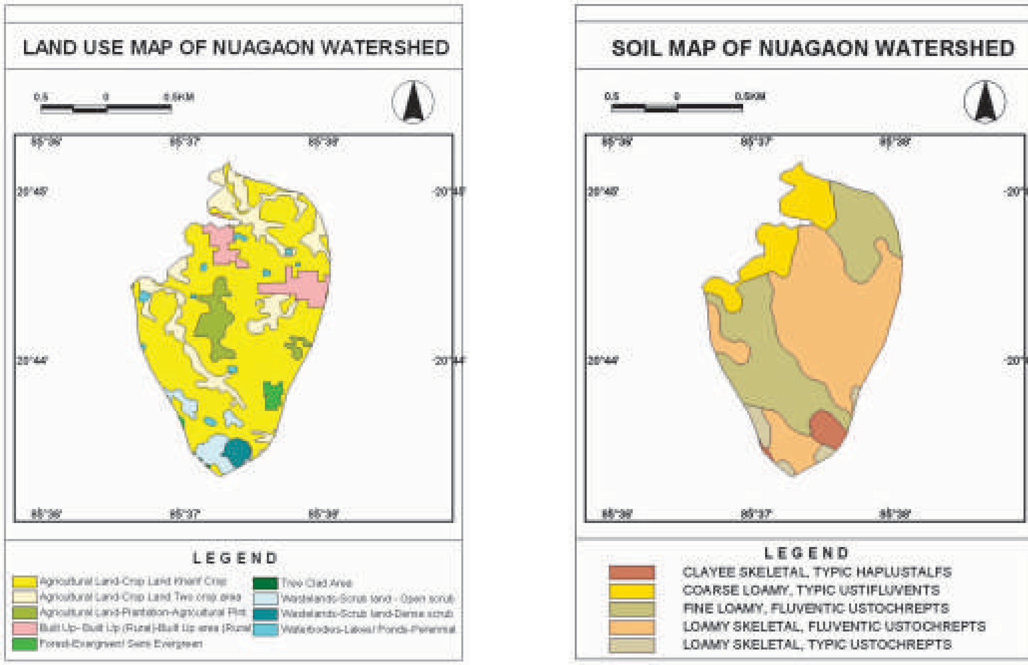


Fig.6- Land use map and soil map of Nuagaon watershed

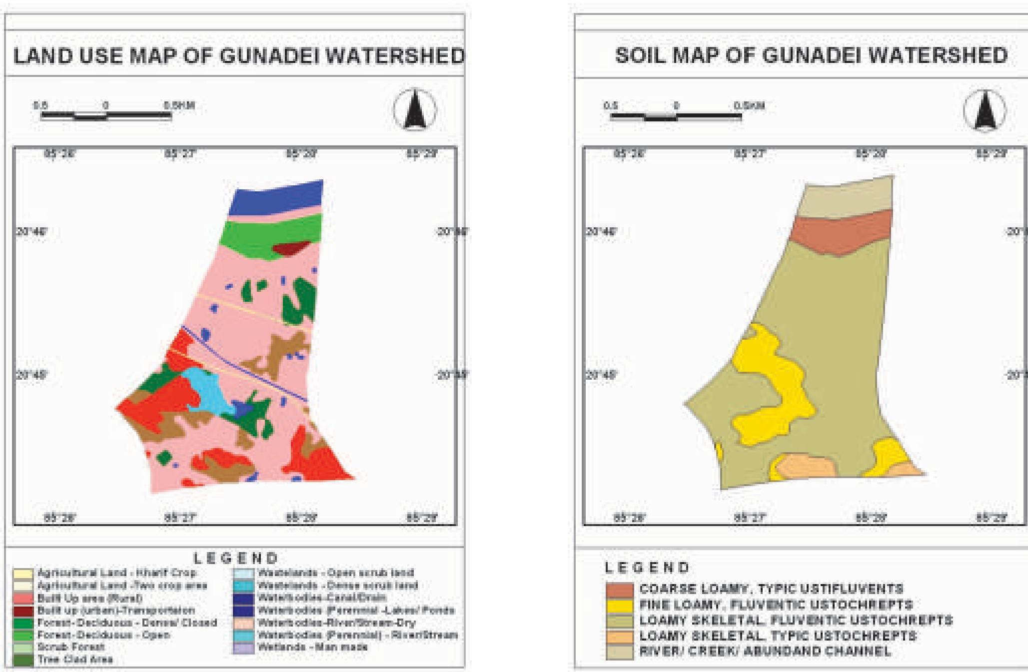
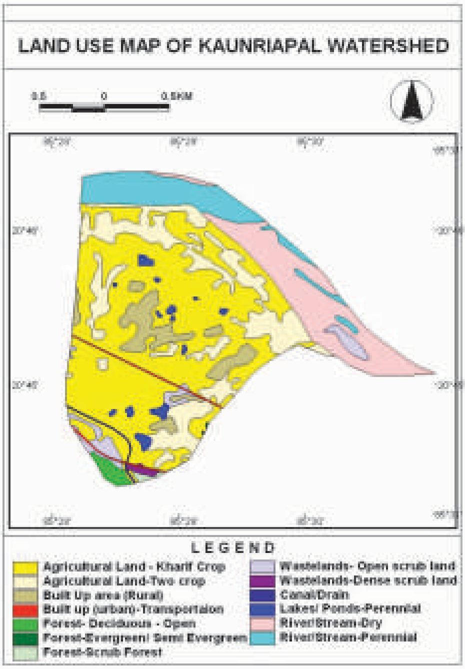


Fig.7- Land use map and soil map of Gunadei watershed



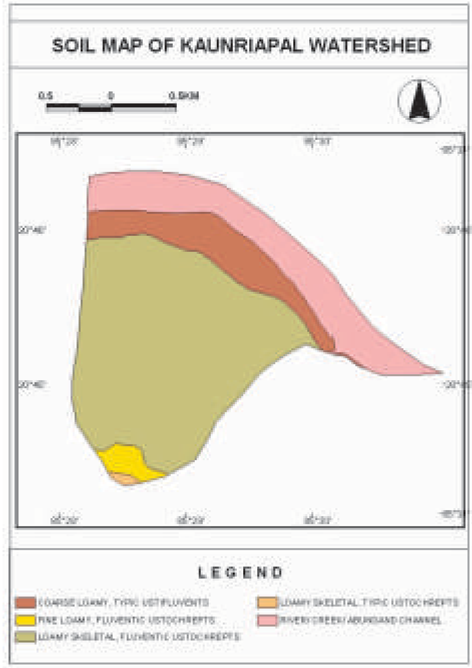


Fig. 8- Land use map and soil map of Kaunriapal watershed

The land use/ land cover variation and distribution of soil types in the Nuagaon watershed are presented in Tables 5 and 6. Total area of the Nuagaon watershed is 540.76 ha. Maximum land use is covered under the category 'Agricultural land-crop land kharif crop' (347.37 ha) followed by 'Agricultural land-crop land two crop area' (88.33 ha). Loamy soil type having skeletal morphology under the soil order Fluventic Ustochrepts (247.83 ha) is predominant followed by 'Fine loamy under Fluventic Ustochrepts (187.81 ha).

Table 5: Land use/ land cover in Nuagaon watershed

Land use	Area (ha)
Agricultural land-crop land kharif crop	347.37
Agricultural land-crop land two crop area	88.33
Agricultural land-plantation-agricultural plnt.	26.95
Built up rural area	35.67
Forest-evergreen/ semi evergreen	6.34
Tree clad area	0.25
Wastelands-scrub land - open scrub	21.54
Wastelands-scrub land-dense scrub	7.88
Waterbodies-lakes/ ponds-perennial	6.44
Total	540.76

Table 6: Soil types and soil orders in Nuagaon watershed

Soil types and soil orders	Area (ha)
Clayey skeletal, Typic Haplustalfs	14.91
Coarse loamy, Typic Ustifluvents	75.13
Fine loamy, Fluventic Ustochrepts	187.81
Loamy skeletal, Fluventic Ustochrepts	247.83
Loamy skeletal, Typic Ustochrepts	15.09
Total	540.76

Land use/ land cover variation and soil types in the Gunadei watershed are presented in Tables 7 and 8. Total area of the Gunadei watershed is 788.44 ha. Maximum land use is covered under the category 'Agricultural land-crop land kharif crop' (372.36 ha) followed by 'Agricultural land-crop land two crop area' (79.63 ha) and 'Wastelands-scrub land - open scrub' (79.37 ha). Loamy soils with skeletal morphology under the order Fluventic Ustochrepts' is predominant (520.19 ha) followed by fine loamy under Fluventic Ustochrepts' (121.43 ha).

Table 7: Land use/ land cover in Gunadei watershed

Land Use	Area (ha)
Agricultural land-crop land kharif crop	372.36
Agricultural land-crop land two crop area	79.63
Built up rural area	28.21
Built up urban area-transportation	7.72
Forest- deciduous - dense/ closed	24.89
Forest- deciduous - open	44.97
Forest-scrub forest	15.08
Tree clad area	57.42
Wastelands-scrub land - open scrub	79.37
Wastelands-scrub land-dense scrub	13.15
Waterbodies-canal/drain-lined	3.99
Waterbodies-lakes/ ponds-perennial	11.94
Waterbodies-river/stream-dry	9.47
Waterbodies-river/stream-perennial	33.32
Wetlands-inland man made	6.93
TOTAL	**788.44**

Table 8: Soil types and soil orders in Gunadei watershed

Soil type	Area (ha)
Coarse loamy, Typic Ustifluvents	58.95
Fine loamy, Fluventic Ustochrepts	121.43
Loamy skeletal, Fluventic Ustochrepts	520.19
Loamy skeletal, Typic Ustochrepts	30.32
River/ creek/ channel	57.55
TOTAL	**788.44**

Total area of the Kaunriapala watershed is 1066.73 ha (Table 9). Maximum land use is covered under the category 'Agricultural land-crop land kharif crop' (504.99 ha) followed by 'Agricultural land-crop land two crop area' (189.94 ha) and 'Water bodies-river/stream-dry (145.37 ha) respectively. Predominat soil type is loamy with skeletal morphology under the soil order Fluventic Ustochrepts (647.31 ha) followed by 'Coarse loamy, Typic Ustifluvents' (Table 10). River/ creek and channels also occupy a major area of 245.15 ha.

Table 9: Land use/ land cover in Kaunriapala watershed

Land Use	Area (ha)
Agricultural land-crop land kharif crop	504.99
Agricultural land-crop land two crop area	189.94
Built up rural area	58.93
Built up urban area-transportation	7.19
Forest- deciduous - open	10.37
Forest-evergreen/ semi evergreen	0.36
Forest-scrub forest	2.42
Wastelands-scrub land - open scrub	28.45
Wastelands-scrub land-dense scrub	3.53
Waterbodies-canal/drain-lined	3.06
Waterbodies-lakes/ ponds-perennial	14.23
Waterbodies-river/stream-dry	145.37
Waterbodies-river/stream-perennial	97.87
Total	**1066.73**

Table 10: Soil types and soil orders in Kaunriapala watershed

Soil type	Area (ha)
Coarse loamy, Typic Ustifluvents	145.13
Fine loamy, Fluventic Ustochrepts	24.92
Loamy skeletal, Fluventic Ustochrepts	647.31
Loamy skeletal, Typic Ustochrepts	4.23
River/ creek/ channel	245.15
TOTAL	**1066.73**

5. Construction of Water Harvesting Structures (WHSs)

Water harvesting structures distributed over six villages were constructed in the farmer's field on participatory basis in the year 2009-10. Farmers agreed to meet a part of the expenditure for construction of water harvesting structures i.e the construction of bunds around the pond. Twelve number of sites were initially identified for construction of water harvesting structures which included two sites of a single farmer. Later it was decided to merge both the water harvesting structures of a single farmer into a single structure. The name of the farmer beneficiaries, the village name, location in terms of latitude and longitude, volume of the water harvesting structure and the command area of the structures is listed in Table 11. Based on the

Table 11: Details of water harvesting structures in the study villages

Name of Farmer	Village	Latitude	Longitude	Volume of WHS (m^3)	Command area (ha)
Tapan Biswal (KLD1)	Khallibandha	20° 43’ 36” N	85° 36’ 47” E	500	1.00
Niranjan Biswal (KLD2)	Khallibandha	20° 43’ 37” N	85° 36’ 48” E	200	0.50
Khageswar Biswal (KLD3)	Khallibandha	20° 43’ 39” N	85° 36’ 48” E	200	0.75
Sribascha Biswal (NG1)	Nuagaon	20° 43’ 49” N	85° 36’ 53” E	1500	2.00
Prafulla Biswal (NG2)	Nuagaon	20° 43’ 54” N	85° 36’ 45” E	2500	4.00
Daktar Brahma-(MDL1)	Mandapala	20° 44’ 43” N	85° 37’ 32” E	1000	1.00
Surendra Prusty –(KRL1)	Kaunriapala	20° 44’ 41” N	85° 29’ 10” E	350	1.00
Upendra Barala –(BLP1)	Belpada	20° 45’ 12” N	85° 28’ 56” E	750	1.00
Ashok Barala-(BLP2)	Belpada	20° 45’ 26” N	85° 28’ 52” E	425	0.50
Laxmidhara Dehury (GND1)	Gunadei	20° 45’ 46” N	85° 27’ 59” E	550	1.00
Gadadhara Dehury (GND2)	Gunadei	20° 45’ 45” N	85° 27’ 59” E	260	0.50

location of the water harvesting structures the pond systems have been symbolized as KLD1, KLD2, KLD3, NG1, NG2, MDL1, KRL1, BLP1, BLP2, GND1 and GND 2, respectively. The volume of the water harvesting structures varied from a minimum of 200 m^3 in models KLD2 and KLD3 to a maximum of 2500 m^3 in model NG2. The command area of the water harvesting structures varied from a minimum of 0.5 ha in KLD2, BLP2 and GND2 to a maximum of 4 ha in NG2. Some of the water harvesting structures constructed in the study area under the project is shown (Plates 1 through 6).

Plate -1: Farm pond of Mr. Sribascha Biswal, Nuagaon

Plate -2: Farm pond of Mr. Daktar Brahma, Mandapala

Plate - 3: Farm pond of Mr. Tapan Biswal, Khallibandha

Plate - 4: Farm pond of Mr. Surendra Prusty, Kaunriapala

Plate - 5: Farm pond of Mr. Gadadhar Dehury, Gunadei

Plate - 6: Farm pond of Mr. Upendra Barala, Belpada

6. Multiple use of harvested water in WHSs

Multiple use of harvested water in 10 numbers of water harvesting structures was done for agriculture, on-dyke horticulture, pisciculture, poultry & dairy farming, mushroom and vegetable cultivation to develop them as integrated farming system (IFS) components; and this was continued for a period of four years from 2010-11 to

2013-14. Agriculture, pisciculture and vegetable cultivation was done by all selected farmers whereas on-dyke horticulture, poultry, dairy and mushroom cultivation was adopted by only some of the farmers as indicated in Table 12. On-dyke horticulture was done by the farmers only in farming systems KLD1, NG1, MDL1, KRL1 and BLP1, whereas poultry farming was adopted in models KLD1, NG1 and BLP1. All the multiple use components including dairy and mushroom cultivation were done in only farming system NG1. Multiple use of water from water harvesting structures by different components is shown in plates 7 through 12.

The different land components of the integrated farming systems were pond area, bund area, upland area and paddy area. The distribution of area of different land components in different system is shown in Table 13. The pond area varied from 150 m^2 each in models KLD2 and KLD3 to 1400 m^2 in model NG2, whereas the bund area varied from 150 m^2 each in models KLD2 and KLD3 to 450 m^2 in model NG2. The upland area varied from 450 m^2 in model KLD3 to 2400 m^2 in model NG1, whereas the paddy area varied from 1100 m^2 in model KRL1 to 13000 m^2 in model NG2. The total area varied from a minimum of 2015 m^2 in model KRL1 to a maximum of 16350 m^2 in

Plate - 7: On-dyke horticulture

Plate - 8: Vegetable cultivation

Plate - 9: Fish culture

Plate - 10: Paddy cultivation

Plate - 11: Poultry in upland

Plate - 12: Duckery in pond

Table 12: Use of water by different components under each farming system models

IFS Unit	Multiple use components						
	Paddy cultivation	Pisciculture	On-dyke horticulture	Vegetable cultivation	Poultry	Dairy	Mushroom
KLD1	√	√	√	√	√	--	--
KLD2	√	√	--	√	--	--	--
KLD3	√	√	--	√	--	--	--
NG1	√	√	√	√	√	√	√
NG2	√	√	--	√	--	--	--
MDL1	√	√	√	√	--	--	--
KRL1	√	√	√	√	--	--	--
BLP1	√	√	√	√	√	--	--
BLP2	√	√	--	√	--	--	--
GND1	√	√	--	√	--	--	--

Table 13: Area distribution of land to pond, bund area, upland and paddy area at different IFS sites

IFS unit	Pond area (m^2)	Bund area (m^2)	Upland area (m^2)	Paddy area (m^2)	Total area (m^2)
KLD1	300	210	500	3100	4110
KLD2	150	150	550	2700	3550
KLD3	150	150	450	2850	3600
NG1	800	360	2400	1600	5160
NG2	1400	450	1500	13000	16350
MDL1	400	240	950	2500	4090
KRL1	225	180	510	1100	2015
BLP1	450	270	2000	1450	4170
BLP2	200	180	950	1700	3030
GND1	400	250	800	3000	4450

model NG2. The pond area was used for fish culture and the bund area was used for growing of horticultural crops, whereas the upland area was used for dairy & poultry farming, mushroom and vegetable cultivation. Banana, papaya, drum stick and arhar were planted on the embankments around the pond as on-dyke horticulture. Vegetables like potato, brinjal, ladies finger, tomato, cabbage, cauliflower, cucumber, ridge gourd, cowpea, onion and chili were cultivated either as *kharif* (monsoon) or *rabi* (post-monsoon) vegetables. The water harvesting structures were used as a source of water for agriculture and other multiple use components in the post-monsoon season, and also for supplementary irrigation to paddy crop during dry spells in the monsoon season.

7. Performance evaluation of short duration aquaculture in WHSs

Low input-based scientific fish culture operation was carried out for three consecutive years (2010-11 to 2012-13) in ten water harvesting structures as a part of multiple uses for enhancing water productivity for rainfed farmers. Pre-stocking preparation such as application of lime ($CaCO_3$) @ 750 kg ha^{-1}, raw cattle dung (RCD) @ 7000 kg ha^{-1} as basal dose and fertilizer (urea : single super phosphate :: 1:1) @ 3 ppm was carried out prior to stocking. Seven days after pond preparation in the 1^{st} week of August, fish fingerlings of Indian major carps (*Catla catla, Labeo rohita* and *C. mrigala*) were stocked after proper acclimatization @ 7500 fingerlings/ha. Stocking composition was 30:30:40. Supplemental feeding was provided with a ratio of 60:40 (rice bran: mustard oil cake) @ 5, 4, 3 and 2% of mean body weight (MBW), twice a day, during 1^{st}, 2^{nd}, 3^{rd} and 4^{th} month to harvesting, respectively. Periodic manuring with RCD @ 500kg ha^{-1} and liming @ 50 kg ha^{-1} were carried out at every 15 days interval to maintain plankton population in the eco-system. Periodic observation on water quality and fish growth parameters were carried out at regular intervals. Major physico-chemical parameters of pond water, e.g., dissolved oxygen (DO), temperature, pH, transparency, total alkalinity, nitrite –N, nitrate-N, ammonia, and total suspended solids were monitored monthly using standard method (APHA, 1995). To evaluate the efficiency of water management, the net total water productivity (NTWP = total economic value of the produce (Rs.) - production cost (Rs.) / total volume of water used in m^3) and net consumptive water productivity (NCWP = total economic value of the produce (Rs.) - production cost (Rs.) / volume of consumptive water use in m^3) was calculated.

The recorded mean minimum and maximum average values of various water quality parameters prevailed in the pond during ongoing experimental period were: water temperature 27.1 - 33.8 ^{0}C; water pH 6.9 – 8.8; dissolved oxygen (DO) 4.5 - 6.9 ppm; total alkalinity 87 - 129 ppm; dissolved organic matter 2.6 - 5.6 ppm; nitrite –N 0.006 -

0.07 ppm; nitrate-N 0.06 - 0.5 ppm; ammonia 0.01 - 0.21 ppm; transparency 29$\pm$4; and total suspended solid (TSS) 197 - 368 ppm. The TSS and DO concentration showed a decreasing trend with the advancement of rearing period while, gradual increase in nitrite, nitrate, ammonia were attributed to increased level of metabolites and organic matter. The periodic observation revealed that other water quality parameters did not show any specific trend. Overall crop performance (pooled over three years) in terms of productivity was 1.35 - 2.73 t ha^{-1} (Table 14), while the net economic return was Rs. 1456.00 – Rs. 11362.00 per water harvesting pond. The apparent feed conversion ratio (AFCR) was 1.19-1.48. Growth rate and biomass contribution in

Table 14: Performance evaluation of short-duration aquaculture in developed IFS units.

IFS unit	Area (m^2)	DOC	Yield (kg)	Productivity (t ha^{-1})	Net return (Rs.)	Total water use (m^3)	Consumptive water use(m^3)	NTWP (Rs. m^{-3})	NCWP (Rs. m^{-3})
KLD1	300	180	46.0	1.53	2392	570	435	4.19	5.49
KLD2	150	150	28.0	1.86	1456	270	198	5.39	7.35
KLD3	150	210	29.5	1.96	1534	300	230	5.11	6.67
NG1	800	240	218.5	2.73	11362	1760	1416	6.45	8.02
NG2	1400	180	189.4	1.35	9848	3080	2492	3.2	3.95
MDL1	400	180	65.0	1.62	3380	760	564	4.45	5.99
KRL1	225	240	48.2	2.14	2506	495	378	5.06	6.63
BLP1	450	180	73.6	1.63	3827	855	635	4.47	6.02
BLP2	200	150	34.5	1.72	1794	360	272	4.98	6.59
GND1	400	180	67.8	1.69	3525	760	580	4.64	6.08

Stocking density: 7500 fingerlings ha^{-1}, DOC: days of culture, NTWP: net total water productivity, NCWP: net consumptive water productivity, Stocking size was 38 g (*C.catla*), 28 g (*L.rohita*) and 34 g (*C.mrigala*). Stocking composition was 30% (*C.catla*): 30% (*L.rohita*): 40% (*C.mrigala*). Selling price of fish was Rs.100.00 per kg.

every pond was always higher by *C. catla* followed by *C. mrigala*. Usually *L. rohita* was grown faster than *C. mrigala*. However, in every pond, bottom feeders (*C. mrigala*) registered better growth rates than the column feeder (*L. rohita*), probably due to their superior feed utilizing capability and their high degree of tolerance to fluctuations of DO and the rich detrital food web that was maintained through periodic manuring, liming and fertilization. The sustainability of short-duration fish culture in WHSs refered to both the ecological and the economic sustainability, which was the capacity of the production system to produce a positive income on a long-term basis. Principally, even if a production system scores high in terms of ecological sustainability, it will not be adopted by farmers if it does not provide sufficient income. However, the estimated net total water productivity (NTWP) of different WHSs ranged from 3.2 to 6.45 Rs. m^{-3}, while the net consumptive water productivity (NCWP) ranged from 3.95 to 8.02 Rs. m^{-3} (Table 14). Higher water productivity not only reduced the need for additional water, but also minimized the operational cost. Further, water productivity is an index of the economic value of water used, a useful indicator of efficient water management that define the relationship between crop produced and the amount of water involved in crop production.

8. Crop diversification and formation of farmer groups

Farmers were encouraged for crop diversification from paddy to vegetables, pulses, pisciculture and mushroom cultivation. During the four year study period (2010-11 to 2013-14), farmer groups were formed in both Dhenkanal sadar block and Odapada block for vegetable cultivation on the banks of River Brahmani by river lift irrigation water. Water lifting pumps were provided to the farmers for irrigation to vegetables. Three farmer groups in the Khallibandha and Nuagaon villages were formed for water melon cultivation by river lift irrigation. In total 40 farmers were involved in three groups and 45 ha was put under cultivation. Two farmer groups were formed in Odapada block for vegetable cultivation by river lift irrigation. A group of farmers in Dhenkanal sadar block carried out mushroom cultivation.

9. Trainings and exposure visits of farmers

Trainings on 'Rainwater management for sustainable agriculture and rural livelihoods' were conducted in each of the six villages, details of which are mentioned in Table 15. Different topics of the training included 'soil and water conservation in watersheds', SRI method of rice cultivation', 'drip and sprinkler irrigation methods', 'rainwater harvesting in farm ponds and its multiple use', 'Scope of NREGA in watershed development' and 'Government schemes in agriculture and water management'. In the training at Khallibandha, farmers from four villages, i.e., Khallibandha, Nuagaon, Mandapala and Khamara villages participated whereas in other trainings, only farmers from the respective villages participated.

Table 15: Details of training in the study area

Sl. No.	Site/ village	Block	No. of farmer	Date
1.	Khallibandha	Dhenkanal Sadar	49	24.3.2009 to 25.3.2009
2.	Gunadei	Odapada	31	12.11.2009
3.	Kaunriapala	Odapada	30	14.11.2009
4.	Belpada	Odapada	30	15.11.2009
5.	Nuagaon	Dhenkanal Sadar	36	30.1.2011
6.	Mandapala	Dhenkanal Sadar	32	1.2.2011

In addition, two 7-day training programs on 'Scaling up of water productivity in agriculture', one each in Dhenkanal Sadar block and Odapada block, respectively were conducted. One 7-days training program was conducted during 20-26 February 2010 at Khallibandha village in which 60 farmers from Khallibandha, Nuagaon and Mandapala villages attended the program. Out of the 60 farmers, there were 11 women farmers. The other 7-day training program was conducted during 12-18 November 2010 at Belpada village in which 58 farmers fram Belpada, Gunadei and Kaunriapala villages attended the program. Out of the 58 farmers, there were 24 women farmers. In both the training programs, 28 training lectures covering almost all aspects of agriculture and water management were delivered to the farmers. The farmers expressed deep satisfaction over the trainings conducted for them as was evident from the feed-back analysis.




Plates 13 to 16: View of trainings to the farmers in study villages

Four exposure visit programmes were conducted for farmers from both the cluster of villages to expose them to soil & water conservation measures, drip and sprinkler irrigations, nursery management, crop management under net house, vermicomposting and organic farming. During 3rd March 2010 and 20th November 2010, exposure visits were conducted for the farmers from the Dhenkanal Sadar block and Odapada block, respectively to Dudhukateni watershed, Sai temple farm, S.M. Agro planters and processors, Sheela nursery and Farm for art of organic farming in

Dhenkanal district. From Dhenkanal Sadar block, there were 36 farmers from Khallibandha, Nuagaon and Mandapala villages. From Odapada block, there were 51 farmers from Gunadei, Belpada and Kaunriapal villages, out of which there were 18 women farmers. During 29th October 2011 and 1st November 2011, exposure visits were conducted for the farmers from the Odapada block and Dhenkanal Sadar block respectively to Soil Conservation Demonstration Centre, Bishwanahakani. During the exposure visit, the farmers were exposed to on-field demonstration of water harvesting structures, contour bunds, contour trenches, loose boulder structures, gravity fed irrigation systems, plantations and green house technologies. From Dhenkanal Sadar block, there were 41 farmers from Khallibandha, Nuagaon and Mandapala villages. From Odapada block, there were 41 farmers from Gunadei, Belpada and Kaunriapal villages, out of which there were 6 women farmers.




Plates 17 to 20: View of exposure visits of the farmers

10. Economic analyses of WHS based integrated farming system

The economic analysis of integrated farming systems was done based on collection of data on yield, production, market price and cost of cultivation of different components of multiple use of water through questionnaire survey of the farmers. The gross income was calculated from the production and market price of the commodities and net income was calculated by deducting the cost of cultivation from gross income. The net income per hectare from individual land components was estimated for all farming system models by dividing the net income by area. Finally, the net income per hectare for different combinations of land components and entire farming system was estimated for every 10 models (Table 16 through 19).

The net return/ ha from the pond area varied from a minimum of Rs. 70,343/- in model NG2 to a maximum of Rs. 1,42,025/- in model NG1 (Table 16). Out of the 10 IFS units, cultivation was done on the embankment in only 5 models. The net return/ ha from the bund area varied from a minimum of Rs. 74,074/- in model BLP1 to a maximum of Rs. 3,19,444/- in model NG1 (Table 17). Intensive cultivation on the embankment of the pond resulted in higher net income/ha from the bunds. The net return/ha in the upland area varied from a minimum of Rs. 41,333/- in model NG2 to a maximum of Rs. 6,10,417/- in model NG1 (Table 18). Poultry cultivation increased the net return/ ha from the upland area substantially. The net return/ha from the paddy area varied from a minimum of Rs. 15,862/- in model BLP1 to a maximum of Rs. 25,375/- in model NG1 (Table 19). The net income/ ha was lowest under paddy cultivation and the highest in uplands especially where poultry was taken up as a component. The net income/ha from the bund area was higher than the pond area especially where intensive cultivation was done in the bund area.

Table 16: Net income from pond area in different IFS units

IFS unit	Expenditure (Rs.)	Gross return (Rs.)	Net return (Rs.)	Net return/ha (Rs./ha)
KLD1	2208	4600	2392	79733
KLD2	1344	2800	1456	97067
KLD3	1416	2950	1534	102267
NG1	10488	21850	11362	142025
NG2	9092	18940	9848	70343
MDL1	3120	6500	3380	84500
KRL1	2314	4820	2506	111378
BLP1	3533	7360	3827	85044
BLP2	1656	3450	1794	89700
GND1	3255	6780	3525	88125

Table 17: Net income from bund area in different IFS units

IFS unit	Expenditure (Rs.)	Gross return (Rs.)	Net return (Rs.)	Net return/ha (Rs./ha)
KLD1	800	3000	2200	104762
KLD2	--	--	--	--
KLD3	--	--	--	--
NG1	9700	21200	11500	319444
NG2	--	--	--	--
MDL1	4000	11000	7000	291667
KRL1	1350	4100	2750	152778
BLP1	1800	3800	2000	74074
BLP2	--	--	--	--
GND1	--	--	--	--

Table 18: Net income from upland area in different IFS units

IFS unit	Expenditure (Rs.)	Gross return (Rs.)	Net return (Rs.)	Net return/ha (Rs./ha)
KLD1	39400	67500	28100	562000
KLD2	1700	4900	3200	58182
KLD3	1900	4800	2900	64444
NG1	365800	512300	146500	610417
NG2	4200	10400	6200	41333
MDL1	3100	9600	6500	68421
KRL1	1600	4320	2720	53333
BLP1	198800	283100	84300	421500
BLP2	2300	6700	4400	46316
GND1	2050	5500	3450	43125

Table 19: Net income from paddy area in different IFS units

IFS unit	Expenditure (Rs.)	Gross return (Rs.)	Net return (Rs.)	Net return/ha (Rs./ha)
KLD1	8500	14700	6200	20000
KLD2	7000	12000	5000	18519
KLD3	6300	11200	4900	17193
NG1	4800	8860	4060	25375
NG2	28000	60000	32000	24615
MDL1	4500	10250	5750	23000
KRL1	2200	4075	1875	17045
BLP1	2600	4900	2300	15862
BLP2	3700	6800	3100	18235
GND1	6480	12000	5520	18400

The net income/ha from different IFS involving different combination of land components is presented in Table 20. The net return/ha from the pond + bund area varied from a minimum of Rs. 47,211/- in model BLP2 to a maximum of Rs. 1,97,086/- in model NG1, whereas the net return from pond + bund + upland area varied from a minimum of Rs. 46,571/- in model BLP2 to a maximum of Rs. 4,75,736/- in model NG1. The net return/ha from pond + bund + paddy area varied from a minimum of Rs. 20,425/- in model KLD3 to a maximum of Rs. 97,543/- in model NG1.

The net income/ha from the IFS area i.e., whole system without considering the fixed cost of the system was the highest in model NG1 (Rs. 3,36,089/-) followed by model BLP1 (Rs. 2,21,647/-) and model KLD1 (Rs. 94,628/-). It was the lowest in model KLD3 (Rs. 25,928/-) followed by model KLD2 (Rs. 27,200/-). The net income/ha from the IFS area i.e., whole system with considering the fixed cost of the system was the highest in model NG1 (Rs. 2,50,624/-) followed by model BLP1 (Rs. 1,44,549/-) and model KLD1 (Rs. 68,691/-). It was the lowest in model GND1 (Rs. 16,708/-) followed by model BLP2 (Rs. 17,769/-). The analysis indicated that by taking up poultry in the uplands and doing intensive cultivation on the bund area in addition to fish culture in the pond would increase the net income substantially from the WHS based IFS models. The huge variation in the net income/ha in different IFS models also emphasized the extent and role of the farmer in building a successful model. If the farmer is enterprising and sincere in his/ her approach, the farming system models would be successful.

Table 20: Per hectare net return from different combination of land components

IFS unit	Net return/ ha (Rs./ha)				
	Pond + bund area	Pond+ bund + upland area	Pond+ bund + paddy area	Total IFS area without considering fixed cost	Total IFS area considering the fixed cost
KLD1	90039	323683	29895	94628	68691
KLD2	48533	54776	21520	27200	22017
KLD3	51133	59120	20425	25928	20817
NG1	197086	475736	97543	336089	250624
NG2	53232	47904	28180	29387	18837
MDL1	162188	106164	51369	55330	32836
KRL1	129778	87169	47382	48888	32908
BLP1	80931	331349	37452	221647	144549
BLP2	47211	46571	23529	30673	17769
GND1	54231	48103	24781	28079	16708

11. Impact analysis

Impact on the farming situation of the farmers on adoption of this pond-based water management technology is realized through a comparison of farming pattern, acreage, production of different components in the system, cost of cultivation and gross income before and after adoption of the technology. Impact analysis in the current study was done by comparative position of physical, social, financial, human and natural assets of the farmers before and after adoption of technology due to intervention.

Physical assets included the type of housing condition, sanitation, conveyance, electric, cooking and communication facility. Social assets mainly referred to the recognition of farmers, their social and political participation, active involvement in developmental works, common services used and group membership pattern. Financial assets were measured on the basis of sources of income, kinds and extents of savings and investment ability, lending and borrowing capacity. Human assets involved language competencies, education/ literacy, farm management skill and mobility. Natural assets were the natural resources owned by the farm family *viz.* farm size, irrigated land, livestock holding, poultry and fish pond. All above-mentioned variables under five types of assets were measured on the basis of the responses of farmers on a 5-point continuum scale (minimum and maximum value is 1 and 5, respectively) during interview schedule survey and focus group discussion. Overall standard of living of farmers was assessed on the basis of their assets holding before and after adoption of a particular technology; the value of overall standard of living ranging from 5 to 25. A sample of 34 farmers including the 10 farmers with water harvesting structures was considered under this impact analyses.

The average level of different types of assets of the sampled farmers before and after the technological interventions is presented in Fig. 9. Out of the five types of assets, physical assets, financial assets and natural assets are found to be below average during pre-adoption stage with physical assets increasing considerably to come to the above average level at the post-adoption stage. Maximum improvement occurred in physical assets (increased by 78%) followed by natural asset (66%) that indicated the improvement in living condition and natural resources especially the water resources. The gain in social, human and financial assets were found to be in the range of 21-23%. Improvement in socio-economic condition and social recognition were also reflected which resulted in achievement in motivation leading to inculcate the entrepreneurial abilities of the farmers. The increased income motivated the farmers to invest and intervene further leading to the growth in physical and financial assets.

The change in overall standard of living of the sampled farmers is presented in Fig.10. It is inferred that living standard of all the farmers except only one, was below average level prior to adoption of technological interventions under the project. However, with the change of farming situation, adoption of technologies helped in bringing the living standard of 10 farm families at above average level as evident from the score of greater than 15. Standard of living of the farmers, who are engaged in short-duration

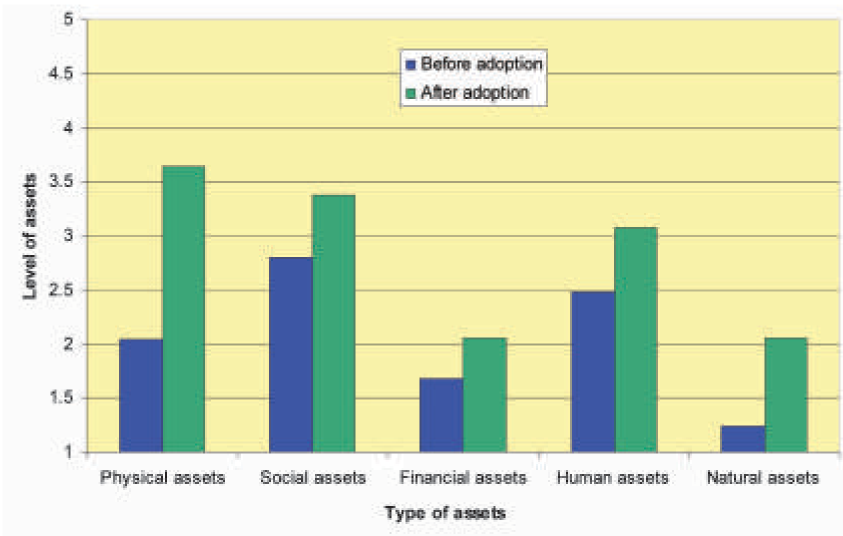


Fig. 9: Average level of different types of assets measuring livelihood of farmers

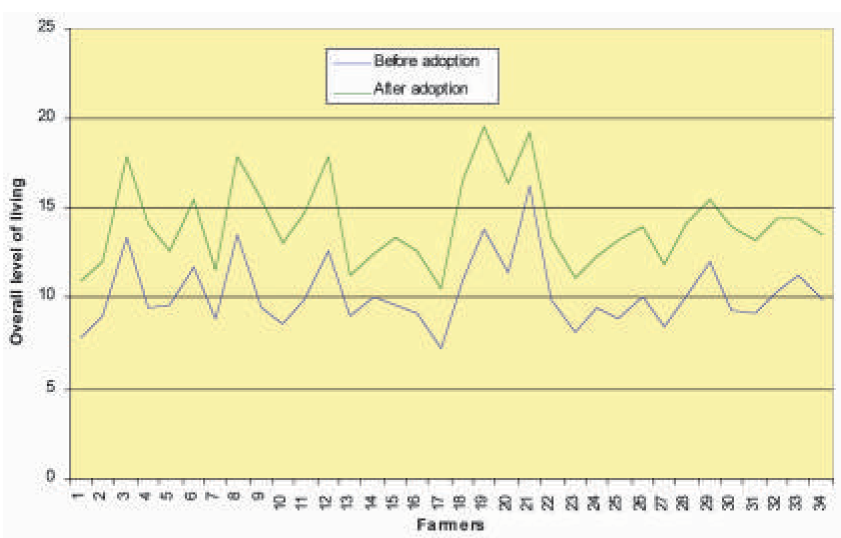


Fig. 10: Overall standard of living of selected farmers before and after adoption

fish farming / poultry farming / dairy farming besides crop farming, improved relatively better. Mean value of overall standard of living of all sampled farmers derived through addition of the mean values of five assets, indicatesd that this had increased from 10.24 to 14.15 (minimum and maximum possible value is 5 and 25, respectively). The minimum score increased from 7.21 to 10.43 while the maximum score increased from 16.21 to 19.57 which clearly showed the improvement in overall level of living of farmers due to adoption of technological intervention provided under the project.

12. Conclusions

The study was carried out in two clusters of villages in Dhenkanal Sadar block and Odapada block in Dhenkanal district of Odisha. The land use and soil map of the study villages were prepared. Water harvesting structures were constructed in farmers' field on a participatory basis in which farmers contributed to a part of the expenditure. Multiple use of water was done from the water harvesting ponds to develop them as integrated farming system models. Crop diversification was done in the study villages along with imparting adequate trainings and exposure visit to the farmers. The economic analysis of the systems of use of harvested water by different components indicated that poultry cultivation in the uplands and intensive cultivation around the embankments of the pond area would be essential in improving the net return from the farming system models. The farmer needs to be very enterprising and sincere for developing a successful integrated farming system model. The impact analysis of the study indicated that there was substantial improvement in the livelihood of the rainfed farmers due to the technological interventions.

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