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DEVELOPMENT OF AN IDEAL AND REPLICABLE WATERSHED FOR RAINFED RICE PRODUCTION SYSTEM IN EASTERN INDIA

N. Sahoo, S.K. Jena, R.C. Srivastava, M. Das
P. Nanda, D.C. Asthana and B. K. James

Water Technology Centre for Eastern Region

(Indian Council of Agricultural Research)

Chandrasekharpur, Bhubaneswar, Orissa - 751 023, India

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Dr. B. K. James
Director, Water Technology Centre for Eastern Region
(Indian Council of Agricultural Research)
Chandrasekharpur, Bhubaneswar, Orissa, 751023, India.
Phone : 91-674-2300060, 2300010, 2300016
Fax : 91-674-2301651
Email : wtcer@stpbh.soft.net
Web site : www.wtcer.stphh.soft.net

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PREFACE

Rainfed rice growing environments are complex, diverse and risk prone and constitute bulk of the rice growing area in eastern India. The average rice yields in the region are lower than the national average, which necessitates improvements of these environments without adversely affecting the natural resource base. Analysis of drought and flood pattern in the rainfed ecosystems reveals that 54.6% of the area in the eastern region (5.7 M ha) is drought prone, 25.5% (2.7 M ha) drought and submergence prone, 10.3% (1.1 M ha) submergence prone and only 9.6% (1.0 M ha) are favourable. The development of land and water resources on a sustained basis without deterioration and with constant increase in productivity is the main stay of mankind. The watershed approach therefore, increasingly being utilized in which, the development is not confined just to agricultural lands alone but covers even the non-agricultural areas starting from the highest point of the area (ridgeline) to the outlet of the natural stream. A participatory approach between the researcher and the farmers are envisaged to understand the needs, problems and potential of the area. The technical assessment of the watersheds should indicate the soil and water conservation problems to be undertaken with respect to agricultural land, wasteland, special problem areas (eroded areas) etc. and the rationale should not only stress upon management of land and water but also the need of people in terms of food, fodder, fuel and fibre with a focus on optimum production. This study was an attempt to evolve the methodologies and criteria for prioritization of critical area in a watershed and suitable scientific approach which also include PRA and people's participation for planning, developing and managing an ideal and replicable watershed in Odagaon block of Nayagarh district in Orissa state.

The authors are grateful to the national coordinator, NATP; Deputy Director General (Natural Resource Management), ICAR, New Delhi; Dr. BRM Rao (PI of NATP-RRPS-17), Dr. Ravisankar, Dr. Subramanium all from NRSA, Hyderabad for their encouragement, suggestion and technical support in carrying out this research work. The authors also acknowledge the sincere efforts and suggestions made by Dr. I.C. Mohapatra, Dr. S.K. Mohanty, Dr. S.R Singh, Dr. D. Panda, Dr. M.A. Sankar, Dr. P.K. Mohapatra and other members of peer review team, scientific advisory panel

etc. during their visit to project sites. Our sincere thanks are also due to all the colleagues, and staff of WTCER, Bhubaneswar for their help at times of need.

In bringing out this technical publication the authors hope that this research bulletin will be very useful to researchers, developmental agencies, farmers and to all those who are engaged in planning, development and management of watersheds in this region. The authors also realize that it is an honest attempt to inform the reader about how to prioritize critical area/ micro watershed in a watershed and what are the engineering and biological measures for an ideal and replicable watershed in eastern India with quantification of its impacts or benefits.

AUTHORS

EXECUTIVE SUMMARY

Yield of upland rainfed rice are very poor world wide due to various factors as it is mostly grown on both flat and sloping unbunded fields which are prepared for dry seeding and very much depend on erratic monsoon rainfall. The development of land and water resources on a sustained basis without deterioration and with constant increase in productivity is the main stay of mankind. The watershed approach therefore, is increasingly being utilized in which, the development is not confined just to agricultural lands alone but covers even the non-agricultural areas starting from the highest point of the area (ridgeline) to the outlet of the natural stream. Prioritization of watershed is essential for implementation of action plan with limited resources. This study was an attempt to evolve the methodologies and criteria for prioritization of critical area in a watershed and suitable scientific approach which also include PRA and people's participation for planning, developing and managing an ideal and replicable watershed in Nayagarh district in Orissa state. The project was taken for action plan preparation with help of GIS and Remote Sensing in Kusumi-Dahuka watershed having catchment area of about 1.5 lakh ha.

The delineation of watershed was done by using survey of India topographical maps at 1:50000 scale. Satellite data was interpreted following standard visual and digital image interpretation techniques. Initially, the soil map of the watershed was prepared at 1:50,000 scale using latest satellite data from IRS-IC /ID satellites following visual interpretation approach with soil profile study, soil analysis data and classification of soils as per soil taxonomy. Digital database for the soil map was prepared using ARC /INFO GIS package and attribute data were incorporated for each soil-mapping unit. Physical and biological resources and socioeconomic status of the watershed was done by survey and data collection. Identification, characterization and prioritization of critical areas were done by detail resource inventory using GIS techniques. The methodology was developed for identification of critical areas based upon above-mentioned information for prioritized land treatment in the watersheds. Different data on crop parameters such as total area under each village, area under cultivation, stand of crop, yield of different crops, optimum crop yield, cropping pattern, cropping intensities, cropping system, crop rotation etc. were collected. Similarly under management practices data on seeds used, fertilizer used, pesticides used were collected. Data on different soil parameters such as soil depth, texture, mineralogy, internal drainage status and slope percent etc. were collected. To know the degradation status of the watershed, village wise data was collected on soil salinity, alkalinity, soil erosion, percentage of gravelliness etc. Water and irrigation resources data were collected on number of bore wells, dug wells, canal, streams and percolation tanks. Besides these data socioeconomic status of the people living in the watersheds was determined village wise. Data on people's participation, approachability, availability of road network etc were collected. To know the status of watershed, treatment data on number of check dams, gully plugging, etc. was collected. The parameters considered for identification of critical areas in the watershed are soil depth, soil texture, internal drainage, slope, erosion and soil reaction which was obtained from satellite as well as ancillary data.

Using these data and methodologies Nagari nala watershed (1312 ha) in Odagaon block was prioritized and action plan map was generated. The morphometric analysis of the micro watershed was done. The developed action plan includes engineering, cropping and plantation measures in a holistic manner for development of the watershed.

The engineering measures for soil and water conservation include percolation tank, water harvesting structure (WHS), check dams, contour bund/ contour trench, land modification, open dug well, diversion weir, loose boulder structure, and renovation of WHS. The impact of percolation tank and WHS was well felt in the watershed by enhancement of the ground water level in the micro watershed and an increase in command area to 25 ha during Kharif and 27 ha during rabi by utilizing the water stored in WHS. Temporary check dams, loose boulder dams and permanent check dams help in storing water and sediment in the upstream and water stored was utilized as supplemental irrigation during dry spells in Kharif season. Contour bund cum trench of 100 m length help storing water and sediment in degraded land and then the land has became suitable site for plantation. Construction of stone masonry spillway prevented erosion of soil and crop damage in 7 ha of upland increasing the crop yield. Open dug wells helped the farmers growing different vegetables during rabi season along with kharif paddy and profit obtained was so much that the farmers has compensated the cost of the construction. The well construction of diversion weir with three gates saved around 25 ha of Kharif paddy. Renovation of WHS resulted the availability of water till May and increase in area under vegetable and pulses.

The cropping program includes variety substitution, management practices, anti-termite treatment, integrated pest management, integrated nutrient management, integrated farming system approach, and inter cropping. Introduction of high yielding upland variety (Vandana), medium land variety (Surendra) and low land variety (Gayatri) paddy in the watershed showed tremendous increase in yield and economic stability to the farmers even during drought year. On an average upland variety gave around 40% increase in yield, medium land variety around 15% increase in yield and low land variety around 13.6% increase in yield in comparison to local variety. However during drought year Vandana gave bumper crop where as there was no appreciable increase in yield in case of Gayatri in comparison to local variety. The adoption of these varieties in the watershed is very high. There was 12.8% increase in yield when line transplanting was adopted in comparison to random planting. Sex pheromone traps were used under integrated pest management to reduce any adverse effects of pesticides, which proved to be beneficial to the farmers of the watershed. Dhanicha was substituted instead of Nitrogenous fertilizer under integrated nutrient management which showed encouraging results. Also the anti-termite treatments were very beneficial to the farmers of the watershed controlling the crop damage un upland. Under management program arhar and black gram on paddy field bunds gave extra income to the farmers along with soil conservation. Integrated farming system which includes fishery in pond and vegetable and plantation on the bund and utilization of pond water for growing vegetable and oil seeds was a very ideal approach in the watershed which enhanced the economic condition of the farmer.

The Plantation program includes teak plantation, and cashew nut plantation. The growth of both plants are satisfactory and it helped converting waste lands to fruit orchard reducing the soil erosion and uplifting the socio economic condition of the farmers. Black gram and green gram, which were intercropped in those plantation areas, helped in nitrogen fixation and increased the fertility of the area. That is no more a wasteland.

Finally an ideal and replicable watershed has been developed in which almost all possible structures under engineering or soil conservation program, all possible cropping program or plantation program was taken up and by this the socio economic condition of the farmers has been uplifted.

*** *** ***

Introduction

About 50% of cropped area is likely to remain rainfed even after full realization of irrigation potential. Government of India has accorded highest priority to the holistic and integrated development of rainfed areas constituting about 65% of the cultivable land to meet the projected food grains requirement; bridge the regional disparity in terms of production and productivity between the irrigated and rainfed areas; restore ecological balance and to generate employment opportunities for rural areas. In rainfed system of eastern region, rice plays still a dominant crop and is also a staple food. It is extensively cultivated in eastern states of India comprising of Orissa, West Bengal, Bihar, Madhya Pradesh and all northeastern states. Therefore, it is essential to understand the potentials/limitations of these areas, so that necessary management practices can be adopted for sustained rice production in the area. The lands suitable for Irrigated rice specifically the lowlands were already exploited for rice cultivation. Rice is also cultivated in uplands worldwide where the yields are poor due to various factors. Rice is mostly grown on both flat and slopping fields, which are not bunded, but prepared and seeded under dry conditions and depend on rainfall for moisture. Therefore, efforts are being made to improve yields of the upland rice through tackling the soil water problems by improving production practices and other soil and water conservation methods.

Rainfed rice growing environments are complex, diverse and risk prone and constitute bulk of the rice growing area in eastern India. The average rice yields in the region are lower than the national average, which necessitates improvements of these environments without adversely affecting the natural resource base. The problems of rainfed rice are basically hydrology-related. The rainfed uplands suffer from the low moisture stress while the lowlands suffer from high moisture availability. The rainfed uplands are both unbunded and bunded. The unbunded uplands have undulating topography and are drought prone while bunded uplands have comparatively favourable moisture regime. The lowlands are currently categorized into three broad groups based on water regime. They are favourable lowlands (0-40 cm water depth), unfavourable lowlands (0-70 cm water depth) and deep water floating rice area (>70 cm water depth). However a more detailed classification of lowlands was in practice earlier. Upland rice occupies 7.1 million hectares in India out of which 5.23 million hectares area is in eastern India only. The mean yield levels of this crop are distressingly low (0.6-0.8 t/ha) and vary with soil type, fertilizer use and agronomic practices. Drought is the major constraint limiting upland rice production. Weeds are the second important constraint accounting for as high as 80% loss in grain yield. The other constraints include: leaching loss of N on account of light textured soils and soil erosion in unbunded upland: inadequate

crop stand caused by broadcast of seeds: use of traditional low yielding rice varieties, sub-optimal and imbalanced use of fertilizer (10 kg N/ha), pest attack (termites, gundhibug and mealy bug) and disease attack like blast, bacterial leaf blight and bacterial leaf streak.

Rainfed lowlands constitute about 16.72 M ha area in eastern India. Rice under these situations suffers from drought in the initial stages because of dry seeding practice followed by the crop establishment. Submergence and floods are the most critical constraints in these situations affecting crop growth adversely. The floods may occur between June to September submerging the crop for 10 days or less. Analysis of drought and flooding pattern in the shallow rainfed lowland ecosystems reveals that 54.6% of the area in the eastern region (5.7 M ha) under this ecosystem is drought prone, 25.5% (2.7 M ha) area is drought and submergence prone, 10.3% (1.1 M ha) area is submergence prone and only 9.6% (1.0 M ha) area is favourable. The other constraints in rainfed lowlands include low solar radiation during Kharif season, lack of adequate drainage, cultivation of low productive lodging-prone varieties, inadequate crop stand, restricted tillering and mortality of plants due to excess water, low level of fertilizer, we adverse soils with iron toxicity problems, delayed transplanting, incidence of pests such as gall midge and stem borer and diseases such as bacterial leaf blight (BLB), sheath blight, brown spot, weed problems, coastal salinity and socio-economic problems.

Rationale

The development of land and water resources on a sustained basis without deterioration and with constant increase in productivity is the main stay of mankind. The watersheds are hydrological units, which are considered as more efficient and appropriate for necessary surveys and investigations for the assessment of these resources and subsequent planning and implementation of various development programs. The watershed approach is more rational because land and water resources have optimum interaction and synergetic effect when developed on watershed approach. The piecemeal approaches such as contour bunding or terracing on individual holding or a group of farmers only marginally benefit as they are done ignoring to what happens to other areas which are influencing the hydrological characteristics. Such sporadic actions fail to attract farmers, as they do not yield benefits proportional to the efforts and investment made. Thus, for maximizing the advantages, all developmental activities should be undertaken in a comprehensive way on watershed basis. The watershed approach therefore is increasingly being utilized in various developmental programs like soil and water

conservation, command area development, erosion control in catchments of river valley projects, dry land/ rainfed farming, reclamation of ravinous lands, control of shifting cultivation etc. The optimal management of watershed on sustainable basis is of utmost importance in today's context. In the watershed approach, the development is not confined just to agricultural lands alone but covers even the non-agricultural areas starting from the highest point of the area (ridgeline) to the outlet of the nala or the natural stream (valley line). A participatory approach between the researcher and the farmers are envisaged to understand the needs, problems and potential of the area. Detailed information about the socio-economic status of the farmers have to be taken into consideration while deciding upon nature and scope of the problem and their needs. The technical assessment of the watersheds should indicate the soil and water conservation problems to be undertaken with respect to agricultural land, wasteland, special problem areas (eroded areas) etc. and the rational, should not only stress upon management of land and water but also to the need of people in terms of food, fodder, fuel and fibre with a focus on optimum production.

By keeping the above points in view this research and developmental activities were taken up for detailed investigation with respect to natural and other resources on watershed basis. The objective of this study was to carry out natural resource inventory of rainfed rice growing areas on watershed basis using remote sensing data at 1:50000 scale and to develop regional level watershed plans; to develop methodologies for identification of critical areas and to implement and validate the action plans in one of the micro watershed.

Methodologies

In order to evolve the criteria for better management for an ideal watershed this study was undertaken on Kusumi-Dahuka watershed comprising of nearly 1.5 lakh hectare in Nayagarh district covering 3 blocks namely Nayagarh, Odagaon and Nuagaon (Figure 1).

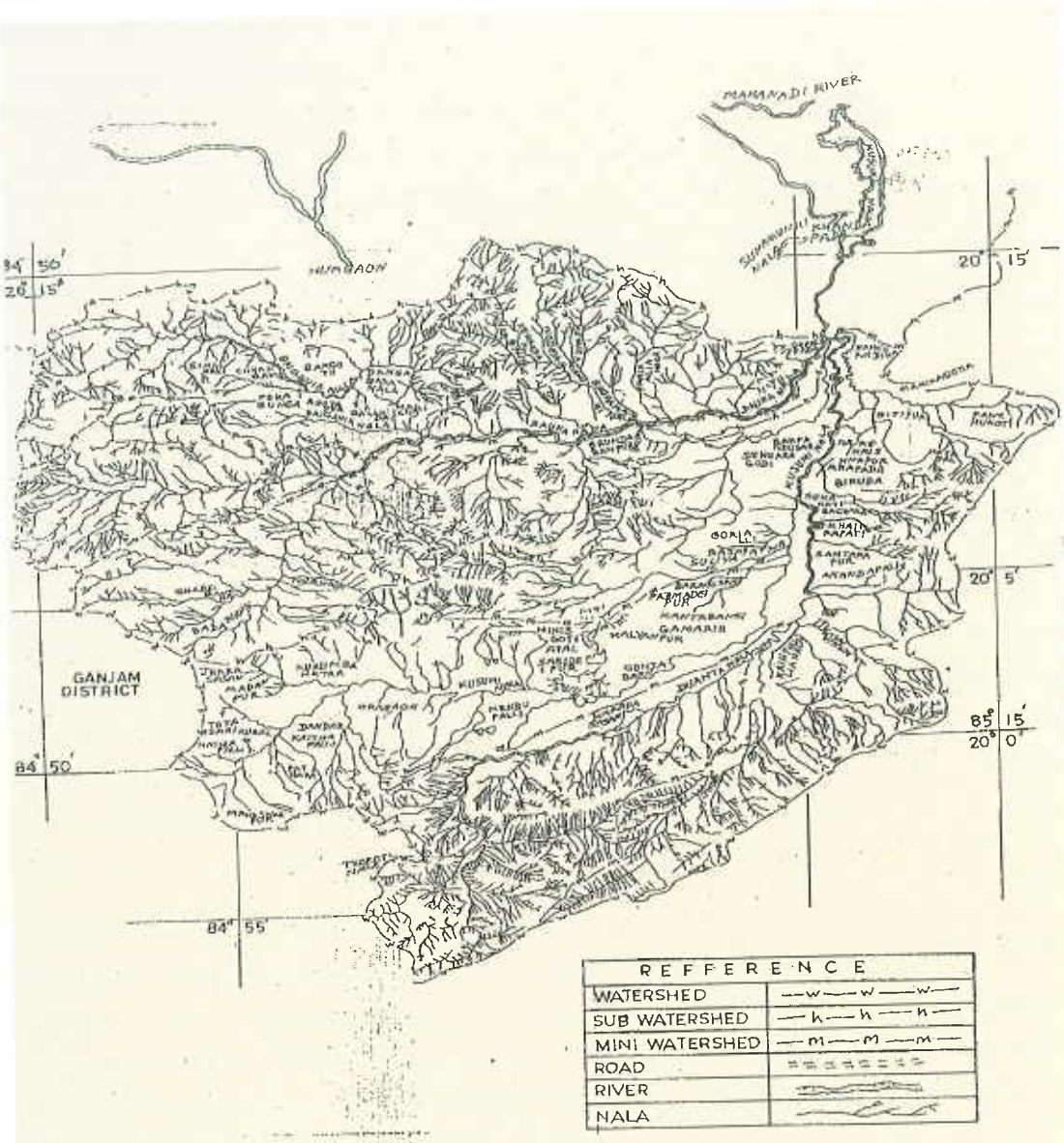


Fig. 1. Map of the Kusumi –Dahuka watershed

The delineation of watershed was done by using survey of India topographical maps at 1:50000 scale. Satellite data was interpreted following standard visual interpretation techniques. Initially, the soil map of the watershed was prepared at 1:50,000 scale using latest satellite data from IRS-IC /ID satellites following visual interpretation approach with soil profile study, soil analysis data and classification of soils as per soil taxonomy. Digital database for the soil map was prepared using ARC /INFO GIS package and attribute data were incorporated for each soil-mapping unit. Location of physical and biological resources and evaluation of socioeconomic status of the watershed were done by survey and data collection. Identification, characterization and prioritization of critical areas were done by detail resource inventory using GIS techniques. The methodology was developed for identification of critical areas based upon above-mentioned information for prioritized land treatment in the watersheds. Different data on crop parameters such as total area under each village, area under cultivation, stand of crop, yield of different crops, optimum crop yield, cropping pattern, cropping intensities, cropping system, crop rotation etc. were collected. Similarly under management practices data on seeds used, fertilizer used, pesticides used were collected. Data on different soil parameters such as soil depth and texture, mineralogy, internal drainage status and slope percent etc. were collected. To know the degradation status of the watershed, village wise data was collected on soil salinity, alkalinity, soil erosion, percentage of gravelliness etc. Water and irrigation resources data were collected on number of bore wells, dug wells, canal, streams and percolation tanks. Besides these data, socioeconomic status of the people living in the watersheds was determined village wise. Data on peoples participation, approachability and availability of road network etc were collected. To know the status of watershed, treatment data on number of check dams, gully plugging, etc. was collected. The parameters considered for identification of critical areas in the watershed are soil depth, soil texture, internal drainage, slope, erosion and soil reaction. Initially for prioritization of area the following seven characteristics of the area was taken into consideration. The watershed that is to be prioritized over others should have

1. Cultivated area > 25%
2. Irrigated area < 25%
3. Treatment percentage < 25%
4. Soil suitability >25%
5. Paddy crop yield < 50% of average
6. Scope for water resource development > 50% area for life saving irrigation
7. High cooperation by farmer is to be assessed through PRA study.

The above prioritization technique is presented in the form of a flow chart, which is given in Figure 2. However again ranking technique was used to further refine the above methodology. By putting weights and ranks to development criteria which comes from different watershed characteristics like crop factor, soil, management factors, and socio economic conditions, the priority index was calculated for each of the factor and then cumulative priority index was obtained. It was further tested through PRA technique to come to the final selection. The next preferred prioritization technique evolved from this study is presented in Figure 3.

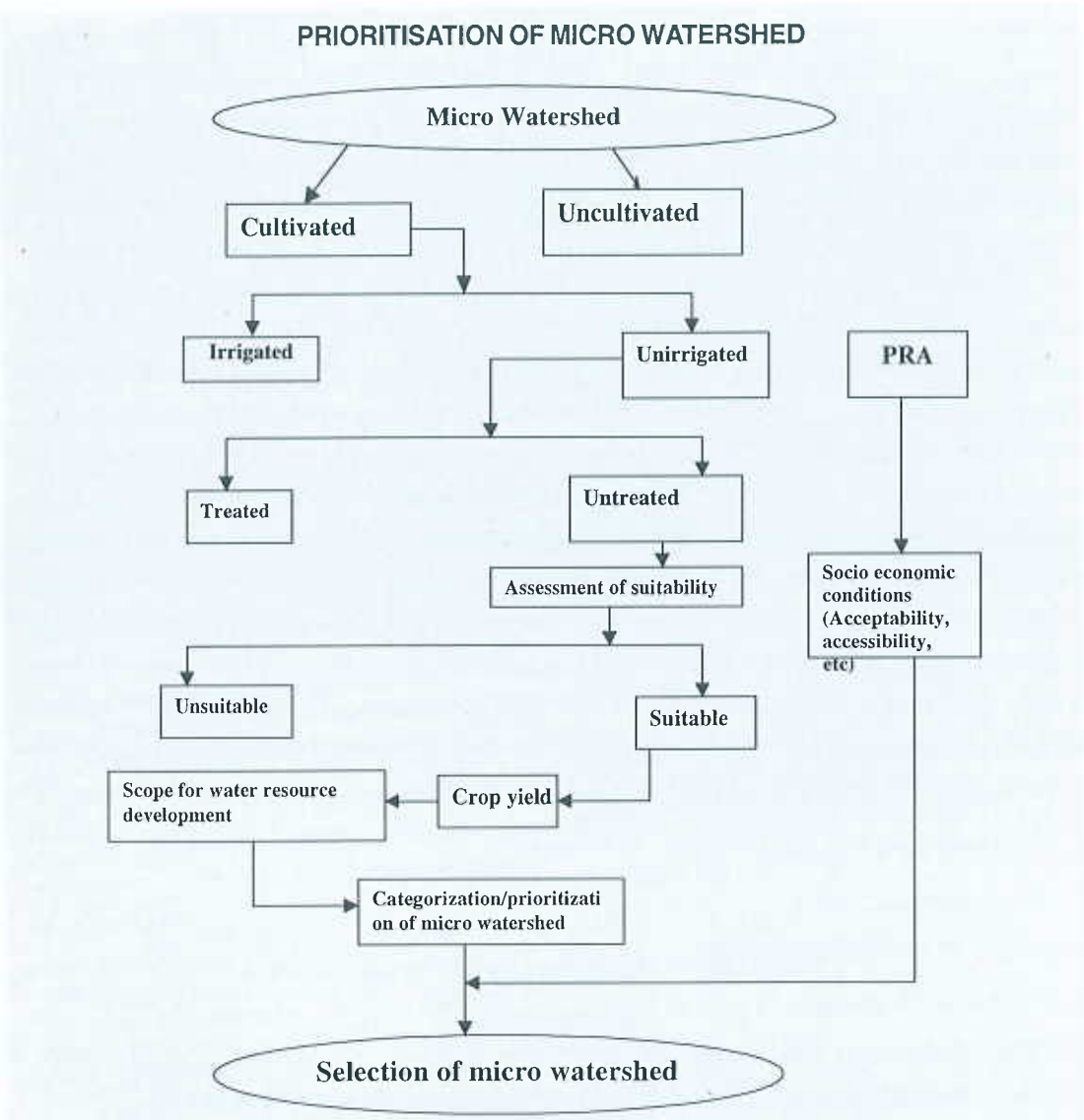


Fig. 2. Flow chart for preliminary prioritisation of micro watershed.

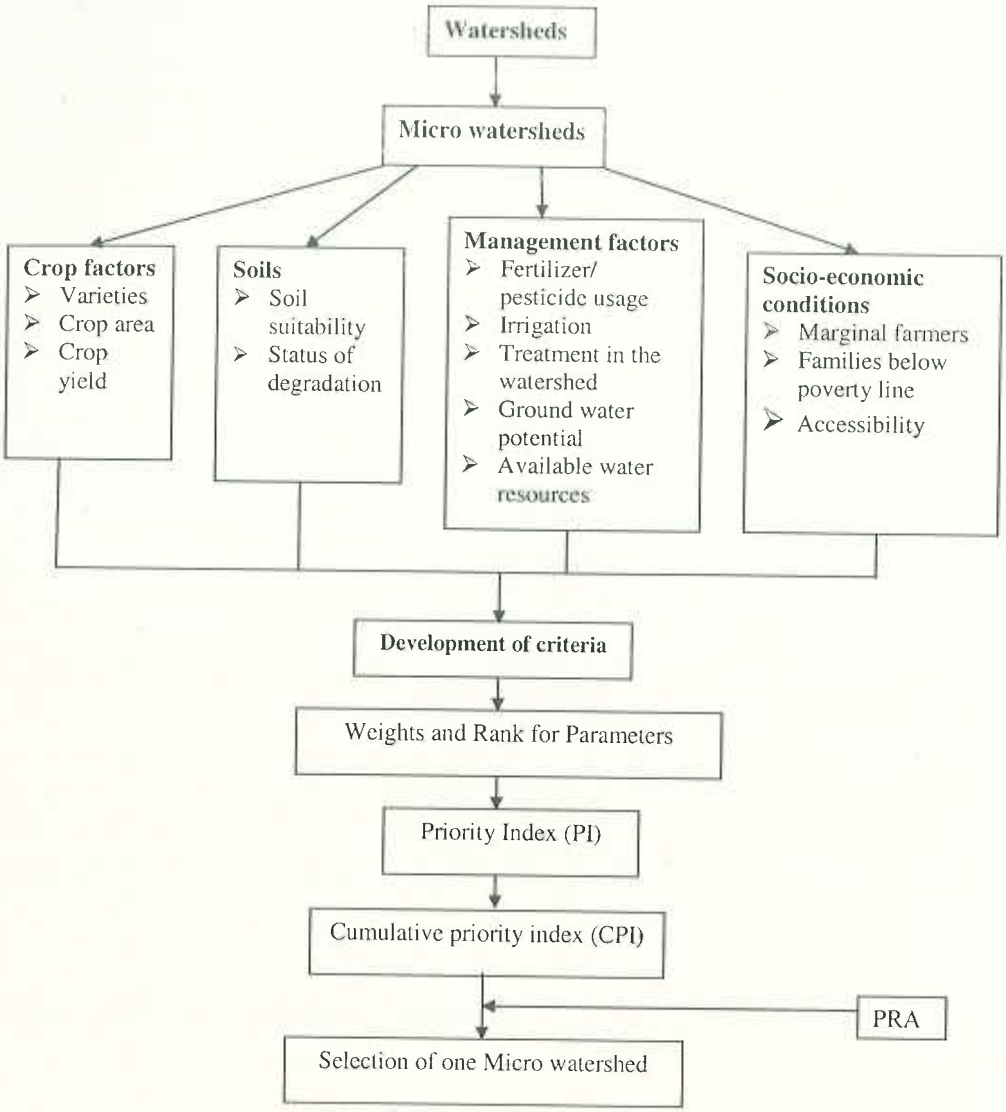


Fig. 3. Flow chart for the methodologies evolved for prioritization of micro watershed.

Modified methodology for critical area identification

Derivative thematic maps viz, soil depth, soil texture, internal drainage; slope erosion and soil reaction were generated and combined to develop a composite map. Rules were framed for identification of critical areas (a critical area is the one which is having more than one soil/ site limitation). Composite map was converted to critical area map. The methodologies based on soil parameters and different thematic layers obtained from remote sensing satellite images were utilized for prioritization of micro watershed, which is present in the form of a flow chart in Figure 4.

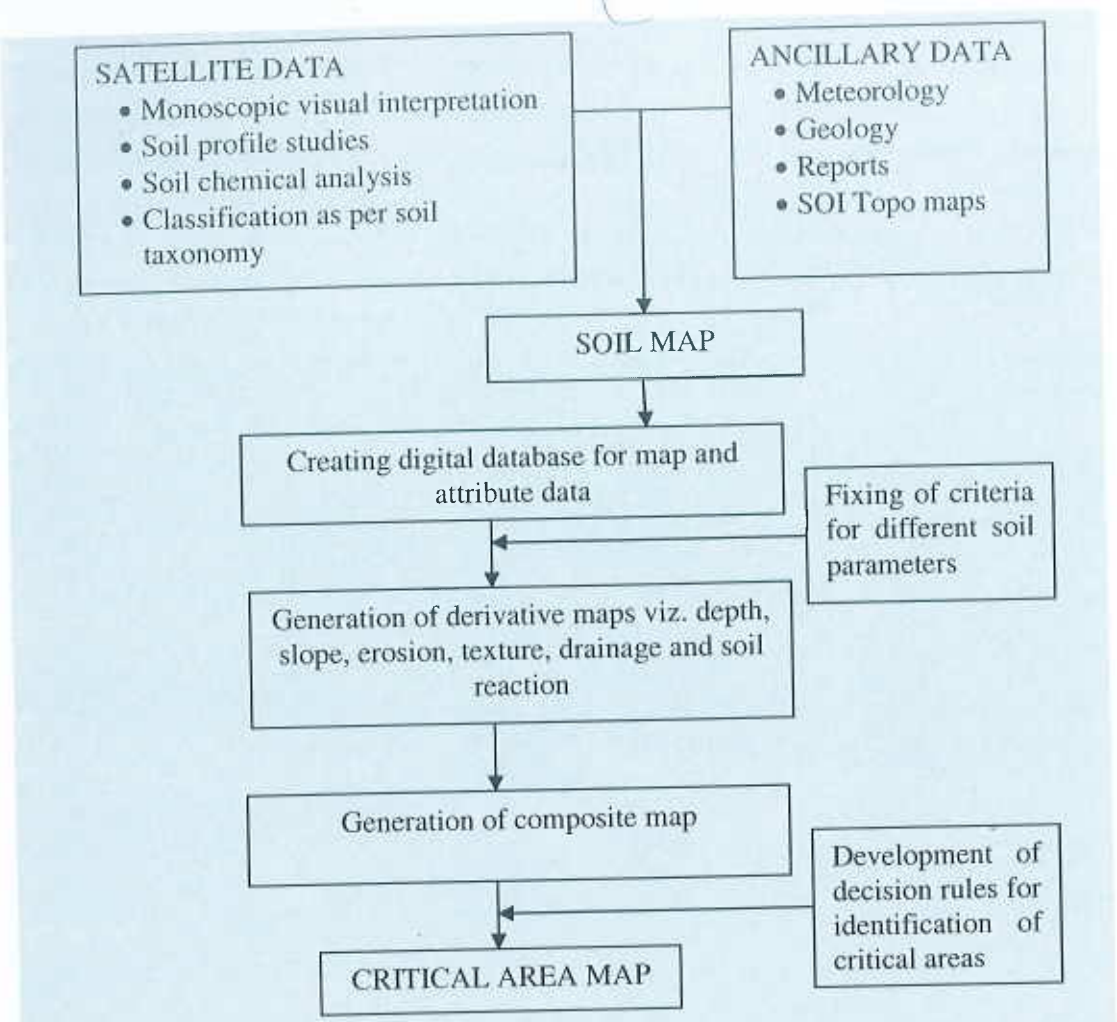


Fig. 4. Micro watershed prioritization methodologies using satellite and ancillary data.

Resource Inventory

The physical and biochemical resource inventory was carried out for 3 blocks of the watershed. Physical attributes of different blocks are given in Table 1. From the physical attributes (Table 1), it is clear that cultivated area was 81%, 70% and 58% of total area in Nayagarh, Odagaon and Nuagaon block respectively. It seems in Nayagarh block watershed portion is filled with forest trees, shrubs and hillocks more than other blocks. Villages are scattered in Nuagaon block more than that in other blocks. Out of 2129 km road network in the watershed Odagaon contains 50% and other blocks 25% each. This shows lack of infrastructure. In case of communication facility, Nayagarh (70%) tops the other two blocks (15% each) of the watershed.

Table 1. Physical attributes of study area.

Sl. No.	Attributes	Name of Blocks		
		Nayagarh	Odagaon	Nuagaon
1.	Latidude Longitude	20°05′-20°13′N 85°03′-85°15′E	19°28′-20°35′N 84°29′-86°25′E	20°3′-20°19′N 84°48′-85°05′E
2.	Number of villages	149	215	219
3.	Number of Towns	01	01	00
4.	Total Area	17852 ha	32410 ha	34594 ha
5.	Drainage	Dahuka nala, Kusumi nala	Duanta nala, Kusumi nala	Baignia, Dahuka nala
6.	Cultivated area	14,600 ha	22,973 ha	20378 ha
7.	Hospital	01	01	01
8.	Public Health Centre	01	01	01
9.	Ayurvedic	01	03	02
10.	Homeopathic	05	02	02
11.	Dispensary	05	07	04
12.	State highway	43 km	32 km	85 km
13.	Metal Roads	148.4 km	112 km	00 km
14.	Latertic Road	291.45 km	349 km	140 km
15.	Earthen Road	91.2 km	513 km	324.4 km
16.	Post office	38	36	22
17.	Telephone facility	28	20	07
18.	General connection	1059	249	184
19.	Marketing	2 nos	3 nos	3 nos
20.	Ordinary well	514	659	458
21.	Hand pumps	748	873	564
22.	Pipe water supply	05	04	02
23.	Sanitary well	03	33	07
24.	Electricity in village	121	164	179
25.	Solar plant	02	00	00
26.	Biogas	14	18	16
27.	Banks	09	10	06
28.	Cooperative society	02	02	01
29.	Industry (small units)	27	17	24
30.	Small scale industry	01	00	00
31.	Live stock centre	12	14	10
32.	Veterinary hospital	02	03	02
33.	Artificial Insem. centre	11	08	07

The agricultural scenario of the watershed is also interesting. In order to find out the solution for increase of productivity, present problem has to be ascertained (Sahoo etal 2003). The different agriculture, land and other crop attributes of study area (block wise) are given in Table 2. From the table it is seen that average productivity of paddy is very less in the watershed. Productivity of vegetables is not satisfactory. In Nayagarh upland is very less (30%) where as in Odagaon and Nuagaon upland is (50%). Hence productivity is more in Nayagarh sector than other places. Fertilizer and organic manure consumption is also low in paddy. It is satisfactory in vegetables. Pesticide application is low. The water resource potential of the study area is given in Table 3.

Table 2. Agriculture, land and other crop attributes of study area.

Agriculture/ land attributes	Name of the Block		
	Nayagarh	Odagaon	Nuagaon
Upland (ha)	3478	7987	6739
Medium land (ha)	5146	8810	6766
Low land (ha)	5976	6176	6873
Soils	Medium textured sandy red loam, clay and heavy clay black soils	Sandy red loam clay heavy clay and black soils	Sandy red loam, clay and heavy black clay soils
Size of holding			
Marginal	62.67%	65.67%	64.87%
Small	19.46%	20.60%	23.70%
Medium	17.45%	13.52%	11.34%
Large	0.42%	0.21%	0.09%
Yield of crop (q/ha)			
Paddy	10.9	10.36	9.87
Wheat	16.2	9.6	16.4
Maize	10.2	13.2	10.9
Pulses	3.1	3.1	2.7
Oil seeds	4.5	4.6	7.7
Fruits	10.1	9.3	94.6
Vegetables	113.2	114.3	117.8
Spices	13.3	19.2	14.4
Sugarcane	845.0	865.0	780.0
Fibres	7.2	6.50	7.9

Table 3. Water Resources potential of study area.

Water resources	Block Name		
	Nayagarh	Odagaon	Nuagaon
Ground water for irrigation	7448 ha m	7620 ha m	7918 ha m
Annual draft	543 ha m	615 ha m	597 ha m
Surface water irrigated area (ha)			
Kharif	7015	8804	3583
Rabi	2426	3529	998
Summer	23.5	42	20
Type of irrigation			
Canal	-	-	-
Tube well (No)	1732	2765	03
Other well (No)	28	16	1230
Lift irrigation (No)	36	15	05
Medium (No)	01	01	-
Minor (No)	06	09	05

From Table 3 it is seen that only 7.2%, 8% and 7.5% of total ground water is used for irrigation purpose in Nayagarh, Odagaon and Nuagaon block respectively. The reason for such low utilization is poverty only. In the watershed people below poverty line are 70.66%, 73.53% and 92.23% in Nayagarh, Odagaon and Nuagaon block respectively. About 60-70% of the total cultivated area is irrigated in Nayagarh and Odagaon block. But in Nuagaon block

the irrigated area is only 25% of the total cultivated area. Due to the medium irrigation project the irrigated area in Nayagarh and Odgaon blocks is more. The other sources of irrigation are tube well, nalas, springs, lift irrigation points and minor irrigation projects. There are moderate numbers of hand pumps, ordinary wells, sanitary wells for drinking water. But during summer season, the water level reduces to as much as 12 m to 17 m below ground level. Consequently a number of hand pumps do not yield water during summer.

The areal extent of different soil parameters such as depth, slope, erosion, texture and drainage condition etc. of the whole watershed is mentioned in Table 4.

Table 4. The areal extent of different soil parameters of the whole watershed

Class	Area (ha)	% Total area	Class	Area (ha)	% Total area
Depth			Texture		
V. Shallow	6898	5.6	Fine	56085	45.2
Shallow	21568	17.4	Mod. Fine	10308	8.3
Mod. Shallow	36558	29.5	Medium fine	2002	1.6
Mod. Deep	4194	3.4	Medium	22233	17.9
Deep	53892	43.5	Medium Coarse	27586	22.3
			Coarse	4896	3.9
Slope	Drainage				
Nearly level	42764	34.5	Imperfect	24194	19.5
Very gently sloping	25691	20.7	Mod. Well	38816	31.3
Gently sloping	36773	29.7	Well drained	24193	19.5
Mod. Sloping	17942	14.5	Excessively drained	4896	3.9
Erosion					
Nil to slight	42704	34.4			
Moderate	58257	46.9			
Severe	22149	17.8			

From the collected information it is seen that most of the people living in Nuagaon block are below poverty line (92.23%). Productivity is low. Cultivable area is less. The major problem is drought or scarcity of water. The water resources at the region are very poor. Ground water is much below the ground level to economically tap in many parts of the watershed. Water resource availability is less, though climatic parameter is more or less same. The monsoon rainfall is 70% in Nayagarh where as in Odagaon it is 54.4% and in Nuagaon it is 65%. Hence drought condition is more in Odagaon than Nayagarh and Nuagaon.

Average yield of upland paddy and lowland paddy is very low. This is due to erratic monsoon, use of local variety of paddy, improper choice of variety, lack of life saving irrigation, cultivation in degraded soil, poor organic matter in soil, low level of fertilizer application and minimal insecticide and pesticide use.

Keeping these various constraints in view, there was an urgent need to increase productivity levels from the rainfed areas by improving rice growing environments through effective land,

soil and water management, tactical farming strategies and appropriate technology transfer process. All these improvements should be farmer friendly, low cost oriented, ecosystem conserving, maintaining natural resource base and lead to sustainable production.

Ideal and Replicable Watershed Plan

Generally watershed development programs are one sided. Sometimes either engineering works are being done or agricultural activities such as fishery/horticulture/forestry/dairy activities are taken up individually in the whole watershed instead of developing it in holistic manner. Farmer's involvement in planning and design stage is not being done. Sometimes (SHG) "Self help groups" and watershed committees are involved but they do not contribute to the project financially in real terms. Sometimes the estimates are flattened and part is shown as people's contribution. That is why work undertaken in one watershed cannot be replicated in other watersheds even with slight modification. However replicable technology for watershed is essential. Many times people talk of ideal watershed where all items of work is synthesized. The works undertaken is as per design. People's involvement is also there. Entire runoff might have been conserved in the watershed either in-situ or through engineering structures. But modern tools have not been utilized to exactly quantify the work and type of work to be undertaken to make it ideal and replicable. While deciding criteria for critical watershed only silt yield index (SYI) has been used whereas in an ideal case peoples expectation, along with socio economic constraint should have been added along with SYI Criteria. It is therefore necessary to establish criteria for an ideal and replicable watershed development action plan and to implement the same successfully.

Critical area identification as per modified methodology

As per modified methodology evolved from this study, knowledge based rules were applied on critical area map and priority zone map was generated for identifying one critical micro watershed. Example of knowledge based rules are:

Rule for high priority: Very shallow soils + Moderately steep sloping + Severe erosion

Rule for medium priority: Moderately shallow soils + Gently sloping + Moderate erosion

Rule for low priority: Deep soils + Fine texture + Nearly level + Nil to slight erosion

The soil polygons were reclassified based on the above parameters and individual thematic layers were generated. Area-statistics were generated for the watershed parameter-wise to identify the critical parameter in the watershed from crop productivity point of view. A composite layer was generated from the individual thematic layers and the critical areas were mapped based on the limitations of the above mentioned soil parameters. Rules were framed to group polygons with severe limitations under each parameter as high priority zone and polygon with no limitations under least priority zone. Polygons with moderate limitations were grouped under medium priority zone. This knowledge base was applied on to the composite layer and composite polygons were reclassified and map showing priority zones were developed (Rao etal, 2004) and presented in Figure 5.

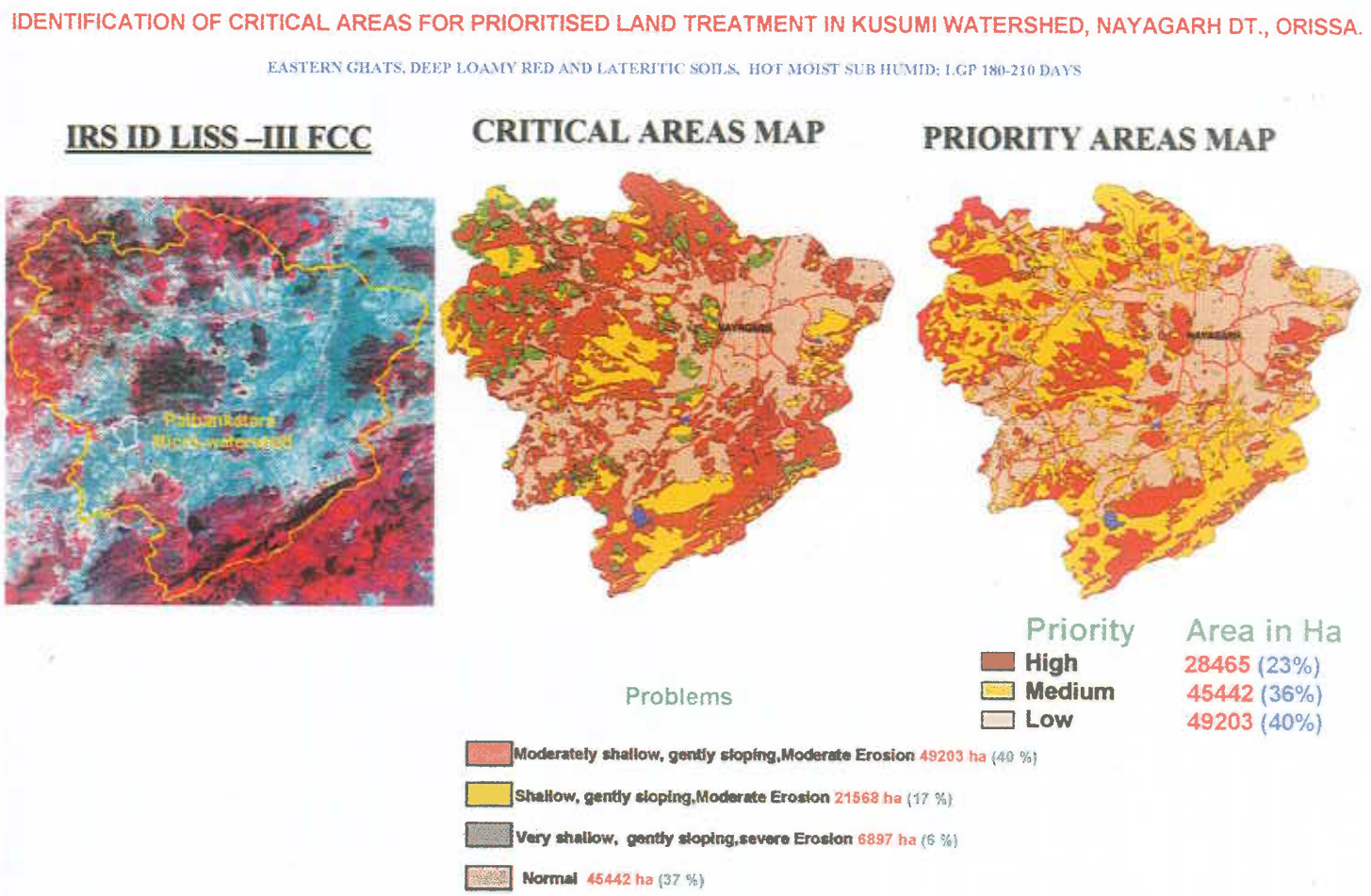


Fig. 5. Identification of critical areas for prioritized land treatment in Kusumi watershed, Nayagarh, Orissa.

A representative micro watershed of an area of 500 –1000 ha was selected for preparing natural resource inventory at 1:12,500 scale using high resolution satellite data. Satellite data at 1:12500 scale of micro watershed was generated by merging high resolution IRS Panchromatic (5.8 m resolution) and LISS III (23.5 m resolution) data. Critical areas were identified in the micro watershed using the above mentioned methodology, and action plan map was generated for the micro watershed.

After following the above methodology and knowledge based rules critical area was identified. The identified critical area was Nagari nala watershed (presented in Figure 6) in the Odagaon block of Nayagarh district of Orissa State, which is located geographically between 20° 1′ 30″ N to 21° 3′ 0″ N latitude 84° 53′ 17″ E to 84° 58′ 0″ E longitude and having total geographical area of 1312.5ha. It is delineated from toposheet numbering 73 D/16. The watershed covers 11 villages namely Kaithapally, Paikabankatara, Dolagobindapur, Madanpur, Dahangi etc. The cultivated area is 870 ha and the rest is forest hilly area. Out of 870 ha, upland constitutes about 80% i.e. 700 ha. The yield of upland rice is very poor (0.7 t/ha) due to local paddy variety, poor stand establishment, poor fertilizer management, weed infestation, water stress at critical period etc.

Watershed Characterization

For water resource development planning and management morph metric parameters of Nagari nala watershed was determined from the toposheet. There are 53 streams of 1st order, 9 streams of 2nd order and one streams of 3rd order. Stream length is 43 km and area of basin is 1312 ha. Length of basin is 4.85 km and perimeter of basin is 16.10 km. The bifurcation ratio, form factor, circulatory ratio, elongation ratio and drainage density were found to be 7.44, 0.558, 0.636, 0.843 and 3.30 respectively. The results reveal that the bifurcation ratio for the watershed is 7.44, which indicates that the drainage pattern is affected by structural disturbances suffered by the area (Jena et al, 2003). Form factor was found to be 0.558 which is high showing that the watershed produces a medium peak flow for a shorter duration and flood flows can be managed by appropriate adoption of control measures. The values of form factor, circulatory ratio and elongation ratio indicates that the shape of the watershed is fan-shaped. The drainage density for the watershed area was found to be 3.30 which is medium indicating that the area is covered by resistant permeable rocks and medium vegetation cover.

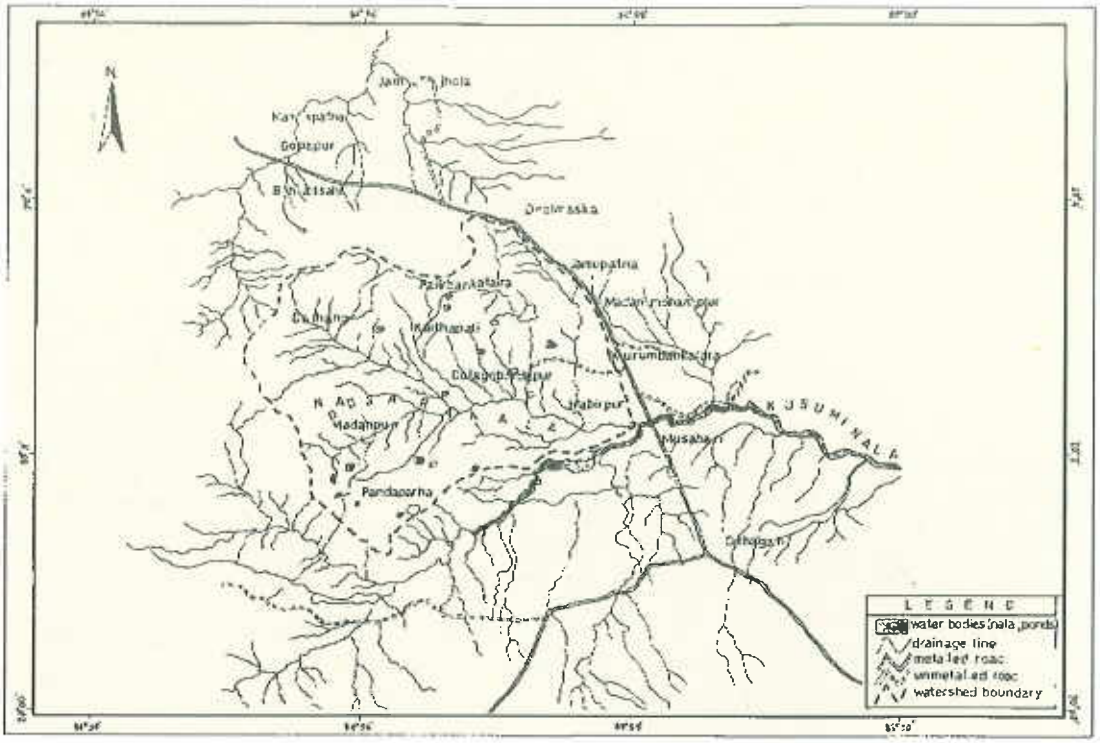


Fig. 6. Location map of Nagari nala watershed.

Problems of Nagari nala watershed

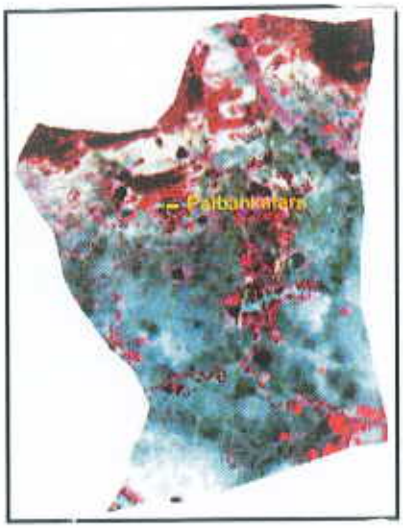
The different problems of Nagari nala watershed are:

1. Heavy soil erosion and formation of gullies,
2. Inadequate number of water harvesting structures,
3. Low yield of crops,
4. Lack of improved technical knowledge,
5. Low adoption of high yielding varieties,
6. Slopy terrain and
7. Poor socio-economic condition

After the selection of watershed, action plan map was generated considering all the data available from different sources, data from remote sensing image interpretation and results from GIS analysis were incorporated while generating action plan map. The false colour composite (FCC) map in which the developmental activities will be under taken is given in

Figure 7 and the action plan map for Nagari nala watershed is given in Figure 8. The different actions/ measures recommended for rainfed rice production systems of the micro watershed area are:

- Intensive agriculture (high yielding variety + integrated nutrition management + integrated pest management)
- Dug well + double cropping (high yielding variety of rice followed by pulses or vegetables) + integrated nutrition management + integrated pest management.



- Farm ponds + high yielding varieties (medium land variety like *Gayatri*)+ integrated nutrition management + integrated pest managements.
- Contour or graded bunding + high yielding varieties (up land variety like *Vandana*) + integrated nutrition management + integrated pest management.
- Soil conservation + horticulture + pasture development
- Soil conservation + silvipasture
- No action –plantation areas
- Percolation tank
- Farm pond (water harvesting structures)

Fig. 7. IRC-IC FCC (PAN + LISS - III) of micro-watershed (path : 105, row : 058, date of pass : 5.4.2000).

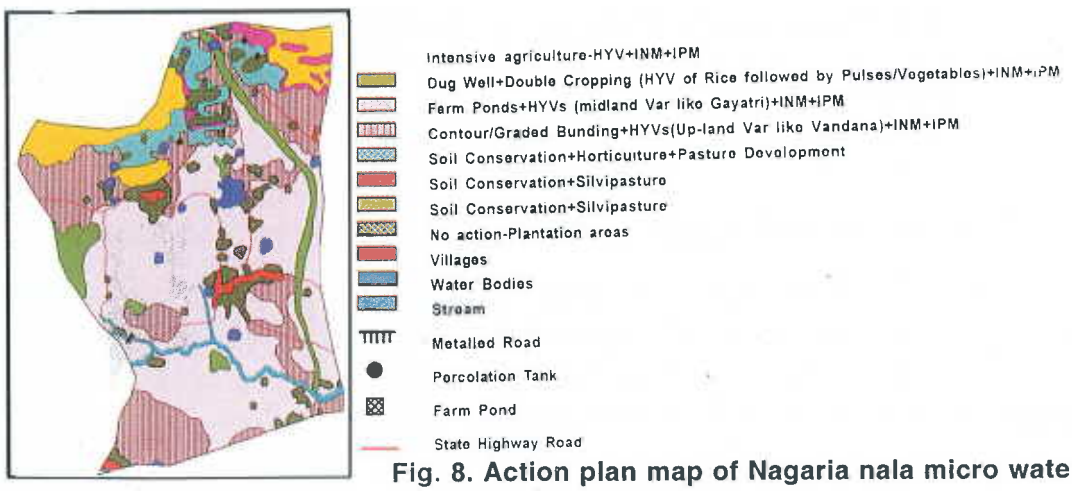


Fig. 8. Action plan map of Nagaria nala micro watershed.

Watershed Development Activities Under Taken

The different watershed management activities under taken in this watershed can by classified as

1. Engineering measures for soil and water conservation

- Percolation tank
- Water harvesting structure (WHS)
- Check dams
- Contour bund/ contour trench
- Land modification
- Open dug well
- Diversion weir
- Loose Boulder structure
- Renovation of WHS

2. Cropping program

- Variety substitution
- Management practices
- Anti-termite treatment
- Integrated pest management
- Integrated nutrient management
- Integrated farming system approach
- Inter cropping

3. Plantation program

- Teak plantation
- Cashew nut plantation

Engineering measures for soil and water conservation

Percolation tank

A percolation tank was constructed at the food hill near Jamupatana village. An emergency spillway was provided for safe disposal of excess runoff. The photograph of the percolation tank is given in plate 1. The design dimensions of the percolation tank is that, the length of tank at the top is 32 m, length of tank at the bottom is 23 m, the width of the tank at the top is 29 m and that at the bottom is 20 m. The depth of the percolation tank is around 3 m. The capacity of the structure is 2784 cubic meter. The cost is Rs. 48,000 only. The water level varies from 2.1 m in July to 1.1 m in December.

Plate 1. Percolation tank near Jamupatna village.

Accumulation of water level in percolation tank started during last week of June and maintained its peak in the month of October, thereafter declined and become dry in 1st week of March.

Impact of percolation tank

Due to construction of percolation tank ground water level has been increased. The water level in the open well has been increased from 4.5 m to 3.9 m from top during the month June and in November the water level varied between 0.9 to 1.3 m in comparison to 1.5 m to 1.8 m from top prior to the construction of percolation tank. Area under *rabi* vegetable have been increased from 25 ha to 45 ha by watering from 20 open wells of 3 m diameter and 6 m depth. The wells are within 250 to 500 m around the percolation tank.

Water harvesting structure

One water harvesting structure (WHS) was constructed in Paikabankatara village in the slope of degraded forest. The catchment area is 20.5 ha. Runoff from another small channel is diverted to the structure by constructing an embankment adjacent to WHS. The length of 3 m high guiding embankment is 10 m. The length of the tank at the top and bottom are 41.12 m and 31.88 m respectively. Width of the tank at the top as well as at the bottom are 29 m and 22.88 m respectively. The depth of the WHS is around 3 m. A spillway of suitable dimension is provided to safely dispose of the excess runoff water from the tank. The photograph of the water harvesting structure is shown in plate 2. The capacity of the structure is 3567 cubic meter. But water stored during monsoon due to embankment cum WHS is 5233 cubic meter. Approximate estimate of runoff diverted during monsoon over the spillway is 1254 cubic meter. The water level in the WHS varies from 3 m in August to 0.6 m in May. The weekly water level fluctuation of both WHS and percolation tank is given in Table 5.

Table 5. Weekly water depth fluctuation (in m) in WHS and Percolation tank.

Month	Water harvesting structure				Percolation tank			
Week	1st	2nd	3rd	4th	1st	2nd	3rd	4th
July 03	0.50	0.60	0.82	1.38	0.20	0.38	0.69	0.82
Aug 03	2.02	2.90	3.00	3.00	1.25	1.50	1.80	1.90
Sept 03	2.90	2.80	2.75	2.75	1.80	1.75	1.70	1.70
Oct 03	3.10	3.10	3.05	3.10	2.10	2.05	2.00	2.10
Nov 03	3.05	3.00	2.95	2.90	1.95	1.80	1.60	1.35
Dec 03	2.80	2.70	2.70	2.45	1.00	0.70	0.70	0.50
Jan 04	2.55	2.45	2.30	2.20	0.35	0.20	0.00	0.00
Feb 04	2.30	2.20	2.05	1.90	0.60	0.35	0.00	0.10
Mar 04	1.75	1.60	1.45	1.30	0.00	0.00	0.00	0.00
April 04	1.15	1.08	0.80	0.80	0.00	0.00	0.00	0.20
May 04	0.60	0.40	-	-	0.00	0.00	0.00	-

During the last week of June 2003 the rainwater started accumulating in WHS. Thereafter it increased upto 3.00 m depth towards end of August. Since the rainfall in September was less as compared to August the water level slightly decreased and it went upto peak (3.10m) during October. Afterwards it started declining upto end of January 2004 (2.20m). Because of rainfall during 1st week of February the water level slightly increased upto 2.30 m and it again went down to only 0.80m during 3rd week of April. Since there was a rainfall of 56 mm during last week of April, the water in WHS maintained its level allowing the evaporation loss and then it decreased to dryness at the end of May. The silt depositions in two loose boulder check dam at the inlet of WHS were 3.91m^3 and 2.40m^3 respectively.

Plate 2. Water Harvesting tank near Paikbanakatara village

Impact of WHS

The command area under the WHS during *kharif* was 25 ha paddy (supplementary irrigation during October) and during *rabi* was 27 ha (25 ha pulses and 2 ha paddy and vegetable).

Check dam

1. Temporary Check Dam

a. Earthen Check Dam : Ten earthen check dams were constructed as gully control structures in the drainage line which were feeding water to Nagari nala stream. Some of the check dams were constructed with local materials like small stones, pebbles, and small branches of trees and grasses.

b. Loose Boulder structures : Loose boulder structures were constructed in the gully line to retard the velocity of runoff making its way to paddy fields. Five numbers of such structures were constructed on the foot hill of Jamupatana hillocks and another five such structures were constructed in the gully coming from Paikabankatara hillock.

2. Permanent Check Dam

Two permanent check dams of masonry concrete were constructed in the feeder nalla coming from Jamupatna hillock to Nagari nala. These dams were constructed on participatory basis.

The project share is 34% and the water user group share is 66%. The total construction cost is Rs. 5000 each. Water is diverted to one side by field channel constructed by user group and the other side by a 5 cm hume pipe buried under the road.

Impact of check dams

Earthen check dams reduced the velocity of runoff and allowed to percolate but its life was very short. Out of 10 check dams during 2003 monsoon 3 dams were breached and 7 dams are still working well. This has decreased the siltation of the WHS. Silt deposit in each check dam after monsoon month varied from 6 to 8 m^3. Loose boulder structure has similar impact like earthen check structure. But all ten structures are in good condition after the 2003 monsoon. Silt deposit also varied from 10 to 12 m^3 in each structure.

Permanent masonary structure has good impact. During *kharif* 2003, 10 ha of paddy has been irrigated during drought time (supplementary irrigation) in eastern side and 5 ha in the western side. Also during *rabi* 15 ha of pulses and 1 ha of sunflower have been irrigated by the structure. The water level in the nearby well (Kurumbakatara Ashram) has been increased from 3.2 m below ground level to 2.9 m during the month of April. Since it was done on participatory basis, user group have removed silt on the upstream of check dam by themselves, to the tune of 10 to 15m^3.

Plate 3. Masonary check dam at Kurumbankatara ashram

Contour bund cum contour trench

A contour bund cum trench of 100 m length was constructed on the sloping degraded land of Paikabankatara village to conserve water and arrest the silt materials above it so as to develop a good fertile land. Dimension of contour bund/trench is as follows. Height is 0.7 m, top width is 0.5 m and bottom width is 3 m. Three overflow spillways have been provided on the bund to dispose off the excess water to keep the bund safe against hydraulic failure.

The constructed contour bund along with the surplus weir is presented in plate 4. As per the advice of Scientific Advisory Panel (SAP) members, in the up steam of this contour bund near the foot hill, all the ten plots were bunded along contour with contour trench. Soil erosion has been reduced to a greater extent. In one season, the trench was filled with silt (width 0.5 m and depth 0.7 m).

Plate 4. Contour bunding with spillway.

Impact of contour bund

The runoff from the hillock has been reduced. Erosion of topsoil has been reduced. Before construction, soil pit was dug for soil strata identification from 0-90 cm in 6 batches. It was seen that there was no soil in top layer except fractured stone pebbles. But after construction of contour bund, it was found that soil structure has been improved in the 30 ha degraded area near hillock. That is why farmers have gone for black gram in the entire area during *kharif* 2002 and *kharif* 2003. The yield of black gram was 3 to 4 q/ha.

Land modification

Near the hillocks of Paikabankatara in the western side, terraced lands have been degraded due to high velocity runoff, soil loss and gully formation. The total area suffered from this malady was around 6 to 7 ha. The bunds were strengthened with stone masonary spill way in each plot on participatory basis (Plate 5). Such stone masonary spillway was constructed in five places with bund strengthening. The total cost of the structure was Rs. 9000 and out of that the farmer's share was 60%.

Plate 5. Land modification with stone masonary spillway.

Impact of land modification

This was constructed during April 2004. On the 1st pre monsoon shower of May, it was seen that excess water has been smoothly diverted from one terrace to other terrace. The slope is 4%. No gully formation is there. Seeing this another group of 8 farmer's have come forward to construct similar work. K*harif* productivity of 2004 was increased with less damage to crop.

Open dug well

Plate 6. Dug well near Kurumbankatara road.

Two number of open dug wells were constructed on participatory basis in the valley line as per action plan. One well is located near Nagari nala (5 m away from nala and 100 m away from WHS) at Kurumbankatara village. The diameter and depth of one open dug well is 4.65m and 6.43 m respectively and that of the other well diameter is 4.63 m and 6.60 m respectively. The second dug well is a little away (500 m) from valley line as the water user group around second dug well are cooperative and technology receptive farmers (Plate 6). In each case 5 to 6% share has been contributed by water user group.

Impact of open well

i. Open well near road side at Kurumbankatara

Near the open well 25 ha *kharif* paddy was saved during terminal drought in November. During *rabi* 1 ha sun flower, 1 ha brinjal, 0.5 ha onion have been grown for the first time. Around 7 ha of pulses was also taken up. The water level varied from 0.5 m from the ground

Plate 7. Vegetable and sunflower near open well of Nagaria nala.

level in July to 4.2 m in the month of May. Recuperation study shows that recharge rate varied from 0.24 m^3/hr to 0.296 m^3/hr during lean period and rainy season. Around 8 farmers are using the water for irrigation.

ii. Open dug well near Nagari nala

The well is of 4.63 m dia and 6.60 m depths. Water level varies from 0.2 m from the ground level in August to 4.5 m in May. Recuperation study shows that recharge rate varied from 0.17m^3/hr to 0.28m^3/hr. The command area of this well is 4 ha in *rabi* season for growing vegetables. The user group takes up 3 tier cultivation. They grow maize in the *kharif* season, vegetables like cabbage and tomato in *rabi* season and brinjal and bitter gourd in summer season. Some farmers in this well command area take up four crops with fifth crop in bund (Plate 7). The four crops are maize, radish/ cabbage, ridge gourd and leafy vegetable. In between plots, coriander leaf cultivation is also there. The number of crops they take in the command area are bean, tomato, maize, radish, coriander leaf, green leaf, peas, cabbage, cauliflower, sun flower, ridge gourd, bitter gourd, chilli, brinjal and pumpkin along with paddy. In total 12 farmers are benefited by this open dug well. As per the survey the farmers get an annual return of Rs.20 000 per ha after meeting the cost of cultivation. From the total command area annual return is Rs. 80,000. Consequently in the very first year the farmers got the construction cost of open well. Hence seeing this 6 farmers have come forward to construct open dug well.

Diversion weir

As per the action plan, people's response, SAP member's advice and PI's concurrence, a diversion weir was constructed on participatory basis in Nagari nala at Kurumbankatara village (Plate 8). The total member of farmers in this diversion water user group was 35. The design of the weir was based on hydraulic, structural and hydrological considerations. During monsoon, peak flow was recorded after heavy storm at a designated point with regular geometrical surface. It was also calculated by curve number technique. The spill way was designed for 0.2 cumec and had 3 openings. The spillway dimension was 0.5 m x 1.9 m. The

Plate 8. Diversion weir on Nagarinala.

length of diversion wire was 11 m and bottom width was 4.6m, height of structure was 3.9 m and spillway height was 2.0 m. There were two spillways, one on left side and one on right side. The total cost of the structure was Rs. 32,000 and the user group's share was 55% and the project share was 45%. The entire construction was carried out and supervised by water user's group.

Impact of diversion weir

The eastern side surplus weir irrigated 75 ha paddy during *kharif* by field-to-field method. Right surplus irrigated 25 ha during *kharif*. During time of drought 100 ha of *kharif* crop was saved. During *rabi*, 15-20 ha could be irrigated from reservoir behind the structure by pumping. Seeing the success of it another water user group got formed to construct another diversion weir 1 km down the stream.

Renovation of water harvesting structure (WHS)

As per action plan, for improving rice productivity in *kharif* two water harvesting structures constructed earlier by govt. department were renovated on participatory basis by forming water user's group. Each group had 15 members. The group member renovated the structure by their own labour. The project share was only 25%. Size of one WHS is 19520 m^3 and that of other is 3782 m^3. The bigger one is near Dwtikeshwar temple and the smaller one is at Dholmaska. The silt deposit from both the WHS was removed. The entire cost of the project was Rs. 16,000.

Impact of renovation

The bigger WHS being at the top of watershed, the capacity increase has big role in the increase of ground water level in the well below the structure. The water level rose up to 0.5m below ground level in August to 2.5 below ground level in May. Even during March, the field below WHS was moist. Increase in *rabi* area due to renovation was 15 – 17 ha of pulses and vegetables. The structure was leased to water user group for fish cultivation and irrigation. The small WHS belonged to tribal community. There were 15 families depending on this. The *kharif* area was increased from 5 ha to 8.5 ha but in *rabi* the area increased by 10 - 15 ha in cultivating pulses, brinjal, tomato and okra.

Cropping Program

Variety substitution

Paddy varieties suitable for different ecosystem was introduced. For upland, drought resistant variety *Vandana*; for medium land disease resistant high yielding variety *Surendra*; and for

lowland, high yielding water logging resistant variety *Gayatri* was substituted with respect to their local varieties. Under this program seeds of all three varieties were distributed @ 5 kg per farmer to 60 farmers of the micro watershed in the first year. In the second year seeds were distributed to another 82 farmers. Total area covered was 17 ha.

Upland variety, *Vandana*

The seed of upland paddy variety *Vandana* was distributed to ten farmers of the micro watershed @ 5 kg in different villages in the first year and in second year 22 farmers were given *Vandana* seed. The yield of first year and second year is given in the Table 6. Average yield obtained was 2.9 t/ha in comparison to 1.70 t/ha (local).

Table 6. Yield comparison for upland variety (*Vandana)* introduced in the micro watershed.

Sl. No	Name of the village	No. of farmers	Area covered (ha)		Yield (t/ha)		Avg. yield (t/ha)	Avg. yield (t/ha) local	% increase
			1st year	2nd year	1st year	2nd year			
1.	Paikabankatara	19	0.4	0.70	2.9	2.40	2.65	1.75	51.4
2.	Kurumbankatara	7	0.2	0.15	2.8	2.4	2.60	1.70	52.9
3.	Kaithapalli	3	0.1	0.10	2.9	2.5	2.70	1.65	63.6
4.	Jampatna	3	0.1	0.10	2.9	2.7	2.8	1.51	85.4

Table 6. Yield comparison obtained from dibbling of seeds in line and random sowing in upland rice variety *Vandana*.

Sl. No	Name of the farmer	Village	Yield form dibble-seeded plot (t/ha)	Yield from random sowing plot (t/ha)	% Increase in yield
1	Fakir Nayak	Jamupatana	2.9	2.6	11.5
2	Rabi Nayak	Jamupatana	2.5	2.2	13.6
3	Chhata Nayak	Jamupatana	2.8	2.4	16.7
4	Niranjan Nayak	Jamupatana	2.7	2.4	12.5
5	Ashok Mohapatra	Jamupatana	2.2	1.9	15.8
6	Biswa Mohapatra	Jamupatana	1.9	1.8	5.6
7	Dayanidhi Barala	K. bankatara	2.6	2.3	13.0
8	Goutam Das Baba	K. bankatara	2.1	1.9	10.5
9	Bidyadhar Sahu	K. bankatara	1.8	1.7	5.9
10	Dandapani Sahu	K. bankatara	2.4	2.0	20.0
11	Prasan Nayak-1	P. bankatara	2.3	2.0	15.0
12	Prasan Nayak-2	P. bankatara	2.4	2.1	14.3
		Average	**2.38**	**2.11**	**1.8**

Impact of variety substitution

Though the area covered under upland variety *Vandana* was 0.8 ha, in the 2nd year the impact was felt in all the four villages. Upland area in Paikabankatara, Kurumbankatara, Kaithapali and Jamupatna village was fully saturated with *Vandana* including our demonstrated area (Plate 9 and 10). The area covered under four villages was 47 ha in 2003 *kharif*. Maximum area was covered in Paikabankatara village (24 ha). Total upland area in the watershed was 119 ha. The impact was felt in around 40% area in the 2nd year itself. The upland paddy variety *Vandana* came up well instead of the drought condition and delayed monsoon of 2002, which is shown in plate 9. This also shows upland paddy with vegetables on the bund. Plate 10 shows Vandana during kharif 2003.

Plate 9. Upland paddy with vegetables on the bund (2002).

Plate 10. Upland drought resistant variety Vandana (2003).

Cropping sequence

Utilizing the well water/ diverted stream water through check dam, different cropping sequence have been presented as

1. **Non rice cropping sequence**
   - Maize- Cauliflower-French been-Bhindi
   - Raddish- Onion/maize-cucumber
   - Tomato-Guar-bitter guard
   - Cauliflower-pumpkin-chilli
   - Cabbage+ sunflower-pumpkin-bhindi
2. **Rice based cropping sequence**
   - Rice- Brinjal+maize-rice
   - Rice-sesamum-rice
   - Rice-sunflower-rice
   - Rice+country bean (on bund)-pointed gourd-rice

Before construction of WHS, percolation tank and two new wells through the project the *rabi*/summer crop coverage was 8 ha. in the year 2002-03 around the dug wells. But during 2003-04, i.e. after construction of watershed components, the area of *rabi*/summer vegetable crop went up to 11.36 ha i.e. increase of 45.5%. This could be due to increase in ground water availability and farmers awareness through the watershed activity. The area under each crop, yield, and frequency of irrigation is presented in Table 7. Yield comparison of medium land rice variety, *Surendra* is given in Table 8.

Table 7. Rabi Crop coverage during 2003-04.

Sl. No.	Crop	Number of farmers	Area (acre)	Yield (quintals)	Av. Yield (t/ha)	Frequency of irrigation
1	Bitter guard	6	1.84	22.59	3.07	4-5
2	Raddish	2	0.09	4.80	13.33	3-4
3	Chilli	5	0.67	17.38	6.49	5-6
4	Cauliflower	4	0.40	28.80	18.00	4-5
5	Cabbage	7	2.95	338.10	28.65	4-5
6	Tomato	15	2.49	197.30	19.81	3-4
7	Brinjal	17	4.43	354.50	20.00	5-6
8	Cucumber	3	0.39	14.50	9.29	4-5
9	Onion	10	0.54	35.24	16.31	3-4
10	Bhindi	8	0.61	8.78	3.60	4-5
11	Guar	2	0.15	2.00	3.33	4-5
12	Maize	8	0.81	15.55	4.80	3-4
13	Sugarcane	9	6.52	1055.00	40.45	4-5
14	Sesamum	2	1.00	1.15	0.29	2-3
15	Sunflower	6	1.32	4.24	0.80	5-6
16	Pumpkin	3	0.33	31.50	23.86	3-4
17	French bean	1	0.20	15.00	18.75	3
18	Country bean	1	0.02	1.00	12.50	-
19	Cumin(leaf)	1	0.08	5.00	15.63	4
20	Pointed gourd	1	0.50	-	-	5
	Total	**25.34**				

Table 8. Yield comparison for medium land variety *Surendra* (135 days).

Sl. No.	Village	Number of experimental plots	Average yield from the plot (t/ha)	Average yield from the local variety (t/ha)	% Increase in yield
1.	Kurum Bankatara	5	4.64	3.88	19.6
2.	Dholmoska	1	4.9	4.2	16.7
3.	Jamupatna	5	4.65	3.84	21.09
4.	Paik Bankatara	27	4.48	3.98	12.56

Two treatments i.e. line transplanting versus scattered transplanting was taken with medium land variety *Surendra* at 10 locations (2.25 acres) in village Kurumbankatara, and Paikabankatara. A higher yield of 13.6% was obtained with line planting as compared to random planting as shown in Table 9. The different photographs showing line versus scatter transplanting are presented through Plate 11, 12, and 13.

Plate 11. An experimental plot under medium land paddy variety, *Surendra*.

Plate 12. A farmer doing line transplanting in the micro watershed.

Plate 13. Better growth and tillering in line transplanting in comparison to scatter transplanting.

Table 9. Yield Comparison of medium land paddy var. *Surendra* obtained from line and scattered transplanting

Sl. No.	Name of the farmer	Village	Yield from line transplanting (t/ha)	Yield from random planting (t/ha)	% Increase in yield
1.	Gautam Das Baba	Kurum Bankatara	5.2	4.6	13.0
2.	Sanysi Das	Kurum Bankatara	5.1	4.6	10.9
3.	Subas Sahu	Kurum Bankatara	4.8	4.2	14.3
4.	Prahallad Pradhan	Kurum Bankatara	4.8	4.2	14.3
5.	Kalia Parida	Kurum Bankatara	4.7	4.1	14.6
6.	Bainchala Parida	Kurum Bankatara	4.6	4.0	15.0
7.	Alekha Nayak	Paika Bankatara	4.0	3.6	11.1
8.	Prasana Nayak	Paika Bankatara	4.8	4.1	17.1
9.	Baikuntha Nayak	Paika Bankatara	4.8	4.2	14.3
10.	Batha Nayak	Paika Bankatara	4.7	4.2	11.9
			4.75	**4.18**	**13.6**

Integrated Nitrogen Management through green manure, Dhanicha

This experiment was carried out in 10 trials (an area of 1.57 acres) in all the three villages taking *Gayatri* as test crop in lowland situation with two treatments i.e. urea alone and secondly *Dhanicha* N + Urea N. The fertilizer dose was maintained at 80:40:40:: N-$P_2$05-K_2O/ha. After harvesting, the yield was found to be almost the same, which concludes that less urea, required in later treatment might be coming from *Dhanicha* source. The yield is given in Table 10. A photograph of a successful INM trial is given in Plate 14.

Table 10. Yield comparison of rice variety *Gayatri* (155 days) obtained from the use of urea- N alone and integrating green manure *Dhanicha*-N with urea-N.

Sl. No.	Name of the farmer	Village	Qty of seed supplied (kg)	Yield from urea-N plot (t/ha)	Yield from dh+N plot(t/ha)	Area covered (m^2)
1	Prasan Behera	K. Bankatara	5	4.3	4.4	810
2	Babula Behera	K. Bankatara	5	4.1	4.0	600
3	Jagannath Behera	K. Bankatara	5	3.2	3.3	735
4	Rajkishore Nayak	Jampatana	5	3.0	2.9	560
5	Niranjan Nayak	Jampatana	2	3.3	3.3	350
6	Udasi Nayak	P. Bankatara	5	2.8	2.9	430
7	Prasana Nayak	P. Bankatara	5	3.0	2.9	520
8	Ramachandra Nayak	P. Bankatara	5	2.6	2.5	650
9	Brundaban Nayak	P. Bankatara	5	2.4	2.3	560
10	Damburdhra Nayak	P. Bankatara	8	1.9	2.0	1130
			Average	3.04	3.05	6345

Integrated Farming System and Pisciculture

A farming system approach was taken at a small pond of Gautam Das Baba in village Kurumbankatara. On the bund at this small pond an area of 240 m^2 area was lying barren (the rest area on the bund was covered with fruit trees earlier). We insisted the farmer to utilize the bund area throughout the year. During *kharif* he took pumpkin, ladies finger and maize crop. During winter tomato, bitter gourd and pumpkin were taken and got satisfactory results. During summer he also cultivated watermelon. Utilizing the pond water he also took vegetable crops like pumpkin, maize, ladies finger and bitter gourd in an area of 0.10 acre and sunflower in 0.45 acre. These lands are adjacent to the pond and at the top crops were taken after rice in *kharif*. Under residual moisture green gram was covered in 2.45 acres. The total area of the farm was 4 acres including pond area. During the year 2003 we gave some fingerlings 4000 numbers (*catla*) at a cost of Rs. 400 and allow growing naturally in the pond water. At the end of April 2004 the harvesting was done and it was observed that the size of the fish was in the range of 150 g to 350 g. The fishes below the size of 250 g were left for next year and the rest (25 kg weight) were sold @ Rs.32 per kg. So the farmer received a total of Rs. 800 in cash. Above all due to this project his overall socio-economic status improved by adopting integrated farming system approach. The photograph of fish and vegetable grown within IFS is given in plate 15 and 16.

Plate 14. Paddy cultivation with and without Dhanicha.

Plate 15. Netting of fish in IFS.

Plate 16. Vegetable cultivation on the embankment.

Anti-termite treatment

Termite is a major pest in upland in rainfed area. Anti-termite treatment has been undertaken in 3 farmers' field. The results are encouraging.

Integrated pest management

Integrated pest management has been taken in the farmers' field. Sex-pheromen trial has been taken to trap the insect/ pest. A sex-pheromen trap installed in farmer's field is shown in the plate 17. This trial showed that a majority of the insects were trapped in the pheromen trap and thus pest management could be done without any adverse impact to environment.

Plate 17. Integrated pest management using Pheromone trap.

Contour bund and plantation program

In degraded land a contour bund (100 m x 3 m x 0.5 m) was constructed across the slope and the land was made suitable for plantation programme. In August, 2002, 600 cashew nut plants and 140 teak plants were supplied to 10 and 3 farmers respectively covering an area of 4 ha. During July 2003, 620 cashew nut plants were distributed to 15 participatory farmers and they planted in their individual degraded land covering an area of 4 ha. As on May 2004, the growth parameters of cashew nut and teak plants are given in Table 11.

Table 11. Year wise growth parameters of cashew nut and teak plantation.

Cashew nut	1st year plantation	2nd year plantation
Date of planting	August 2002	July 2003
Av. Diameter	8.6 cm	3.8 cm
Av. Height	2.10 m	1.55 m
No. of branches	5-6	4-5
Date of flowering*	Feb, 2004	-
Teak		
Date of planting	August 2002	
Diameter	4.5 cm	
Height	1.70 m	

* *The farmers are advised to cut the flowers of the plants below 3 years of age.*

The farmers had made heaps near the root and rings of 0.5 m radius around the cashew nut plant for in-situ soil moisture conservation. Also for control of leaf curl disease and tikka disease of cashew nut spraying of insecticide like chlorophyriphos was done. Anti-termite treatment was taken before planting of cashew nut and teak. The photograph of cashew nut plantation is given in Plate 18.

Plate 18. Cashew nut plantation in a degraded land.

From soil conservation point of view as well as from bund stability point of view, it was advised to keep the bund under some crop. Black gram as well as arhar was recommended to be grown on the bund. The picture is shown in plate 19 and plate 20.

Plate 19. Arhar grown on the bund of paddy field.

Plate 20. Black gram grown on the bunds of paddy field.

The monthly rainfall at Odagaon is provided in the appendix- I. The project was reviewed several times, which is given in Appendix –II. The Standard soil/ site parameters, classifications, their ranges and limitations for identification of critical area in the watershed is provided in Appendix-III.

Conclusion

For mitigating drought and increasing productivity of rainfed rice, watershed development and management is essential. Hence an ideal and replicable watershed was developed which include engineering measures for soil and water conservation, cropping programme, plantation programme and fodder and horticulture programme etc., taking into account the soil map, land use map, slope map and critical area map developed through remote sensing and GIS. All these points have been incorporated in developing the present Nagari nala watershed, which is regarded as an ideal and replicable watershed. Overall impact is felt in the entire watershed by which cropping intensity has increased, migration has reduced, degraded land has been developed into cashew nut plantation area, high yielding variety of paddy has been spread to 6 to 7 times more area and water level in well has been increased showing more ground water availability. For future development of any watershed the entire procedure followed in this bulletin may be adhered to. The main thrust should be to integrate all programs including engineering measures under a single windows basis.

In order to sustain the watershed programme, the proposal must have bankability prerequisites. If we look at the development of Nagari nala watershed, all the prerequisites of bank loan availability has been fulfilled. The income of the stakeholder has been increased, due to which migration has been reduced by 42%. Farmers have been trained in *rabi* cultivation and there by 53% of the stake holder have repaid their all cooperative bank loan to be eligible for future loans. For this well designed plan B: C ratio in the 1st year was 0.92 but it was increased to 2.3 by the end of the project (3 years). This will still increase when cashew nut plantation will start yielding after 4th year onwards.

Reference

1. Jena, S. K., Sahoo, N., Rao BRM., Srivastava, R. C., Das, M., and Nanda, P. (2003) "Development of Watershed Management Action Plans using Remote Sensing and GIS". Proc. of International Conference on water and Environment held at RRL, Bhopal, 15-18th Dec 2003. pp 197 - 208.
2. Rao, B.R.M., (2004) Development of Regional Scale Watershed Plan and Methodologies for Identification of Critical Areas for Prioritized Land Treatment in the Watershed of Rainfed Rice Production System. Proceeding of 3rd Annual NATP Workshop, June 9-10, 2004 pp. 1-10.
3. Sahoo, N., Jena, S. K., Srivastava, R. C., Das, M., and Nanda, P., (2003) " Integrated Watershed Development and Management Approach for a Sub-humid Watershed in Orissa". Proc. of XXII Annual Convention of AHI and International Seminar on "Watershed Development" held at Andhra University, Visakhapatanam 16th Oct to 18th October 2003, pp V15 - V16.

Appendix - I
Monthly rainfall at Odagaon

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1982	0	0	0	100	0	10	75	210	168	18	4	0	585
1983	0	49	28	115	94	63	265	185	206	110	0	0	1115
1984	0	20	0	30	18	64	237	177	140	23	0	0	709
1985	29	93	15	24	14	77	172	100	180	153	0	0	857
1986	26	10	8	18	63	156	205	198	85	95	124	14	1002
1987	14	0	29	16	34	95	69	47	118	97	95	0	614
1988	0	44	14	56	38	95	96	94	224	127	0	0	788
1989	0	0	33	11	28	217	120	385	99	89	0	0	982
1990	0	62	25	158	185	143	215	390	52	212	444	0	1886
1991	8	22	22	89	14	102	261	274	79	104	9	0	984
1992	0	65	0	23	38	207	251	236	79	106	0	0	1005
1993	0	0	38	48	98	114	217	249	131	57	0	0	952
1994	0	37	32	93	80	45	117	420	238	108	0	0	1170
1995	38	15	0	16.5	532	92	171	165	67	162	140	95	1493.5
1996	5	0	8	22	13	130	209	210	156	32	22	31	838
1997	18	0	48	100	7	203	214	731	188	0	0	75	1584
1998	12	77	11	11	88	121	157	62	71	69	57	0	736
1999	0	0	0	0	53	198	126	60	72	213	34	0	756
2000	0	0	0	11	90	199	128	150	37	130	0	0	745
2001	0	0	33	10	42	262	329	198	107	138	15	0	1134
2002	26	0	26	41	137	117	103	190	95	96.7	42	2.5	875.7
2003	0	30	3	14	37	106	284	622	234	369	14	38	1750.5
2004	7	11	0	21	32	135	198	245	135	95			

Appendix - II

Review of the project by a Peer review team:

A Peer Review Team evaluated this project in the month of September 2002. The photograph of the review team taken during the discussion at the project site is given in plate 21. Suggestions given by the review team was incorporated in the work. The CCPI and the team members of this project are highly thankful to the above said Peer Review Team for their appreciation and encouraging words.

Plate 21. Visit of Peer Review Team.

Review of the project in SAP meeting held at Kolkata

The project was reviewed in SAP meeting held at Kolkata during 26-27th December 2002. The review committee appreciated the progress of the project.

The SAP review members Dr. I.C. Mohapatra, Dr. P.K. Mohapatra, Dr. M.A. Shankar and Dr. D. Panda have visited the watershed to review the progress. They were highly satisfied with the work.

A farmer's training was conducted during 9th March 2004 to show the work to all the farmers of the adjoining watershed. During this training ASCO Nayagarh, DAO Nayagarh, Head, Central Horticultural Experiment station, Head, CTCRI regional center and Head, CARI regional center have visited the watershed along with Director, WTCER.

A brochure on "Ideal and replicable watershed management" in Oriya was released by the Director, WTCER, Bhubaneswar for the farmers.

Dr. BRM Rao, PI of the project visited the site along with Dr. Rabisankar on 5th April 2004 to see the progress of work. He gave few guidelines for *kharif* program.

Plate 22. Farmers training programme.

Plate 23. Dr. BRM Rao, PI's visit to the site.

APPENDIX-III

Standard soil/ site parameters, classifications, their ranges and limitations for identification of critical area in the watershed

(a) Soil Textural Classes

Surface texture	Texture class	Family class	Clay distribution
Very fine	Heavy clay	Very fine	60 or more
Fine	Silty clay, clay	Fine	40-60
Moderately fine	Sandy clay, very fine sicl, cl	Fine	35-40
Medium fine	Fine scl, coarse cl, sicl	Fine loamy	28-35
Medium	Loam; sil; coarse scl	Coarse loamy	18-27
Medium coarse	Sl, coarse loam; soil	Sandy	10-18 silt 10-15%
Coarse	Loamy sand		
Very coarse	Sand		

(b) Soil depth classes

Soil depth (cm)	Series
<10	Extremely shallow
10-25	Very shallow
25-50	Shallow
50-75	Moderately shallow
75-100	Moderately deep
100-150	Deep
150+	Very deep

(c) Slope class

Slope Class	% Slope
Level to nearly level	0-1
Very gently sloping	1-3
Gently sloping	3-8
Moderately sloping	8-15
Moderately steeply sloping	15-30
Steeply sloping	30-50
Very steeply sloping	>50

(d) Drainage classes

Description
Extremely poor
Very poor
Poor
Imperfect
Mod. Well drained
Well drained
Some what excessive
Excessively drained

(e) Soil reaction class

Description	pH range
Normal	6.5-7.5
Slightly alkaline	7.5-8.5
Moderately alkaline	8.5-9.0
Strongly alkaline	9.0-9.8
Slightly acidic	5.5-6.5
Mod. Acidic	5.0-5.5
Strongly acidic	4.5-5.0

(f) Erosion classes

Class		
Nil to slight	e1	Sheet or rill erosion
Moderate	e2	Rills
Severe	e3	Deep gullies
Very severe	e4	Ravenous land

Visit of the SAP review members to the Watershed (with in the background)

Visit of Scientists of WTCER and other ICAR institutes to the watershed

Percolation tank at Jamupatna

Water level measurement in open dugwell in the watershed