Research Bulletin
35

Blending of Advance and Traditional Technologies for Watershed Management

Gouranga Kar, Ashwani Kumar and Ravender Singh

WTCER

WATER TECHNOLOGY CENTRE FOR EASTERN REGION
(Indian Council of Agricultural Research)
Bhubaneswar - 751023, Orissa, India
2006

Research Bulletin

Blending of Advance and Traditional Technologies for Watershed Management

Publication No. 35

Gouranga Kar, Ashwani Kumar and Ravender Singh

WATER TECHNOLOGY CENTRE FOR EASTERN REGION
(Indian Council of Agricultural Research)
Chandrasekharpur, Bhubaneswar - 751023, Orissa, India
2006

Kar Gouranga, Ashwani Kumar and Singh R., 2006. Blending of Advance and Traditional Technologies for Watershed Management. Research Bulletin. No. 35, Water Technology Centre for Eastern Region, P.O.: S.E. Railway Project Complex, Chandrasekharpur, Bhubaneswar-751023, India.

Published by
Dr. Ashwani Kumar
Director,
Water Technology Centre for Eastern Region,
P.O.: S.E. Railway project complex, Chandrasekharpur,
Bhubaneswar-751023, Orissa, India.

Principal Investigator of the project
Dr. Gouranga Kar, Scientist (S.S.),
Agrometeorology.

Printed By
Capital Business Service and Consultancy,
B-51, Sahid Nagar, Bhubaneswar, Ph: (0674) 2545484

FOREWORD

In the new millennium, watershed management has emerged as a new paradigm for planning, development and management of land, water and vegetation resources through development of efficient farming system. Soil and water conservation program and sustainable land use planning on watershed basis in different agro-climatic regions of the country have already proved more beneficial, economical and ecologically protective for enhancing crop production because it relates with development of all types of land and ecosystem. Development of soil and water conservation plan on watershed basis requires gathering of precise information on a number of parameters of both static and dynamic nature comprising of geology, geomorphology, hydrology, soils, land use/land cover, soil erosion, drainage pattern, climatic etc. Survey techniques and manual methods for integrated survey over large area may be critical in making information available to the planners on time. With the introduction of modern tools like remote sensing both from aerial and space platforms, a better means of data acquisition system of different existing natural resources and hydrologic parameters is now available. The geographic information system (GIS), which has been designed to restore, manipulate, retrieve and display spatial and non-spatial data, is an important tool in analyzing existing natural resources such as land use/land cover, soils, topographical and hydrological conditions etc. To carry out resource monitoring and assessment of area of interest, information derived through remote sensing and GIS is faster and accurate.

Thus the remote sensing along with GIS application aid to collect, analysis and interpret data rapidly on large scale and is very much helpful for soil and water conservation planning on watershed basis. Keeping the urgent needs of modern tools for watershed management, this bulletin has immense value for different target groups.

I appreciate the efforts of Dr. Gouranga Kar and his team to document this research bulletin where different modern tools of watershed management have been presented. I hope this bulletin will be very much useful for extension workers, planners and researchers who are engaged in watershed management at grass root level to improve productivity of rainfed area.

(Ashwani Kumar)
DIRECTOR

Preface

In recent years, modern tools like remote sensing technology, GIS has made great achievements and contributed significantly in the management of natural resources, disaster management, environment monitoring etc. Remarkable development in space technology currently offers satellite which provides better spatial, spectral and temporal resolutions (more frequent revisits), stereo viewing and on board recording facilities. Presently, Indian Remote Sensing Satellite IRS-ID provides multispectral data with 23 m resolution and panchromatic data with 5.0 m resolution and IRS P6 with 5.8 m multispectral resolution. Thus high-resolution satellite data not only improve identification of different features but also helps in mapping cadastral level detailed information on 1:12,500 scale. The merge data of LISS III and PAN are helpful in interpreting various features like soil, hydrogeomorphology, drainage, plantations, cropping pattern, forest etc. of a watershed.

Keeping the importance of modern tools along with traditional technologies for watershed management, the research bulletin on "Blending of advance and traditional technologies for watershed management" has been published by WTCER, Bhubnaeswar which documented some case studies in a tribal dominated watershed using modern tools like GIS, GPS, remote sensing technique. The action plan on alternative land and water resources development was developed keeping the existing landuse/land cover as a base which was validated in some parts of the watershed and was found profitable and sustainable. We hope the bulletin will be useful for researchers, planners, extensions workers who are working at the grassroot level for watershed management.

We are grateful to Director General, ICAR and secretary, DARE, Deputy Director General (NRM), ICAR, Additional Director General (IWM), ICAR for their constant encouragement to carry out this important study for the welfare of tribal farmers. We are thankful to authorities of NRDMS, DST, Govt. of India providing financial support to carryout the study.

(AUTHORS)

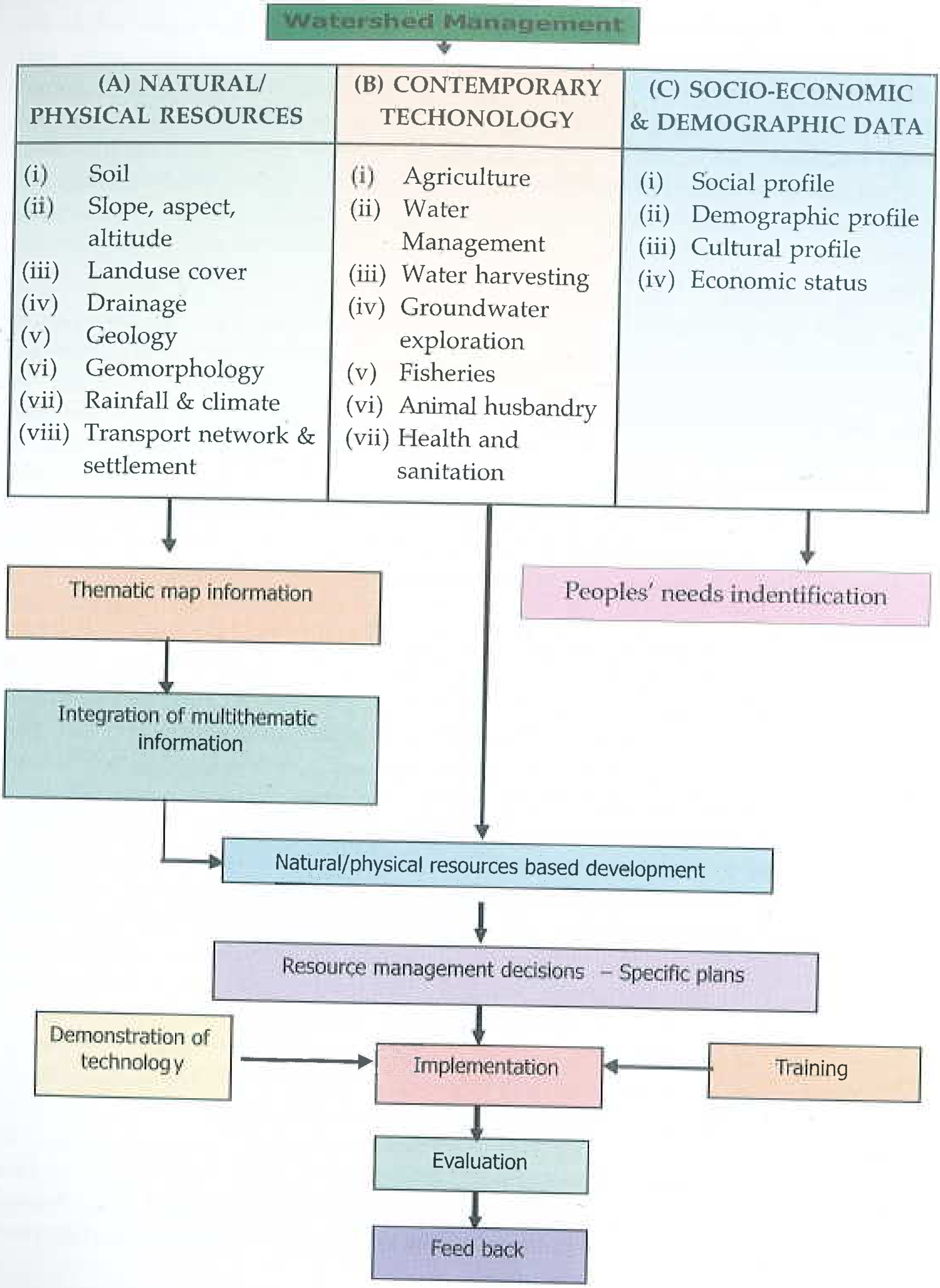
CONTENTS

1.0 WATERSHED MANAGEMENT – AN INTEGRATED APPROACH

Watershed management has been defined as an integration of technologies within the natural boundaries of a drainage area for optimum development of land, water and plant resources to meet the basic minimum needs of the people in a sustainable matter. Watershed management, in its broadest sense, refers to the prudent use of its land and water resources. Management of a watershed may involve proper land use planning, construction of rainwater harvesting structures, construction of reservoirs on the streams, irrigation projects, soil conservation, forest management and afforestation. In the rainfed farming area, the watershed management must strive to conserve all the precipitation, which it receives in order to raise its productivity.

Watershed characterization requires generation and gathering of precise information on a number of parameters of both static and dynamic in nature comprising of geology, geomorphology, hydrology, soils, land use/land cover, soil erosion, climate etc. In any watershed, resources are in general interdependent. At any instant of time, the watershed has a wide spectrum of characteristics viz., (a) watershed topography: it consists of mountain, hills, plains, gullies, vallies and so on. Each is characterized by variable slope and area, from one location in the watershed to another location. (b) land mass of the watershed (land use, soil types, and underlying geology) (c) meteorological factors (rain, radiation, evaporation, wind, temperature etc.) (d) socio-economic factors (per capita income, per capita availability etc.) But all these natural resources are interdependent and integrated in such a way that use of one resource may influence the other resources. As for example, the meteorological factors and land characteristics of the watershed will have a pronounced effect on the type of vegetation that grows there and its distribution over the surface of watershed. The vegetation may vary from desert with minimal growth, grasses, forest to dense bush vegetation associated with tropical rain forests. The vegetation will in turn affect the surface runoff, through the removal/storage of soil moisture. Topographical, meteorological, geological and vegetation characteristics interact to affect the development of drainage network of the river. Topographical and geologic conditions determine the formation of lakes, water falls, the possible site for reservoirs. Soils, vegetation, wind and rainfall characteristics determine the rate at which surface erosion takes place. Thus, it is seen that watershed management need integrated approach where all the factors are interdependent and an integrated survey is required for planning optimum utilization of watershed resources for enhancing its productivity. Manual survey and methods alone in integrated survey are time consuming and tedious and information may not available to the planners on time. With the introduction of modern tools like remote sensing (both from aerial and space platforms), geographic information system (GIS) and global positioning system (GPS), better means of data acquisition system are now available to use for watershed management. These advance tools along with traditional technologies will be useful for development of action plan on alternative land and water resources.

Flowchart - 1 : Flow chart for watershed management



Watershed management solutions must:

- Deal with rural poverty.
- Develop programmes that protect and rehabilitate degraded areas, particularly those that pose hazards to human life and welfare.
- Develop awareness for soil and water conservation.
- Develop community based organizations that assist the rural poor to implement soil and water conservation measures and to improve their livelihood.

2.0 REMOTE SENSING AND GIS FOR WATERSHED MANAGEMENT

Remote sensing refers to the acquisition of information about an object / phenomena, without these being any physical contact. Generally, the information were acquired remotely by scientific devices called "sensors" which are generally mounted on platforms like aircrafts or satellites and can thus obtain a synoptic view over a vary large area. The most widely used remote sensing techniques are based on the detection/ sensing of electromagnetic radiations, which are reflected/scattered or emitted by objects. The reflections or emission of radiations at different wavelengths by objects depends on the physical structure of the objects and their condition. The whole edifice of remote sensing is built on the premise that all objects have characteristic spectral signatures. By analyzing these spectral signatures, it is possible to detect, identify and classify various objects/phenomena. The remotely sensed data thus furnish information, which in turn, leads to better knowledge of the earth's environment and its resources and will be useful for watershed management.

In recent years, remote sensing technology has made great achievements and contributed significantly in management of natural resources, disaster management, environment monitoring etc. Remarkable developments in space technology currently offers satellite which provide better spatial, spectral and temporal resolutions, (more frequent revisits) stereo viewing and on board recording facilities. Presently, the Indian Remote Sensing Satellites (IRS-IC, IRS-ID) provide multispectral data with 23 m resolution and panchromatic data with 5.0 m resolution. The Resourcesat (IRS P6) is supplying multispectral data with 5.8 m resolution. Thus high-resolution satellite data not only improve identification of different features but also helps in mapping cadastral level detailed information on 1:12,500 scale. The merge data of LISS III and PAN are helpful in interpreting various features like soil, hydrogeomorphology, drainage, plantations, cropping pattern, forest etc. Frequent coverage of the same area due to the repetitive nature of the satellite provides us ample scope to monitor the activities in the watershed with frequent intervals for generating action plan on alternative land and water resources, for applying mid course correction and for assessing long term effectiveness of the program implemented and monitoring. Now the availability of high-resolution data from RESOURCESAT, CARTOSAT has further opened up new vistas in the area of watershed management.

Geographical Information System (GIS) is a data base system in which most of the data are spatially indexed and upon which a set of procedures are operated in order to answer queries about spatial entities in the data base. GIS can be used for integrated study of resource management because of its capacity to design, organise an error free digital data base for natural resources in the form of separate layers.

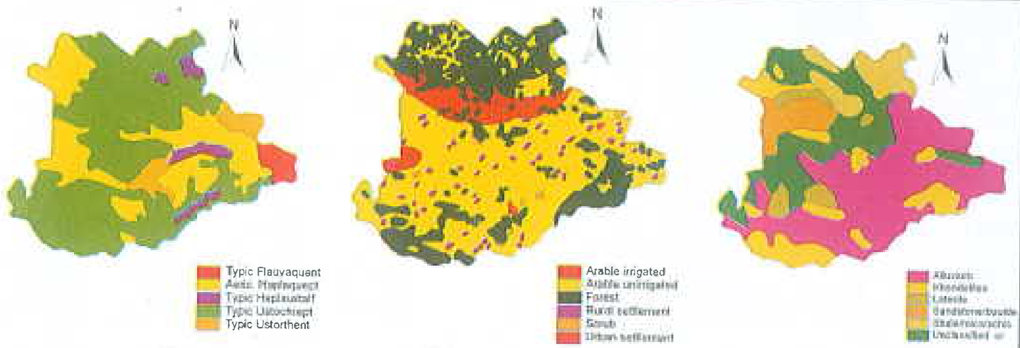
In general there are three basic notations *viz.*, points, lines, polygons are used in geographic information system for representing the spatial location of geographic phenomena inside the watershed. As for example, a road is represented by line or arc comprising a starting XY co-ordinates and an end XY co-ordinates. A pond could be represented by an area or polygon entity consisting of a set of co-ordinates whereas, a well could be represented by a point entity consisting of a single XY co-ordinate pair. These are mostly commonly defined on maps using X, Y Cartesian co-ordinates such as longitudes, latitudes. The Cartesian co-ordinates are then transferred to X, Y co-ordinates of GIS file. With the availability of high resolution satellite data, GIS, GPS (global positioning system) and computer based models, the natural resources appraisal becomes easier, faster, accurate which increases the scope of applicability of satellite remote sensing data and GIS for regional level planning to improve productivity of watershed.

3.0 BLENDING OF MODERN AND TRADITIONAL TECHNOLOGIES FOR WATERSHED MANAGEMENT

Presently, the satellite data along with conventional data could be effectively utilized in GIS environment for watershed development on sustainable basis. Different aspects of watershed management possible through modern tools (remote sensing, GIS and GPS) along with tradtional technologies are :

- Watershed characterization and prioritization
- Inventory and assessment of natural resources viz., soil, land cover, geology.
- Identification, inventorying and assessment of stressed and non stressed crops.
- Assessment of areas suitable for soil and water conservations, identification of sites of water harvesting structures.
- Land use planning and precision farming.
- Ground water targeting: Locating sites where the prospects of ground water are high.
- Determination of the quantity and quality of water available and that which is actually used for irrigating crops.
- Distinguishing of lands irrigated by surface water bodies or through ground water withdrawals, locating water bodies and monitoring changes in water-spread area
- Assessment of withdrawals from surface water bodies as well as from ground-water aquifers.
- Water logging and salinity problems in irrigated lands.

- Energy balance study, evapotranspiration and scheduling of irrigation.
- Identification of existing erosion prone areas and estimation of sediment yield index.
- Estimation of runoff, soil loss due to water and wind erosion.
- Snow mapping: Estimating area extent and forecasting runoff.
- Flood mapping: Mapping inundated and flood-prone areas, and damage assessment.
- Morphometric and drainage network analysis and precision farming.



(a) Soil map of Dhenkanal District

(b) Landuse map of Dhenkanal district

(c) Distribution of rock in Dhenkanal district

Fig. 1 : Natural resources of the study district (Dhenkanal), Orissa, India

4.0 IMPROVING TRADITIONAL WATERSHED MANAGEMENT WITH MODERN TOOLS AND TECHNOLOGIES- A CASE STUDY IN A TRIBAL DOMINATED WATERSHED

4.1 The study watershed

A tribal dominated area, called Bahasuni watershed of Dhenkanal district, Orissa was taken as study area. Study area lies between $20^0 35'$ to $20^0 39'$ N latitude and $85^0 32'$ to $85^0 35'$ E latitude and falls under Survey of India (SOI) toposheet No. 73 [illegible]. The total area of the watershed is 12.6 sq.km. The climate of the area was characterized by hot and sub-humid climate with mean monthly maximum temperature of 46^0 C in May and mean monthly minimum temperature of 9.0^0 C in December. (Table-1). The area is part of Saptasajya hills of Dhenkanal district, Orissa and according to NARP (1979) classification, the area comes under the mid-central table land agro climatic zone of Orissa. The watershed is dominated by two tribal villages viz., Majhi Sahi and Bana Sahi with their typical tribal farming system. Physiographically, the area rises from east to west and has average elevation of 300 meters from mean sea level. The zone is undulating and has folded topography, surrounded by hillocks. The highest flood level at the outlet was 85 m above mean sea level (msl). Highest and lowest relief were

Table 1 : Mean monthly major weather parameters of study area.

Month	Maximum Temp. (°c)	Minimum Temp. (°c)	Morning humidity (%)	Afternoon humidity (%)	Rain (mm)	Wind Speed (k/hr)	Av. Vapour Pressure (mb)	Atm. Press. (mb)
January	30.9	9.7	75	47	15.5	4.8	14.05	999
February	36.5	10.0	70	38	17.2	5.8	14.3	996
March	38.7	12.7	66	33	25.4	6.6	15.3	994
April	44.6	20.6	64	34	37.5	8.1	19.7	990
May	46.2	21.5	65	39	64.8	9.6	24.3	986
Jun	42.0	23.6	73	60	263.6	9.3	27.9	983
July	35.7	24.6	82	77	369.1	8.2	30.1	983
August	38.0	23.4	83	79	281.6	7.2	30.4	985
September	33.6	23.4	83	77	220.6	6.3	29.9	988
October	33.8	18.6	80	67	93.6	5.5	25.7	993
November	32.2	11.5	74	53	25.2	4.5	18.2	997
December	29.4	9.0	73	48	4.5	5.0	14.4	999

Fig. 2 : Overview of watershed in the IRS-P6 satellite imagery

Fig. 3 : Spatial location of the study watershed

440 m and 82 m above msl, respectively. The drainage network and contours were extracted from SOI toposheet which depicts the dendritic nature of drainage of watershed. The watershed has undulated topography with steep slopes and dense and degraded forest and vegetation. The main sources of water are 4-5 small surface water bodies (ponds/tanks), situated inside the watershed. The rock type of the watershed is low grade metamorphic rock with slates, which are highly fractured and foliated. The watershed boundary was delineated after super imposing the ridge line demarcated on SOI toposhet with the IRS-P6 satellite imagery (Fig.-2). The spatial location of watershed area is given in Fig- 3.

4.2. Land use classification of the watershed using remote sensing data

Photo-1 : Varification of IRS-P6 satellite imagery with ground truth

Based on spectral signature and radiometric resolution, different categories of land use were identified on the image using supervised classification with GEOMETICA V 9.0 image processing software. Supervised classification is carried out in stratified manner for both *rabi* (dry) and *kharif* (rainy) seasons of IRS-P6, LISS-IV MX (October, 2004, January 2005), satellite imagery using maximum likelihood classifier together with extensive ground truth observation. The classification proceeds through selection of the training sets based on pattern recognition and a prior knowledge of the land use data for classification. The location of a specific land use/cover type for training sets collection was gathered through ground truthing at the same time as the remotely-sensed data, so that the data corresponds as much as possible. Ground truthing refers to the acquisition of knowledge about the study area from fieldwork analysis, aerial photography, or personal experience. Global positioning system (GPS) receivers were also used to conduct ground truth studies and collect training sites.

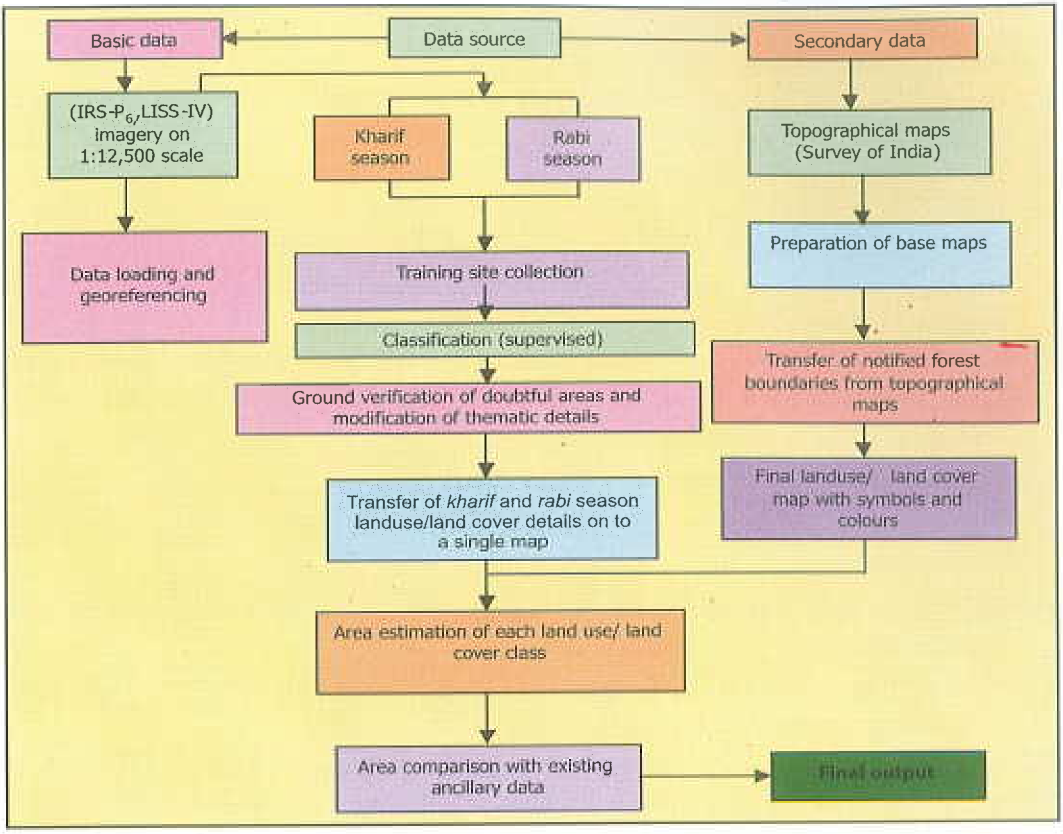
In brief following steps were followed for land use analysis

1. Data acquisition, loading, and geo-referencing.
2. Ground truth and training site collection.
3. Stratified classification of the two season's data.
4. Refinement after classification of images and adjusted classification based on ground information collected.

5. Aggregation of land use system in *rabi* (dry/winter season) and *kharif* (rainy season).

6. Evaluation and final output.

The detailed procedure for determining landuse classification is given in flowchart-2.



Flowchart-2 : Methodology for mapping landuse/ land cover using supervised classification of satellite data.

4.3 Descriptions of satellite data

Satellite	:	IRS-P_6 (RESOURCESAT)
Sensor	:	LISS-IV (MX)
No. of bands	:	Three
Resolution	:	5.8 m (multispectral)
Revisit	:	5 days
Type	:	Precision geocoded (multispectral)
Scale	:	1:12,500
Date of scene	:	15-10-2004, 07-01-2005
Launch vehicle	:	PSLV-C5
Path/ Row	:	84-88/20-24

Advantage of landuse classification using remote sensing data

- Delineation of land use/ land cover and their study on the spatial distribution covering large area is possible using remote sensing data because it provides a large synoptic coverage on single imagery.
- It provides a reliable, near real time base line information.
- It is relatively fast and economical for gross estimates as compared to any other method of surveying.
- It provides data in four different bands of the Electromagnetic Spectrum (EMS). Availability of such data in black and white and False Colour Composite (FCC) bands make it very useful for delineating the land use / land cover classes distinctly.
- It provides both analog and digital data. Such data is available for both visual and digital analysis for extraction of thematic information.
- It provides repetitive coverage of the same area and multidate data is useful for monitoring land use / land cover changes.
- The different spectral and spatial resolution data are available for mapping of natural resources and merging it with other satellite sensor data for better feature detection and discrimination.

Some of the limitations of satellite data

- Only broad land use categories up to level II are identified because of limited spatial (ground) resolution of the imagery.
- Similar spectral response from different objects cause spectral confusion and misinterpretation.
- Homogeneous object is required for accurate landuse study, which may not exist in mixed cropping system.

The land use categories of the watershed classified with supervised clasiffication of IRS-P6 data, GPS survey and extensive ground truthing are given in Table-2 and the study revealed that altogether 12 classes of land use i.e. water body, upland agriculture, low land agriculture, current fallow, residual hills, built-up area, dense forest, plantation, degraded forest, ravine land, etc. were found in the watershed. The brief description of existing land use is given below.

1. **Built up land**: The built up land includes human settlements, building which is being converted for non-agricultural use.

2. **Agricultural land**: It is defined as the land primarily used for agriculture and for production of food, fibre, other commercial and horticultural crops. It includes both rainfed and irrigated land. In the study watershed agricultural land is predominantly rainfed, dominated by rice (both upland and lowland rice), which covers only 12.7 ha in the watershed (9.84% of total watershed area).

3. **Plantations**: It is described as an area under agricultural plantation crops which requires some agricultural management techniques. It includes rubber, casuarinas,

Table-2 : The existing land use pattern in the watershed derived using IRS-P6 satellite data alongwith groundtruth observation.

Sl.NO	Landuse/land cover	Area (ha)	% of Total area
01	Water body	12	0.90
02	Upland agriculture	78	6.07
03	Lowland agriculture	49	3.77
04	Forest plantation	175	13.60
05	Built-up area	23	0.20
06	Barren rocky	15	1.79
07	Current fallow	154	12.00
08	Grazing land	225	17.51
09	Dense forest	289	22.46
10	Degraded forest	242	18.79
11	Gullied or ravenous land	19	1.50
12	Plantations	12.02	0.15
	Total area	**1285.7**	

cashew, eucalyptus and other horticultural crops. In this watershed 12 ha area is under cashew and rubber plantation .

4. **Current fallow**: This land includes agricultural land, which is taken up for cultivation but is temporarily uncropped for some years because of some land reclamation is required on such land. In the watershed, 154 ha area is under current fallow.

Photo-2 : Typical upland agricultural land in the watershed

Photo-3 : Cashew plantation in the watershed

5. **Reserve forest**: It is an area within the notified boundary consists of trees and other vegetation capable of production timber and other forest produce. Type of forest is demarketed on the basis of density of forest. Generally, in forest area, where the vegetation is over 40% is called dense forest, between 20-40%, it is designated as open forest and below 20%, it is called degraded or under utilized forest. Within the watershed boundary, 288 ha comes under notified dense forest and 174 ha is under degraded forest.

Photo-4 : Current fallow available within the watershed area

Photo-5 : Dense forest inside the watershed

Photo-6 : Degraded forest inside the watershed

6. **Grazing land**: These are marginal agricultural lands, which have been left barren, because of poor physical properties of soils and undulating terrain. The land is full with grass generally used as grazing purpose. With proper water and soil management practices, these land can be brought under social forestry/ silvi-pasture. In the watershed such area represent 225 ha of land.

Photo-7: Large area under grazing land within the watershed

7. **Water body**: Five small waterbodies of 11 ha area is available inside the watershed.

8. **Ravinous and gullied land:** In the watershed 19 ha area is under ravenous land, which requires suitable soil conservation measures.

Photo-8 : Village pond is the main waterbody available inside the watershed

Photo-9 : Ravenous land within the watershed

5.0 DRAINAGE NETWORK AND MORPHOMETRIC ANALYSIS OF WATERSHED USING GIS

The drainage and contours lines of the watershed were digitized from Survey of India toposheet of 1:50,000 scale and updated with satellite data. These were used as input to ARC/INFO GIS software. Thereafter, different morphometric parameters of watershed were computed in GIS environment after editing errors, building topology of drainage network. The GIS coverage was projected through polyconic projection and spheroid everest geoid system. After projection, the transformation was done to change the coordinates using a projective transformation function. Different morphometric parameters like linear aspects of basin, basin size, basin shape, basin relief and basin texture were determined and are presented in Table-3.

Important morphometric parameters of the watershed and their significance in water resources development

(i) Drainage Pattern

The drainage pattern are good indicators of land form and bedrock type and also suggest soil characteristics and site drainage conditions. Study reveals that predominant drainage pattern of the watershed is dendritic, indicating existence of rocks with uniform resistance to erosion (Fig.-4). 'Dendritic' pattern is the irregular branching of channels ("tree like") in many directions, common in massive hard rock terrains especially in granite and gneiss rock and flat lying areas. This pattern is developed where rocks are devoid of marked structural control suggesting uniform resistance to erosion in the watershed.

Table-3 : Morphometric parameters of the watershed derived using GIS tool.

Sl. No.	Parameter	Value
1.	No. of stream of order 1	38
2.	No. of stream of order 2	13
3.	No. of stream of order 3	08
4.	No. of stream of order 4	01
5.	Mean length of order 1	874 m
6.	Mean length of order 2	484 m
7.	Mean length of order 3	1142 km.
8.	Mean length of order 4	1784 m
9.	Total watershed area	12850000 m^2
10.	Watershed perimeter	16.41 km
11.	Basin length	4.99 km
12.	Total length of streams of all order	34076.2 m
13.	Drainage density	2.7 km/km^2
14.	Stream frequency	0.032 $/km^2$
15.	Fineness ratio	2.07
16.	Form factor	0.498
17.	Circulatory ratio	0.579
18.	Elongation ratio	0.398
19.	Bifurcation ratio	3.05
20.	Total relief	358 m
21.	Relief ratio	0.0716
22.	Relative relief	0.0218
23.	Ruggedness number	0.716
24.	Hypsometric integral (H)	0.45

(ii) Linear aspects of drainage net work

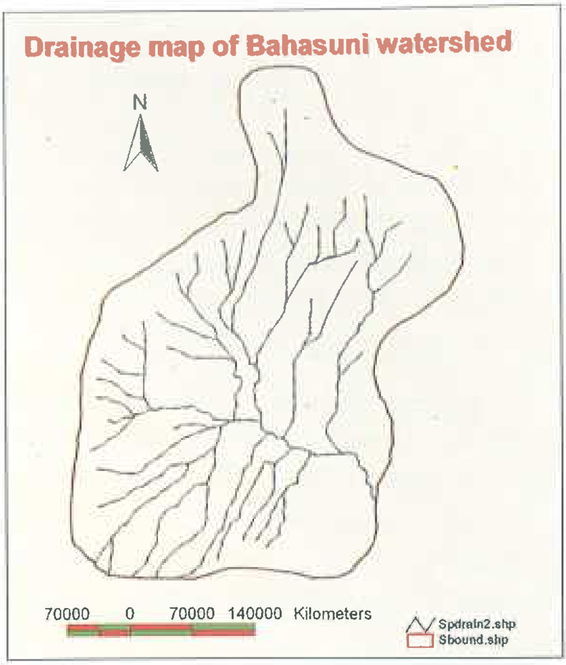


Fig-4 : Drainage pattern of the watershed

Stream order, stream length and bifurcation ratio are the main linear aspects of channel system of watershed. The smallest fingertip tributaries in the watershed are designated as first order, where two first-order channels join, a channel segment of order 2 is formed, where two of order 2 join, a segment of order 3 is formed and is so on. Study reveals that in the selected watershed there were 38 first order, 13 second order, 8 third order and 1 fourth order channels. Mean length of a stream-channel segment of a particular order reveals the characteristic size of components of drainage network and its contributing basin surfaces. It was found that mean length of first order channel was 874 m, length of second order was 484 m, while length of third and fourth order were 1142 m and 1784 m, respectively. Bifurcation ratio of the watershed was 3.05, which was moderate one, indicates geologic structures do not distort the drainage pattern of watershed. Generally when geometrical similarity was not maintained by drainage channels, minimum possible value of 2.0 may occur. High bifurcation ratio was observed in regions of steeply dipping rock strata. The more the value of bifurcation ratio, the more will be the number of lower order streams as a result the higher will be sediment yield. The basin was elongated in north to south direction with medium bifurcation ratio, suggests that the basin experiences neither extended steep flows nor sharp peak flows but a moderate one.

(iii) Basin size

Watershed area, perimeter and basin length are the three parameters that determines basin size. With increase in the basin length and basin area, the sediment yield increases. The factors controlling the basin length are resistance, weathering and permeability of rocks formation apart from the climate and vegetation. The watershed, area, perimeter and basin stream length were computed as 12.85 sq. km., 16.41 km and 4.99 km, respectively.

(iv) Basin Shape

The circulatory ratio and elongation ratio are the main basin shape parameters, which determines intensity of erosion or occurrence of flood in the basin, which has a maximum value of 1. The circulatory ratio was calculated as 0.56 for the present watershed. Lesser value indicates elongated shape of the basin. In the present case, the value is 0.56, thereby indicating that the shape of the basin is fairly elongated and suggests that the area is not prone to floods. An elongation ratio of 0.398 indicates a strong relief having wide variety of climatic and geologic type features.

(v) Basin relief features

Total relief of the basin is the difference in the elevations of the highest point (upper reach) and lowest point (basin outlet). The total relief of the watershed was 358 m and the relief ratio was 0.71 m/km. Relief ratio is an indicator of intensity of erosion. Relative relief is the ratio of the relief of the basin to the perimeter of the basin, which is 2.1 m/km^2 for the study area. This is an indicator of potential energy available in the drainage basins for the soil erosion process.

(vi) Basin texture

Main factors that determine basin texture are drainage density, fineness ratio and stream frequency. The drainage density of the basin affects runoff, the higher the drainage density greater will be runoff and vice versa. Lower drainage density indicates the presence of permeable formation in the sub-surface, which favoured regions of highly resistant or highly permeable subsoil materials, under dense vegetation cover. High drainage density is favoured in regions of weak or impermeable subsurface materials, sparse vegetation and mountainous relief. In the study area drainage density was computed as 2.7 km per square kilometer area, which is relatively low. It indicates low relief of the watershed with permeable strata and moderate runoff. The fineness ratio and stream frequency were computed as 2.07 and 0.032/ km^2 respectively. The higher the stream frequency, the greater is the surface runoff, consequently the more sediment yield.

(vii) Hypsometric integral

Hypsometric (area-altitude) analysis is the relationship of horizontal cross-sectional area of drainage basin to elevation, which is used to determine the geomorphic stages of watershed. The watershed is said to be in equilibrium, if the hypsometric integral is greater than 0.60 and monadnocks become conspicuous when integral drops below 0.35. In the present watershed, hypsometric integral was computed as 0.45. Since hypsometric integral value ranged between 0.35 to 0.60, the watershed is said to be in equilibrium stage and less susceptible to erosion.

6.0 SUSTAINABLE LAND USE PLANNING ON WATERSHED BASIS USING ADVANCE TOOLS ALONG WITH TRADITIONAL TECHNOLOGIES

Most of eastern India (Assam, West Bengal, Orissa, Jharkhand, eastern U. P and Chhartisgarh) is bestowed with good quality of natural resources basic to agriculture (soils, hydrology, topography etc.) and plenty of rainfall (1000 to 2000 mm), but poor management of these resources has lead to a situation where people of this 'resource rich' region are 'resource poor'. The land use and cropping systems in most of these regions are in-appropriate, exploitive and unscientifically planned, resulting in very low productivity and cropping intensity. In such a situation, site-specific, sustainable land use and cropping system plans based on potential and prospects of existing natural resources, especially soil hydro-physical properties and topography, may improve productivity and profitability.

With recent developments in technologies for determining a location in a field, storing and retrieving soil fertility data and monitoring yields, farming at an even finer scale is now possible. In this context, application of geospatial and precision technologies is important to the productivity, profitability and sustainability of agriculture as well as the protection of agricultural soils from depleting soil fertility. In particular the evolution of geographic information system (GIS), the global positioning system (GPS) and remote sensing (RS) technologies has enabled the collection and analysis of soil fertility parameters in watershed.

With the availability of high-resolution satellite data (IRS-ID, RESOURCESAT-1)and GIS analytical capabilities, variable parameters that can affect agricultural production like soil fertility variability along with physical parameters of soils, crop variability (e.g. density, height, nutrient stress, water stress, and chlorophyll), anomalous factors (e.g. weed, insect and disease infestation, wind), and variations in management practices (e.g. tillage, crop seeding rate, fertilizer and pesticide application, irrigation patterns and frequency) can be evaluated, and precision farming can be planned. Land specific cropping system will increase the cropping intensity and productivity of the watershed for predicting water retention.

Development of pedotransfer functions

Water retention and available water capacity are the main determining factors for growing second crops after rainy season rice in the region. These parameters may directly be determined using laboratory methods (by measuring soil water content over a range of matric pressure heads) or indirectly by relating water retention functions (pedo-transfer functions) to some easily measured soil physico-chemical parameters such as soil texture, oven-dry bulk density, organic carbon, cation exchange capacity etc. Estimation of soil hydraulic properties by pedotransfer functions can be an alternative to troublesome and expensive measurements.

In this study land specific cropping system was developed based on potential and prospects of existing soil hydro-physical properties, slope and land use/cover of a tribal dominated watershed and pedotransfer functions were developed to predict available water capacity.

Photo-10 : Collection of soil samples for laboratory analysis

The detailed methodology starting from data collection, analysis, action plan development and implementation of precision farming in the study watershed are given in four following sequential steps.

Step-1: Appraisal of spatial distribution of soil hydro-physical properties, topography and existing land use using remote sensing and GIS

For determining spatial soil hydro-physical properties, grid profile sampling (250m x 250m) was done in the watershed during field campaigns and spatial distribution of the same was performed throughout the watershed using GIS. (Flow Chart-3). Water retention at field capacity, wilting point and available water capacity was estimated by using pressure plate apparatus. The processed soil samples (< 2 mm size) were analyzed for their mechanical composition (soil texture analysis) following international pipette method. The spatial coverage of soil texture was prepared from IRS-P6 (LISS-IV) satellite imagery based on the basic elements of image characteristics like tone, texture, shape, size, pattern, association etc. along with extensive ground truth observations and textural analysis (International Pipette method). The organic carbon content of the soils was determined by following standard procedures. The organic carbon, soil water constants and soil texture, oven-dry bulk density, cation exchange capacity (CEC) and calcium carbonate of 0.15, 0.15-0.30, 0.30-0.60, 0.60-0.90 and 0.90-1.2 m soil depth of the watershed was used to develop pedotransfer function. Soil oven-dry bulk density was estimated on undisturbed samples collected with metal cores of 4.2 cm diameter and 5.8 cm height.

The slope map was prepared from contours of Survey of India Toposheet. The slope percentage was calculated as,

$$\frac{\text{Vertical drop}}{\text{Horizontal distance in between the contours}} \times 100$$

After preparing individual thematic maps of available water capacity, soil texture, organic carbon, land use, and slope from different sources, these were scanned and on-screen digitized using Raster to Vector (R2 V) software to form ARC INFO GIS coverage. The digitized map i.e. vector layer of different thematic coverage was then cleaned and checked for errors like dangles and pseudonodes etc. After removing errors, the layer was built for topology using commands in the PC ARC/INFO 4.0 GIS package. Each coverage was projected using 'Polyconic Projection' and 'Spheroid Everest' geoid system for area estimation of different classes for a particular theme Arc View (Version 3.8.1) GIS software was used for spatial analysis through query building tools after integrating all individual thematic coverage into composite land development unit (CLDU) map.

Spatial variability of different natural resources as studied using remote sensing and GIS alongwith traditional technologies are given below.

6.1 Existing land use categories of the watershed

The land use categories of the watershed were analyzed using IRS-P6 data, GPS survey and extensive ground truthing. The area under each land use classes are given in Table-2 and spatial distribution of same are given in Fig-5. Study revealed that altogether 12 classes of land use i.e. water body, upland rice, low land rice, fallow, residual hills, built-up area, reserve forest, plantations, degraded forests, ravine land, were existed in the watershed. The watershed is dominated by forest, grazing land, current fallow. Only 6% of the watershed area is covered by arable land with 78 ha and 49 ha area under upland and lowland agricultural field, respectively. Five small ponds were also available inside the watershed.

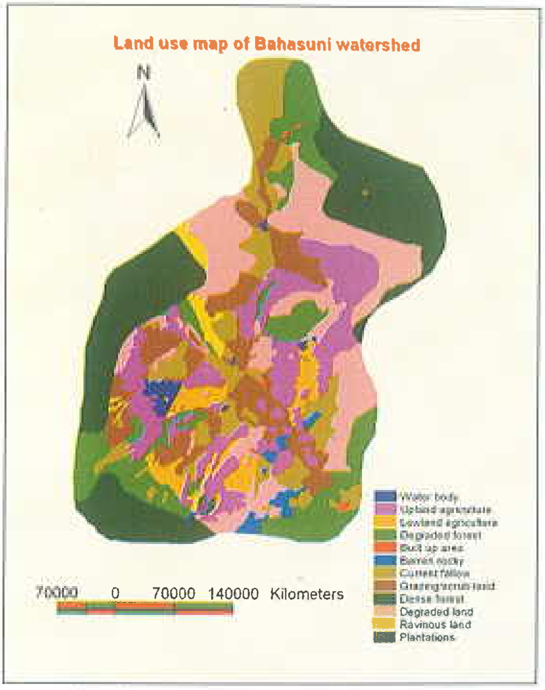


Fig-5 : Landuse map of the watershed derived from IR6-P_6 satellite data

6.2 Spatial variability of soil texture

The soil texture of 0 to 0.30 m depth was geo-spatially mapped and are presented in Fig. 6. The data (Table-4) indicate that sandy loam was the main soil texture at 0 to

0.30 m depth, covering an area of 628 ha, followed by sandy (298 ha) and sandy clay loam texture (185 ha). Coarse textured soils were mainly found in unbunded upland topography, whereas, the heavy textured soils occurred in lowland valley fill areas of the watershed. The clay soil was found in low-land rice areas which represents 25 ha area in the watershed, where residual soil moisture can be expected after harvest of rainy season rice. The area under different categories of soil texture was computed using ARC/INFO software and are presented in Table-4.

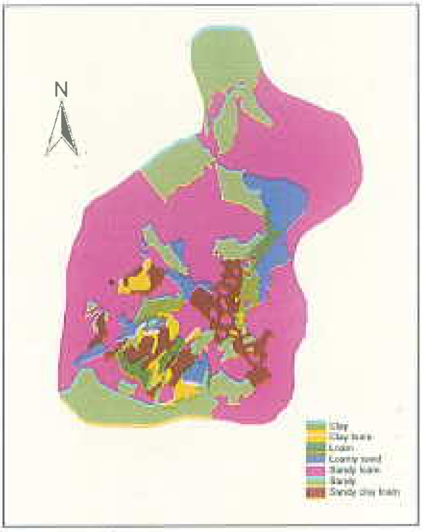


Fig-6 : Distribution of soil texture inside the watershed

Table-4: Variation of soil texture in the watershed:

Soil texture	Area (ha)	% of total area
Clay	25.1	1.95
Clay loam	37.2	2.903
Loam	25.6	1.999
Loamy sand	90.7	7.076
Sandy loam	628.1	55.301
Sandy	297.7	23.472
Sandy clay loam	184.5	7.589
Total	**1285**	**100.29**

6.3 Spatial distribution of available water capacity of soils

The available water capacity in different parts of watershed was grouped into 6 classes: 0.10-0.12, 0.12-0.14, 0.14-0.16, 0.16-0.18, 0.18-0.20 and > 0.20 m^3 m^{-3}. Spatial distribution of available water capacity is presented in Fig-7 and the areas under each soil texture category are given in Table-5. Study revealed that most of the area was dominated by water storage capacity of 0.14-0.16 m^3 m^{-3}, followed by category of 0.16-0.18 m^3/m^3 and 0.12-0.14 m^3 m^{-3}.

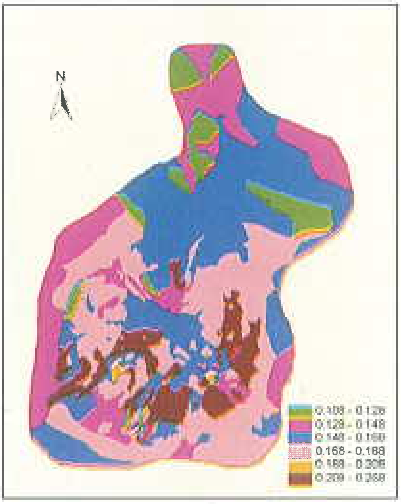


Fig-7 : Variation of available water capacity (m^3/m^3) within the watershed

Table-5: Variation of available water capacity (m^3/m^3) in the watershed:

Category	Area (ha)	% of total area
0.108-0.128	86.6	6.754
0.128-0.148	266.2	20.765
0.148-0.168	439.7	34.067
0.168-0.188	380.4	29.674
0.188-0.208	3.9	0.3079
0.208-0.268	111.8	8.7258
Total	**1285**	**100.2937**

6.4 Spatial distribution of soil organic carbon

Organic carbon content was low in different parts of watershed and was mainly responsible for low fertility status of soil. The geo-spatial distribution of the organic carbon (%) for upper soil profile (0 to 0.30 m) is depicted in Fig. 8. It ranged between 0.25 to 0.85 % in different parts of the watershed, indicating low organic carbon content status. Organic carbon was very low in the light textured (0.3 – 0.4%) upland and hence, monoculture rice based agriculture, should be avoided. Integrated nutrient management including inclusion of

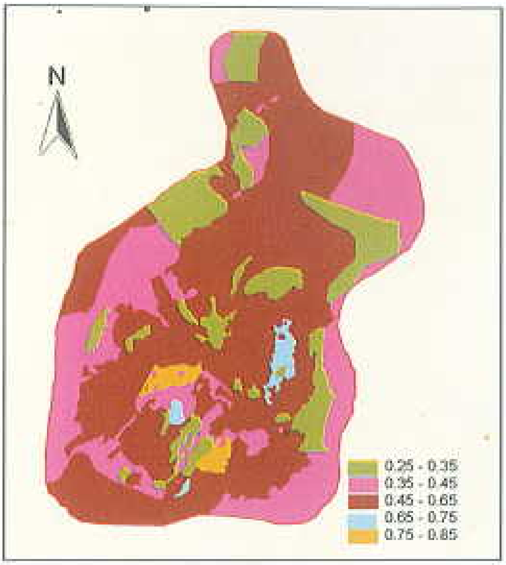


Fig 8 : Distribution of organic carbon (%) inside the watershed

Table-6: Variation of organic carbon (%) in the watershed:

Organic Carbon (%)	Area (ha)	% of total
0.25-0.35	193.3	15.07
0.35-0.45	348.6	26.96
0.45-0.65	586.3	45.73
0.65-0.75	138.2	10.77
0.75-0.85	20.3	1.58
Total	**1285**	**100**

legumes in the cropping system during rainy season and addition of organic matter @ 2 t/ha. are advocated to sustain the soil fertility of such soils with higher and assured net economic return. In medium to heavy textured soils with lowland topography, majority of the area was having organic carbon content of 0.65 to 0.75 %. The area under different organic matter status was classified in different parts of the watershed and are presented in Table-6.

6.5 Slope coverage

The slope map was prepared from contour map of Survey of Toposheet and are presented in Fig. 9. Study reveals that majority of slope was under very gentle slope (1-3%) with the area being 612 ha (Table-7). The gentle slope (3-5 %) was existed the area of 420 ha where soil was light to medium textured with unbunded to bunded field. Higher slope (> 35 %) was found in residual hills or degraded forest area.

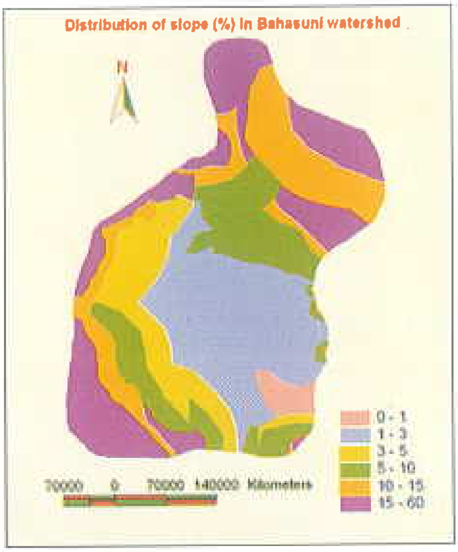


Fig-9 : Slope map of the watershed

Table-7: Category of slope in the watershed area

Slope (%)	Category	Area (ha)	% of total area
0-1	Nearly level	29.74	2.319
1-3	Very gentle	329.6	25.712
3-5	Gentle	159.9	12.24
5-10	Moderate	219.4	17.113
10-15	Moderate steep	233.9	18.250
15-40	Steep	316.1	24.657
Total		**1285**	**100**

6.6 Pedotransfer functions for prediction of soil water constants and available water capacity

Since direct measurement of water retention characteristics over large area are expensive, burdensome and tedious, in this investigation some of the easily measured soil physical and chemical properties were determined in rainfed rice area and pedotransfer functions were derived through regression equations to predict water

Table-8 : Correlation matrix of different soil hydro-physical parameters.

	Sand (%)	Silt (%)	Clay (%)	Bulk Density (Mg/m³)	Organic carbon (%)	Ca Co3 (%)	CEC (me/100g)	θ (F.C) (m³/m³)	θ (PWP) (m³/m³)	θ (AWC) (m³/m³)
Sand(%)	1									
Silt (%)	-0.83*	1								
Clay (%)	–0.46*	0.51*	1							
Bulk Density (Mg/m³)	0.63*	-0.60*	-0.62*	1						
Organic Carbon (%)	–0.12	0.18	-0.13	-0.53*	1					
CaCo3 (%)	-0.53*	0.49*	0.53*	-0.59*	0.11	1				
CEC (me/100g)	–0.68*	0.51*	0.85*	-0.61*	0.12	0.53*	1			
θ(F.C) ($m^3 m^{-3}$)	–0.80*	0.63*	0.83*	-0.59*	0.13	0.54*	0.76*	1		
θ(PWP) ($m^3 m^{-3}$)	–0.72*	0.59*	0.90*	-0.59*	0.14	0.56*	0.79*	0.89*	1	
θ(AWC) ($m^3 m^{-3}$)	–0.73*	0.75*	0.60*	-0.64*	0.196	0.58*	0.63*	0.90*	0.78*	1

* $P < 0.05$

(CEC, cation exchange capacity ; PWP, permanent wilting point ; FC, field capacity, AWC= available water capacity)

Table-9: Linear regressions (y = bx+a) for predicting soil water constants and available water.

y=Output (FC/PWP/AWC)

x= Inputs (soil physical & physico-chemical properties), a=constant, b=slope

a	b							R^2
	Sand (%)	Silt (%)	Clay (%)	Bulk Density (Mg/m^3)	Organic carbon (%)	Ca Co3 (%)	CEC (me/100g)	
				For field capacity (θ, m^3/m^3)				
1.51	-0.013	-0.103	-0.023	0.049	-0.003	0.019	0.012	0.81
-5.314	0.053	0.093	0.032	-0.113	-0.003	0.019	-	0.79
-9.314	0.111	0.115	0.119	-0.312	-0.063	-	-	0.87
-9.308	0.093	0.132	0.103	-0.192	-	-	-	0.78
-4.210	0.049	0.058	0.069	-	-	-	-	0.78
-0.708	-0.018	0.114	-	-	-	-	-	0.81
0.499	- 0.014	-	-	-	-	-	-	0.82
0.501	- 0.016	0.012	-	-	-	-	0.007	0.864
				For wilting point (θ, m^3/m^3)				
8.798	-0.009	-0.098	-0.094	0.049	-0.019	0.019	0.003	0.76
6.83	-0.063	-0.071	-0.0712	-0.023	-0.019	0.017	-	0.83
3.59	-0.035	-0.039	-0.039	-0.089	-0.023	-	-	0.83
5.31	-0.057	-0.049	0.047	-0.041	-	-	-	0.8
5.99	-0.069	-0.069	-0.049	-	-	-	-	0.88
0.48	-0.009	0.0065	-	-	-	-	-	0.73
0.39	- 0.006	-	-	-	-	-	-	0.76
0.38	- 0.004	-0.006	-	-	-	-	0.002	0.79
				For available water (θ, m^3/m^3)				
-7.91	0.084	0.089	0.083	0.0043	0.015	0.005	0.004	0.69
-11.41	0.129	0.132	0.129	-0.087	-0.017	0.006	-	0.71
-12.79	0.133	0.151	0.143	-0.119	-0.014	-	-	0.69
-13.89	0.157	0.149	-0.157	-0.141	-	-	-	0.63
-10.32	0.113	0.119	0.107	-	-	-	-	0.68
0.29	-0.013	0.004	-	-	-	-	-	0.64
0.31	- 0.012	-	-	-	-	-	-	0.63
0.13	- 0.003	0.004	-	-	-	-	0.003	0.60

content at field capacity, permanent wilting point and available water capacity. The correlation matrix for different hydro-physical properties viz., sand, silt, clay, bulk density, organic carbon, calcium carbonate and cation exchange capacity on water content at field capacity, wilting point and available water was computed for rainfed rice area of the watershed and results are presented in Table 8. Study revealed that moisture retention at field capacity, wilting point and available water in these soils was influenced by two sets of factors influencing in opposite direction with one set of factors viz, silt, clay, organic carbon, calcium carbonate and cation exchange capacity influencing positively, while sand and bulk density influencing negatively. The available water content was also influenced by the same set of factors and in a similar manner.

The results revealed that water content at field capacity and wilting point had a close relationship with clay (r = 0.83* and 0.90*, respectively) and cation exchange capacity (r = 0.76** and 0.79**, for field capacity and wilting point, respectively). These were significantly but negatively associated with sand and bulk density indicating that with increase in value of either sand or bulk density or with decrease in magnitude of clay or silt or cation exchange capacity, water content, q (m^3/m^3) of these soils at field capacity and wilting point, decreases. Coarse fraction (sand) had a close relationship with bulk density (r =0.63**), whereas negative association existed between coarse faction and finer fraction i.e. silt (r = 0.60**) and clay (r = 0.62**) of these soils. Available water showed positive correlation coefficient values with silt, clay, calcium carbonate and cation exchange capacity and negative values with sand and bulk density. Stepwise regression equations were developed to predict field capacity, wilting point and available water capacity from measured soil physico-chemical properties and is presented in Table 9.

6.7 Estimation of soil loss from different landuse systems of the watershed

The Universal Soil Loss Equation (USLE) was used for the assessment and prediction of soil erosion due to water runoff. The methodology for estimating the amount of soil loss (E) using USLE (Wischmeier and Smith, 1978), are:

$$E = R.K.L.S.C.P$$

Where, E is the mean annual soil loss (t ha^{-1} yr^{-1}), R is the rainfall erosivity factor, K is soil erodibility, L is slope length, S is the steepness of the slope, C is crop management and P is the erosion control practices. The USLE was analysed in ARC/INFO GIS environment as per the methodology mentioned in the Flowchart-3. Annual erosion index (R) was calculated by summing erosion values for all the months in a year (1970-2003).

Soil erodibility (K factor) is the function of physical characteristics of soil and its management, including both land and crop management. The erodibility index (K) for each soil structural group within the watershed was calculated using the emperical equation of Wischmeier and Smith (1978):

$$K= (2.1\ M^{1.4})\ 10^{-4}\ (12\text{-}a) + 3.25(b\text{-}2) + 2.5(c\text{-}3)$$

Where M= particle size parameter, (% silt + % very fine stand) or (100- % clay)

a=% organic matter.

b=soil structure class (1 for very fine granular; 2 for fine granular; 3 for medium to coarse granular; and 4 for blocky, platy or massive)

c=soil permeability class (1 for rapid; 2 for moderate to rapid; 3 for moderate; 4 for slow to moderate; 5 for slow; and 6 for very slow)

Three major soil structural groups were identified in the watershed *viz.*, fine granular, sub-blocky and medium course granular. The computed K factor for these three groups are 0.0893, 0.07072 and 0.07991, respectively.

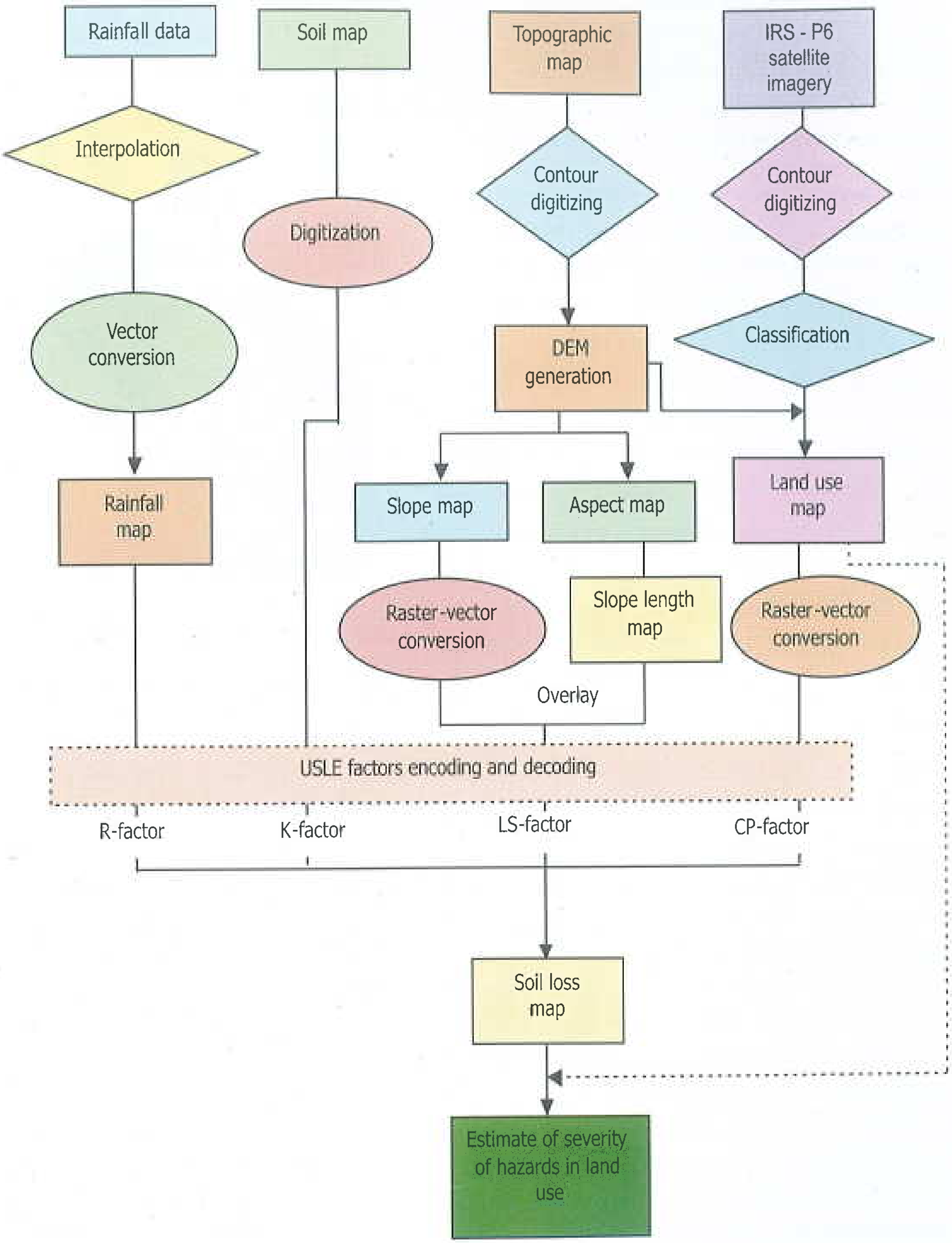
The slope length (L) for different types of land use was determined, using GIS tool along with information from the field survey. Data on aspect, land use and slope maps were overlaid to map the slope legth. L and S were treated as a combined factor to find the LS index. Altogether 15 contour lines of 20 m interval were identified and the highest being 480 m.

The C factor was taken as 0 to 1 depending upon the type of landuse system prevalent in the watershed. Taking the example of fallow degraded land, dense forest, crop land, the C factor was taken as 1.0, 0.001, 0.35, respectively.

Table-10: Soil erosion class within the watershed

Annual soil loss rate ($t\ ha^{-1}\ yr^{-1}$)	Severity of Class	Area (ha)	% of total
0-1	Very slight	181.1	14.1
1-5	Slight	376.1	29.3
5-10	Moderate	452.1	35.2
10-25	Severe	75.3	5.8
25-50	Moderately severe	117.3	9.1
50-100	Very severe	49.4	3.8
100-200	Extremely severe	28.6	2.1
200-400	Very severe	5.7	0.59
Total		**1285**	**100**

Flow chart-3: Steps for estimating soil erosion from different parts of the watershed



The annual soil loss in terms of t ha^{-1} $year^{-1}$ was estimated from different land use systems of the watershed as per the methodology described in flowchart-3. Based on category of annual soil loss, the watershed has been divided into 8 categories and are presented in Table 10. Spatial distribution of the same are depicted in Fig. 10. Generally upto soil loss rate of 10 t ha^{-1} $year^{-1}$ is no soil conservations are required for optimum land productivity.

In this watershed, the annual soil losses ranged from only 0-1 t ha^{-1} $year^{-1}$ to as much as 100-400 t ha^{-1} $year^{-1}$. Most of the area belongs to the moderate (35.8%) and slight category (29.3%) of erosion hazard severity. Some very slight erosion (14.13%) was observed mainly in rainfed lowland and upland paddy fields. Moderate erosion was mostly seen in up land areas. About 20% of the watershed had a severe to very severe erosion hazard. Such areas were found in ravenous and degraded land and foothills covered in dry forest. This sheds its leaves during the dry season, allowing rain to splash directly on the soil surface and detach soil particles.

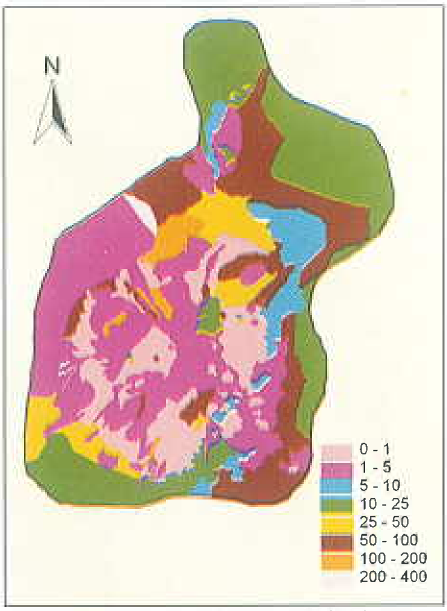


Fig-10 : Annual soil loss (mt/ha/yr) in Bahasuni watershed

Step- II: Development of action plan on sustainable soil use and cropping system in the watershed using remote sensing and GIS

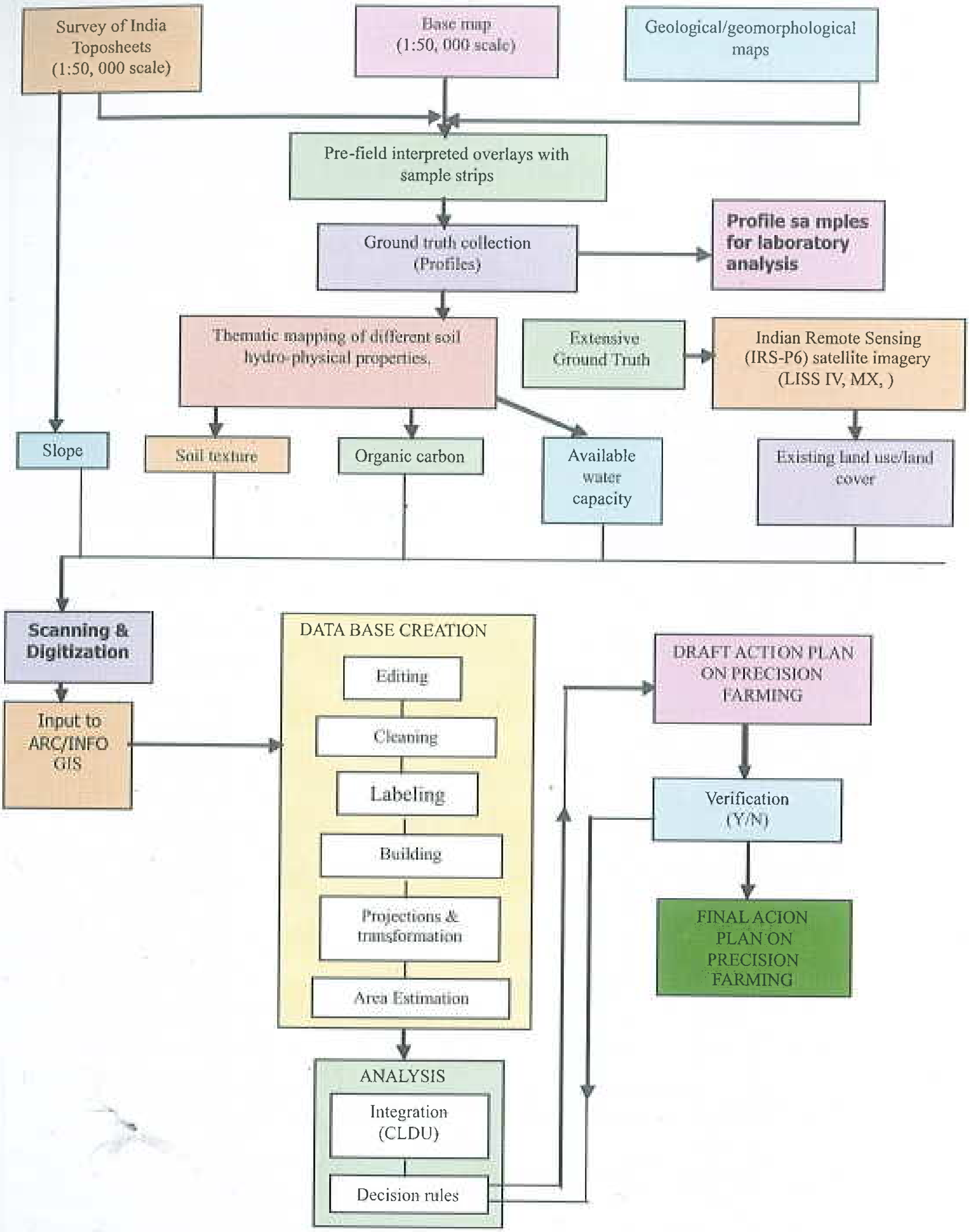
Decision rules were developed in GIS environment to develop sustainable alternative landuse plan based on potential and prospects of existing soil and natural resources. The existing soil properties along with slope and landuse pattern were entered in ARCINFO GIS environment to form Polygon Attribute Table (PAT). The criteria for developing alternative, sustainable landuse system are given in Table-11. The methodology for preparing digital database of soil hydro-physical properties and development of action plan are presented in Flowchart-4.

Based on potential and prospects of existing soil hydro-physical properties, land use / cover and slope, action plan on alternative sustainable land use and cropping system was developed using GIS tools. The area under alternative, sustainable land use systems are given in Table-12. The watershed area was dominated by forest and grazing land in different land topography and in some areas current fallow, residual hills or degraded forest were found. In the action plan map site specific land use planning

Table-11 Action plan development on alternative landuse system based on existing natural resources

Present land use system	Texture	Organic matter range (%)	Available water capacity range (m^3m^{-3})	Slope range (%)	Proposed land use system
Current fallow	Sandy	0.29	0.009-0.122	3 – 5 %, 5 – 10 %	Horticulture (cashew, lemon, mango)
Rainfed rice	Sandy loam	0.29-0.63	0.12-0.139	1 – 3 %, 3 – 5 %	Crop diversification (field crops)
Rainfed rice (bunded)	Sandy loam	0.42-0.45	0.14-0.16	1-3	Vegetable crops
Current fallow	Sandy loam	0.35-0.65	0.128-0.140	1 – 3 %	Crop diversification (field crops)
Rainfed rice (mono cropped)	Sandy loam to clay loam	0.45-0.48	0.130-0.141	1-3%	Double cropping with irrigation
Degraded forest	Sandy loam, loam	0.40-0.68	0.118-0.135	1 – 3 %, 3 – 5 %	Agroforestry
Degraded forest	Loam	0.62	0.111-0.123	3 – 5 %, 5 – 10 %	Hortipasture
Rubber plantation	Sandy loam	0.45	0.129-0.139	3 – 5 %	Plantation
Residual hills	Sandy, sand loam	0.29-0.45	0.106-0.145	3 – 5%	Forestry
Residual hills	Sandy loam	0.38-0.52	0.119-0.199	> 35	Forestry
Residual hills	Sandy loam	0.38-0.42	0.119-0.123	3 – 5 %	Agroforestry
Rice (100days) - fallow	Sandy loam	0.38-0.45	0.109-0.123	1 – 3 %, 3 – 5 %	Maize (90 days)-horsegram
Rice (100days) – fallow	Clay loam	0.65-0.68	0.220-0.257	3 – 5 %	Maize (90 days)-horsegram
Rice (125 days) - fallow	Loamy sand	0.52-0.68	0.194-0.239	1 – 3 %, 3 – 5 %	Rice (120 days)-linseed/safflower
Rice (125 days) - fallow	Clay loam	0.45-0.68	0.257-0.285	1 – 3 %, 3 – 5 %	Rice (120 days)-linseed/safflower
Rice (125 days) - fallow	Clay	0.70-0.75	0.257-0.306	0 – 1 %, 1 – 3 %	Rice (120 days)-linseed/safflower
Rice (145 days) - fallow	Clay loam	0.52-0.68	0.227-0.257	1 – 3 %	Rice (150 days)-pea/blackgram
Rice (145 days) - fallow	Sandy loam	0.50-0.52	0.173-0.195	3 – 5 %, 1 - 3 %	Rice (150 days)-pea/blackgram
Rural settlement	–	–	–	–	Rural settlement

Flow chart- 4: Flow chart of preparing digital database of soil hydro-physical properties



was suggested. In light textured araple, upland, rice was discouraged owing to its low and unstable productivity and crop diversification with low water requiring crops such as maize, groundnut, blackgram, cowpea, pigeonpea, were suggested through sole or intercropping. Double cropping on such soils was suggested through maize-horsegram/sesamum rotation. Idea of crop diversification in light textured upland rainfed rice soils is to emphasize that these crops can provide an assured income in soils with low water retention capacity and even with low rainfall because water requirement of these crops are less than that of rice.

Table-12 : Alternative land resources development of watershed (Proposed)

Alternative landuse	Proposed area (ha)	% of total
Agro-forestry	62.8	4.89
Crop diversification (Horticulture, field crops)	221.8	17.26
Forestry	91.4	7.11
Horti-pasture	225.7	17.56
Plantation crops	15.2	1.18
Rice-based double crops	54.1	4.21
Silvipasture	527.3	42.12
Soil conservation	34.5	2.68
Rural settlement	26.7	2.06
Water body	25.6	1.90
Total	**1285**	

On the other hand in the rainfed rice ecosystem with moderate available water capacity and medium textured soil, rice of 120 days was suggested during rainy season. The low water requiring crops like blackgram, linseed, safflower, were suggested during dry season (winter) utilizing carry-over residual soil moisture after harvesting of rice. In the rainfed medium and heavy textured rice land where irrigation facilities exist, double cropping with vegetables like gourd, bean, tomato, carrot, radish, potato, oilseeds like groundnut, sunflower, flowers like marigold, tuberose, were suggested to grow based on existing natural resources and socio-economic demand. In the lowland valley fill area with heavy textured soil and higher available water capacity rainfed rice based cropping system was suggested through rice (145 days)-pea/blackgram/lathyrus rotation. Agro-forestry, horti-pasture, horticultural plantation like cashew orchard, pomegranate, ber, plantation were also suggested to grow in upland degraded forest areas where arable crop cultivation was not possible. The grazing land can be converted into agro-forestry, or horti-pasture development depending upon the slope and available water capacity. The spatial distribution of developed action plan on attentive suggested landuse plan are given in Fig. 11.

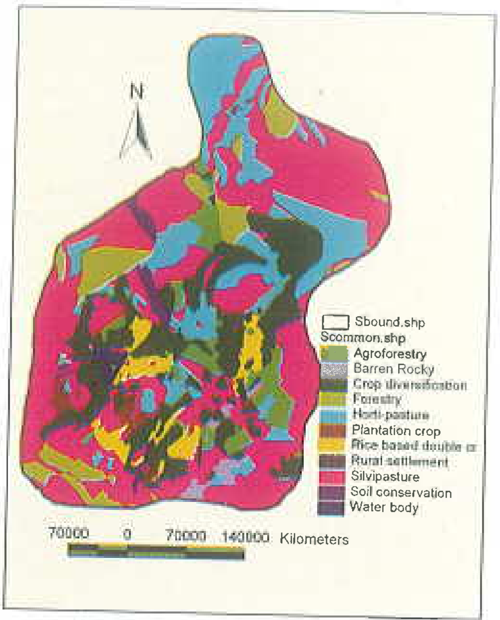


Fig. 11 - Spatial distribution of developed action plan on alternative land use

Step –III : Blending of modern and traditional technologies for water and soil conservation measures.

Realizing the importance of conservation of water and soils in the watershed, various soil and water conservation measures were adopted after indentifying areas in the action plan map using remote sensing and GIS. These water and soil conservation measures directed towards improved use and management of land and water resources in order to increase and stabilize agricultural production and check soil erosion.

(i) Summer tillage

The practice of summer tillage (off season tillage) with pre-monsoon showers (during May) was introduced in agricultural land to recharge the soil profile. It also facilitated to sow the crops immediately after onset of southwest monsoon. Off season tillage increases water content of soils and reduce runoff and also reduced pest and weed infestation. In the Bahasuni Watershed, Dhenkanal 4 ha area was demonstrated by performing summer tillage.

(ii) In-situ rain water conservation / performing ritge and furrow methods of sowing

In upland, water holding capacity is very low and water does not accumulate due to unbunded situation. To conserve the rainwater, ridge and furrow method of sowing was designed and crop diversification and rice substitution were recommended. Farmers were advised to make ridge and furrow at 20 days after sowing for upland nonpaddy profitable crops like maize, groundnut by performing earthing up operation. The furrow can be utilized for in-situ water conservation during light shower. The same furrow can be used for draining out of stagnant water during heavy downpour.

Photo-11 : Summer tillage operation inside the watershed

Photo-12 : Ridege and furrow methods of sowing of maize after substituting upland rice

(iii) Tapping of spring water from ridgeline of watershed for agricultural diversification

A cement tank cum under ground pipe line system at the cost Rs. 10,000/ha was developed to tap perennial spring water from hill top (ridge line of watershed) at

Photo-13 : Farmers are using spring water as irrigation through developed system

Photo-14 : Collection of spring water in to a cement tank from ridge line of watershed

Photo-15 : Farmers are cultivating carrot with spring water

Photo-16 : Cabbage cultivation with spring water

Majhisahi village, Dhenkanal. Now the farmers are growing high value crops like vegetables, flower (marigold) and short duration fruits (papaya, banana) with that water and earning 35,000 per hectare. Irrigated areas of the village were increased from 1.2 ha to 8.5 ha of that village comprises of 20 tribal families. Water from spring is available @ 30 liter per minute in lean periods to 170 liter per minutes during monsoon months.

(iv) Construction and renovation of runoff recycling pond and development of irrigation system by installing underground pipeline

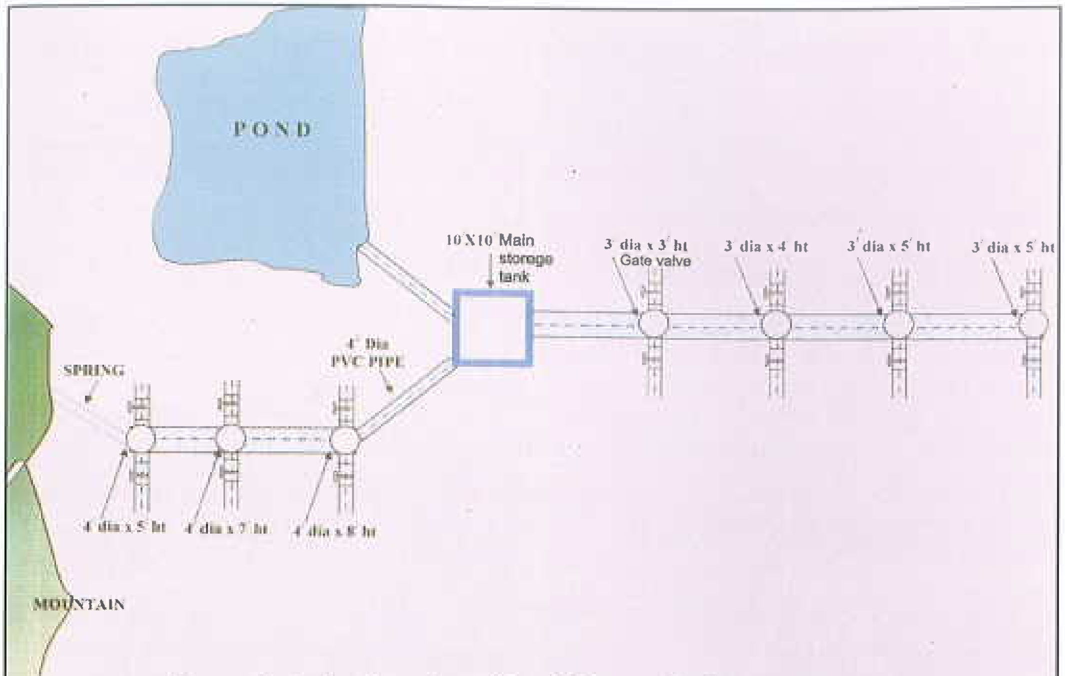
After construction and renovation of runoff recyling pond, 2.35 ha-m rainwater storage capacity was created in the tribal village Banasahi, Dhenkanal (Bahasuni watershed) and underground pipe line of 1.1 km (PVC pipe: 110 mm, 4kgf) with very low maintenance was installed for irrigating the crops through which water can flow using gravity. Due to installation of pipe line the conveyance efficiency was increased upto 95%. Due to creation of water resources and installation of pipeline irrigation system, the irrigated area of the Banasahi village increased from 2 ha to 18 ha in 2005-06. Net return from second crops ranged between Rs. 13,808 to 22,810 per hectare.

Photo-17 : Visit of Director, WTCER Dr. Ashwani Kumar to runoff recycling pond of watershed

Photo- 18 : Bumper sunflower with harvested rainwater

(v) Construction of cross bundh to collect runoff in watershed

A cross bund of 120 m length was constructed in Majhisahi village with top and bottom width of 3 m and 23 m, respectively (Photo-19). The runoff water was tapped from the hill with the help of this cross bundh. To strengthen this bundh, stone patching was done towards waterside (photo-20). Now, in dry season/ winter, farmers utilize this harvested water for irrigation. The cost of construction of croffbundh was Rs.35/m^3.



Layout of pipeline at majhisahi for spring water collection

Lay out of pipeline at banasahi for collecting irrigation from pond

Photo- 19 : Construction of cross bundh

Photo- 20 : Stone patching on the wall of cross bundh

(vi) Construction of bunds around the field

In the areas just below the pond, due to continuous seepage waterlogging condition arises. As a result, crops other than rice can not be grown in that land. Due to lack of proper bunding farmers are not able to grow even rice in that land. Field bund (dyke height 20 cm) was constructed around the field and now farmers are growing rice in that land. This bunding helps conservation of rainwater, maximization of infiltration, checking of soil erosion (photo-21).

(vii) Diversion channel

Diversion channel (single/double) were made parallel to contours to collect runoff water and to reduce soil erosion from the watershed. Catchment area above diversion channels were planted with vegetation to check erosion. The diversion channels were made with bottom width 0.45 and top width of 0.60 m (photo-22).

(viii) Earthen drainage channels to remove excess water

Generally, due to excess runoff in rainy season, water comes out of the field in haphazard way. Farmers also generally are not concerned about the systematic disposal of water through a particular outlet. As a result, field of adjacent farmers

Photo- 21 : Construction of bund around rice field

Photo- 22 : Diversion channel demonstrated is deteriorated. The earthen drainage channels were made to remove excess water from the fields of the watershed (photo-23).

(ix) Brick made irrigation channels for increased conveyance efficiency

A rectangular irrigation channel in Kadalipal watershed with 0.75 m height and 0.45 m bottom width was constructed in 220 m length to collect irrigation water from the water harvesting pond. The conveyance efficiency was increased up to 90% after this intervention (photo-24).

Photo- 23 : Earthen drainage channel

Photo- 24 : Brick made irrgation channel

(x) Loose bolder structure (LBS)

Small loose boulder structures were constructed at suitable places of the watershed, which will act as a barrier of soil and water retention. It reduced impact of runoff water and prevented formation of gully, because LBS reduced the velocity of water to a non-erosion level.

Photo- 25 : Losse bolder structure in the watershed to check runoff and soil loss

(xi) Conjunctive use of ground water and rainwater

Small dug wells (4 m diameter) in the corner of the crop field of the watershed was constructed where, water table is shallow. The water from the dug well is collected to provide supplemental irrigations during dry spells of kharif crop (mainly rice) and for growing rabi crops during winter/ dry season. From his small dugout pond, farmers lift the water through indigenous waterlifting devices like 'Tenda' to irrigate small command areas, mainly for growing vegetable crops (Photo 27).

Photo- 26 : *Construction of dug well in the corner of the field*

Photo- 27 : *Farmers are using 'Tenda' for irrigating rabi (winter) crops from the well*

Step-IV : Implementation of developed action plan on cropping systems in different rainfed arable land of the watershed.

Since the watershed was dominated by rainfed rice area where productivity and cropping intensity were low, the action plan on alternative cropping system prepared by using remote sensing and GIS was implemented at some locations in the rainfed rice area of the watershed.

(i) Crop diversification in light textured rice soils

The productivity from rainfed upland fluctuates drastically from year to year due to vagaries of southwest monsoon, occurrence of dry spells during growing season and existance of light textured with low water holding capacity and severe nutrient deficiencies, acidic soils. Traditionally farmers of the region grow rice in rainfed light textured upland simply to cover the fallow during rainy season, neither they get net positive return nor they expect any yield certainty from such land. For obtaining food, yield certainty and net positive economic return rather, they heavily depend on medium and lowland rainfed rice ecosystem which covers about 48% of total rice area of the region. Under this situation in upland crop diversification and rice substitution were suggested with low duty crops like maize, blackgram, cowpea, greengram, groundnut, pigeonpea etc. This may be the best option at the hands of farmers for drought mitigation and increased productivity of such land. Idea of crop diversification in rainfed upland rice area is to emphasize that these crops can provide assured and higher return even with low rainfall and in soils with low water holding capacity because water requirements of these crops are less than that of rice. Further, absence of flooding does broaden the scope of growing diversified crops in upland ecosystem.

To explore the possibility of crop diversification in rainfed light textured rice soils, groundnut (*Arachis hypogea* L.), pigeonpea (*Cajanas cajan* L.), blackgram (*Vigna mungo* L.), groundnut+pigeonpea (4:1), groundnut+blackgram (4:1) were tested in 4 ha of land comprising 10 farmers of the watershed considering one farmer as one replication. The crop rows were made across the slope and excess water disposed off through grass waterways to avoid breaching of ridges. Excess runoff was collected in farm pond for supplemental irrigation during dry spells. Rice of 90 days duration (cv. Vandana) was grown as control. Double cropping was also implemented through maize-horsegram/ sesamum rotation.

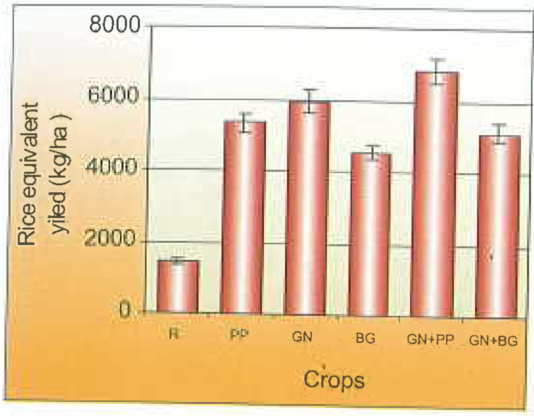
Photo-28 : Crop diversification with low water requiring crops

Photo-29 : Director, WTCER, Dr. Ashwani Kumar visits crop diversification site

Photo-30 : Introduction of elephant foot (Amorphophallus) in upland of watershed

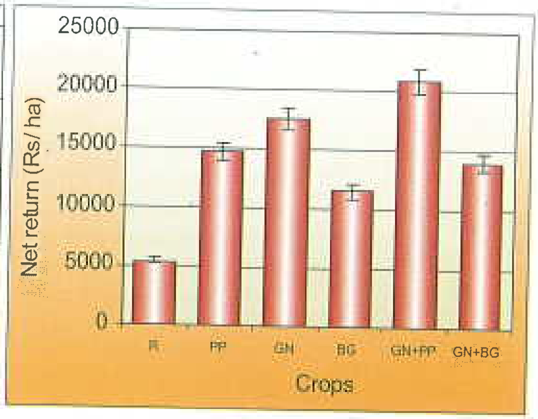
Photo-31 : Pigeonpea was grown as intercropping with rice at Banasahi, Dhenkanal

Study revealed that through crop diversification in light textured rice soils, productivity and profitability were enhanced by 3-4 times than that of sole rice. Productivity of different crops/crop combinations grown on light textured soils was converted into rice equivalent yield for better comparison. Study revealed that (average of two years' of pooled data (Fig. 12 a), highest rice equivalent yield (6839 kg ha^{-1}) was obtained from groundnut+pigeonpea followed by sole groundnut (5940 kg ha^{-1}) and sole pigeonpea (5315 kg ha^{-1}) while sole rice produced only 1930 kg/ha. Higher net economic return per annum was also obtained from groundnut+pigeonpea followed by sole groundnut and sole pigeonpea (Fig. 12b). From double crops in rainfed upland 7500 kgha^{-1} equivlent yield was produced rice through maize (cob) horsegram cropping system.



(Pooled data of 2004-05 & 2005-06)

Fig-12(a) : Rice equivalent yield from diversified crops



(Pooled data of 2004-05 & 2005-06)

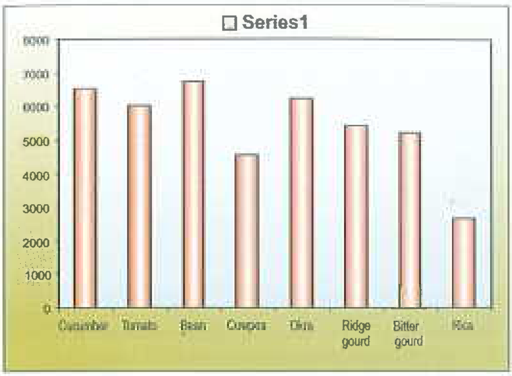
Fig-12(b) : Net return from rice/ substituted crops

(ii) Crop diversification with vegetables in heavy textured rainfed upland soils during kharif (rainy season)

After substituting rice in rainfed bunded upland, profitable vegetable crops like cucumber, tomato, bean, cowpea, okra, ridge gourd, bitter gourd were grown. The package of practices followed for growing vegetable crops are given in Table 17(b). Highest rice equivalent (6702 kgha^{-1}) was obtained from bean followed by cucumber (6500 kgha^{-1}) and okra (6215 kgha^{-1}). Whereas rice yield of only 2650 kgha^{-1} was obtained from the same land. Highest net return was obtained from bean (Rs.20050 ha^{-1}) followed by cucumber (Rs.19000 ha^{-1}) and okra (Rs.18860/ha). On the other hand, sole rice yielded net return of Rs.4600 ha^{-1}. Rainfed vegetable cultivation after subsituting rice in bunded upland was found highly profitable and sustainable [Fig. 13 (a) and 13 (b)].

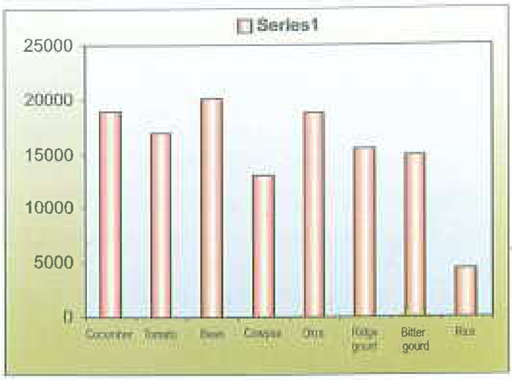
(iii) Cropping systems in rainfed medium textured rainfed rice ecosystem

As per the action plan map in medium textured soils, instead of local varieties,



(Pooled data of 2004-05 & 2005-06)

Fig-13(a) : Rice equivalent yield of diversified vegetable crops in upland



(Pooled data of 2004-05 & 2005-06)

Fig-13(b) : Net return from diversified vegetable crops in rainfed upland

Photo-32 : Spine gourd is a profitable crop in rainfed upland

Photo-33 : Crop diversification with cucumber crop

Photo-34 : Bumper growth of Okra in upland

Photo-35 : Bean, a highly profitable crop in rainfed upland

improved rice variety 'Lalat' of 120 days duration was grown in rainy season with improved management. Seedlings of 3 weeks age were transplanted with 15x10 cm spacing and at 3-5 cm depth. During winter season (dry season, November to March), low water requiring crop safflower (*Carthamous tinctorious*

L. cv. 'Bhima'), linseed (*Linum usitattisimum* cv. 'Sekhar') and greengram (*Vigna auress* L.) were advocated and tested in farmers' field of 2 ha of land utilizing carry-over residual soil moisture and winter rainfall after rice.

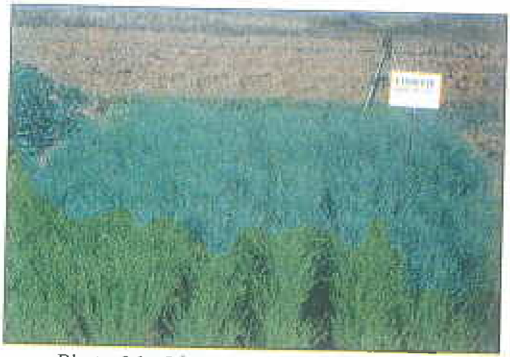
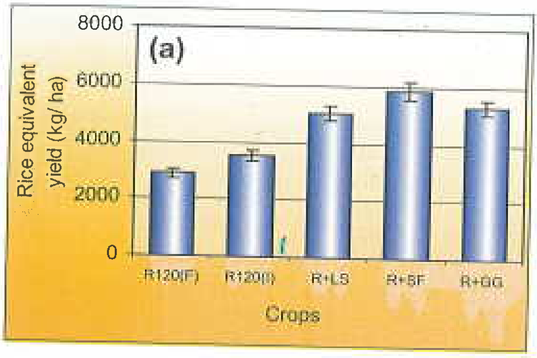


Photo-36 : Linseed after rice in rainfed medium land

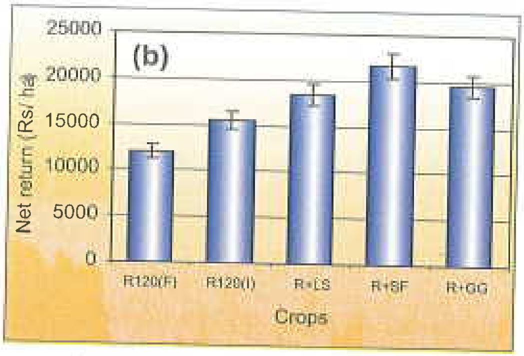
The productivity of double crops (rice-linseed/safflower/greengram) was converted into rice equivalent yield and compared with that of sole rice to visualize the enhancement of yield after introduction of new cropping system. Sole rice of 120 days duration was grown as a control under both improved and farmers' management practices. Rice equivalent yield of 5028, 5861 and 5307 $kgha^{-1}$ were obtained from rice-linseed, rice-safflower and rice-greengram, respectively (from 2004-05 and 2005-06 years' pooled data), whereas sole rice produced only 3540 and 2870 $kgha^{-1}$ yield under improved and farmers' management, respectively (Fig. 14a). Study revealed that productivity, cropping intensity and profitability of medium textured rainfed rice area can be improved through crop management technologies utilizing residual soil moisture after rice (Fig. 14b).



(Pooled data of 2004-05 & 2005-06)

Fig-14(a) : Rice equivalent yield of different cropping systems in medium land

SF = Safflower, LS = Linseed, GG = Greengram



(Pooled data of 2004-05 & 2005-06)

Fig-14(b) : Net return of different cropping systems in rainfed medium land

(iv) Cropping systems in heavy textured rice soils (lowland)

Under the rainfed rice area with higher available water capacity and heavy textured soil, improved rice variety 'Gayatri' of 150 days duration was suggested and implemented in 5 ha of such land during rainy season involving 15 farmers of the watershed. On the same land, blackgram (*Vigna mungo* L.) pea (*Pisum* *sativum* L.) and gram (*Cicer arietinum* L.) were grown during dry season utilizing carry-over residual soil moisture after harvest of rainy season rice.

The productivity of double crops (rice-pea / blackgram / gram) was converted into rice equivalent yield for comparison purpose. Rice equivalent yields of 6458, 6378 and 5089 kgha^{-1} were obtained from rice-pea, rice-blackgram and rice-gram, respectively (from two years' pooled data), whereas sole rice produced 3240 and 4050 kgha^{-1} yield with farmers' and improved management respectively (Fig. 15a). The net returns increased in the order : sole rice (farmers management), sole rice (improved management), rice-gram, rice-blackgram and rice-pea (Fig. 15b).

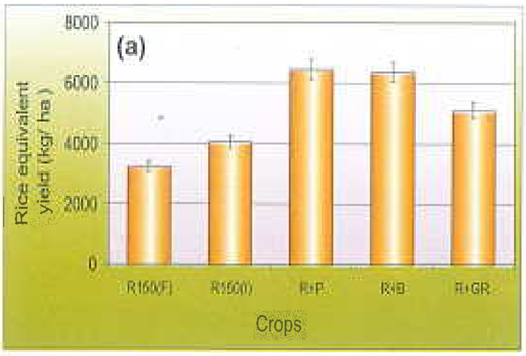


Fig-15(a) : Rice equivalent yield of different cropping systems in rainfed lowland

R = Rice, P = Pea, B = Blackgram, GR = Gram

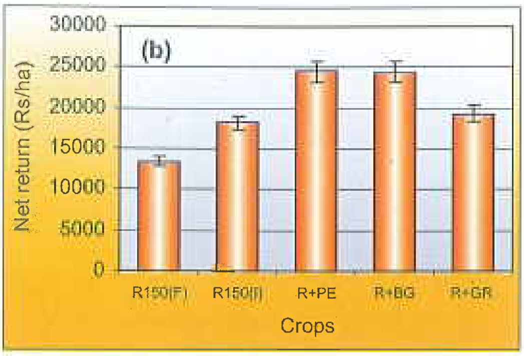


Fig-15(b) : Net return of different cropping systems in rainfed lowland

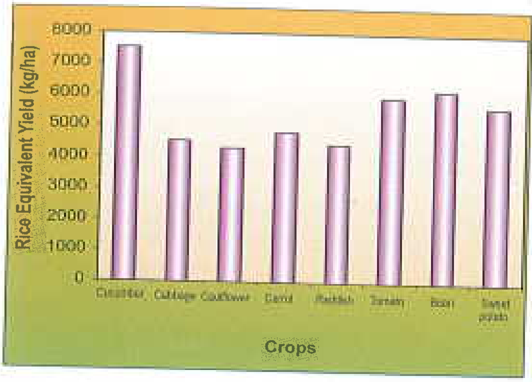
(v) Double cropping with irrigation from created water resources

Double cropping was introduced in the watershed areas nearby waterbody and where irrigation facilities exist. After rice, diversified crops like bean, winter

Photo37 : Rainwater harvesting in the village pond

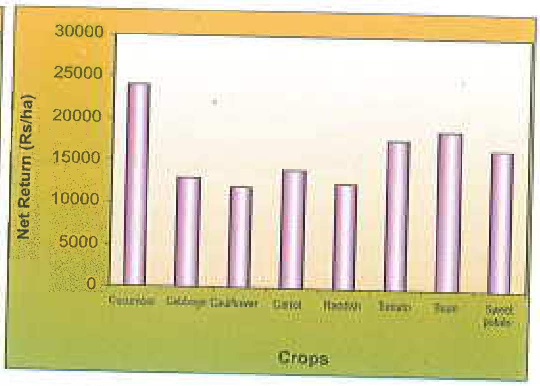
Photo-38 : Growing of sunflower with 3 supplemental irrigation maize, tomato, sun flower, cucumber, pumpkin, watermelon, radish, sweet potato were grown with the help of irrigation water from created water resources.

In the study watershed most of rainwater goes as runoff and it is not accessed and utilized for productive purpose. After harvesting excess runoff water in tank/ pond, it was recycled for growing vegetable crops. The winter vegetable crops like cucumber, cabbage, cauliflower, carrot, radish, tomato, bean, sweet potato were grown as per standard package of practices. Four supplemental irrigations were applied to cucumber, cabbage, cauliflower, carrot, tomato and three irrigation were givven to radish, bean and sweet potato. (60mm irrigation was applied with each irrigation). Study revelated that with four irrigations, the highest rice equivalent yield of 8527 kgha^{-1} was obtained from cucumber followed by bean (7220 kgha^{-1}) and tomato (6962 kgha^{-1}). Highest net return of Rs.24078 ha^{-1} was achived from cucumber followed by from bean (Rs.18875 ha^{-1}) and tomato (Rs.17750 ha^{-1}). [Fig.16(a) and 16 (b)] during winter season.



(Pooled data of 2004-05 & 2005-06)

Fig-16(a) : Rice equivalent yield (kgha^{-1}) from diversified crops with supplemental irrigation



(Pooled data of 2004-05 & 2005-06)

Fig-16(b) : Net return (Rsha^{-1}) from diversified vegetable crops with supplemental irrigation

Photo-39 : Bumper tomato crop with 4 irrigations

Photo-40 : Bean provides quick return with 3 supplemental irrigations

Photo-41 : Profitable sweet potato cultivater after rice which requires less water

Photo-42 : Growing of cabbage with 4 supplemental irrigations

Other agronomic interventions

(1) Maintenance of sowing attributes and selection of crops/ varieties

Selection of crops for diversification and rice substitution in rainfed upland areas is of paramount importance for yield and rainwater utilization. The crops must be of short duration; low duty or deep rooted which can extract soil moisture from deeper soil layers during dry spell. The diversified upland field crops were introduced are given in Table 13(a) . The advance sowing attributes like seed treatment, line sowing, proper spacing, fertilizer dose were also followed to demonstrate in the watershed.

Table 13 (a) : Package of practices adopted for crop diversification in rainfed upland rice area.

Crop	Varieties	Spacing (cmxcm)	Seed rate (Kg ha^{-1})	Fertilizer dose (N:P:K)
Maiza	Navjyot	60×30	15	80:40:40
Groundnut	Smruti	30×10	80 (Kemel)	20:40:40+250kg zypsum ha^{-1}
Pigeonpea	UPAS-120	60-75× 20-25	15-20	20:40:40
Blackgram	T-9	30×15	20	20:40:0
Greengram	K-851	30×10	25	20:40:0
Horsegram	Madhu	25×10	20	20:40:0
Sesarmun	Gujrat-1	20×10	5	30:15:15
Rice	Vandarn	20×5	80	40:20:20 + 2tha^{-1} FYM

In the *kharif* and *rabi* season several vegetable crops like cucumber, pumpkin, carrot, sweet potato, tapioca, bean were introduced. Package of growing these crops are given in Table 13(b).

Table 13 (b) : Package of practices for growing vegetable crops during *kharif* and *rabi* season

Crop	Suitable varieties	Seed rate (kg/ha)	Spacing (cm x cm)	Manure requirement (t/ha)	Fertilizer dose (kg/ha)		
					N	P	K
			Kharif				
Okra	Utkal Gourav, Arka Anamika,	10.0	45x45	20	80	40	40
Bean	Arka Vijay	8-10	120x120	12	20	50	50
Cowpea	Pusa Barsati	10-12	30x60	12	20	60	50
Cucumber	Sabitri	2-2.5	150x150	12-15	40-50	35	20
Bitter gourd	Pusa Domausmi, Arka harit	5	120x120	12-15	40-50	35	20
Pumpkin	Guamala, Baidabati	6-7	200x200	12-15	40-50	35	20
Ridge gourd	Pusa Nasdar	5	100x100	12-15	40-50	35	20
			Rabi				
Okra	Utkal Gourav,	10.0	45x45	20	80	40	40
Bean	Arka Vijay	8-10	120x120	12	20	50	50
Chilli	NP46-A,	1.5	45x60	20	100	60	50
Cucumber	Sabitri	2-2.5	150x150	12-15	40-50	35	20
Tomato	BT-2, BT-10	0.5	45x60	20	75	40	40
Radish	Pusa Chetki	8-10	30-45 x 15-30	12	20	50	50
Cauliflower (late)	Pusa Snowball-16	0.38 -0.40	45x60	50	220	85	270
Cabbage	Golden Acre	0.5	45x60	50	220	100	220
Pea (late)	Rachna	80-90	25x20	20	55	20	40
Watermelon	Sugarbaby,	2-2.5	400x100	30-35	75-80	50	50
Carrot	Pusa Meghali	5-6	15x10	30	40	22.5	125
Bitter gourd	Pusa Domausmi, Arka harit	5	120x120	12-15	40-50	35	20
Pumpkin	Guamala, Baidabati	6-7	200x200	12-15	40-50	35	20

(2) Intercropping/ mixed cropping:

To obtain more benefit from land, intercropping/mixed cropping was introduced in the watershed. The leguminous crop (pigeonpea) was intercropped with non-leguminous crops (rice) to restore fertility status of soils. The low water requiring crops were intercropped with moderate water requiring crops, which had different growth habits (maize & cowpea).

Photo-43 : Maize + cowpea intercropping in upland

Photo-44 : Rice + pigempea intercropping

(3) Introduction of *kharif* and *rabi* vegetables with wooden support:

To avoid moist soils or stagnant water during heavy downpour, wooden support was provided to grow crops like cowpea, ridge gourd, bitter gourd, spine gourd, bean etc. The fruit quality was also improved with that system.

Photo-45 : Growing of cowpea with wooden support

Photo 46 : Growing of bilter ground with wooden support

(4) Integrated weed management

In the upland, rice substituted crop, proper weed management must be accomplished. Timely weed control increases the yield. Pre-emergence application of Simazine/ Altrazin @ 1 kg ha^{-1} for maize. Pendamethaline @ 1 kg ha^{-1} in case of groundnut, Thiobencarb @ 1 kg ha $^{-1}$ for pigeonpea, Butachlore @ 1 kg ha $^{-1}$ for rice followed by one hand weeding at 25-30 days after sowing to control the weed.

(5) Integrated pest management

Farmers were trained to apply different botanical pesticides like Neem cake, Neem seed powder with inorganic chemicals for pest control in vegetables. As apart of organic farming tomato and merigold were grown as intercropping. It has been found that due to presence of chemicals in merigold, pest infestation in tomato was reduced.

Photo-47 : Integrated pest management in vegetables.

Photo-48 : Tamato + marigold crop as intercrop

(6) Introduction of high yielding varieties of rice:

Tribal farmers of the watershed were cultivating mainly local rice varieties. We have collected high yielding breeder seeds of rice from CRRI, Cuttack for different land topography like Vandana and Anjali for upland, Lalat and Naveen for medium land (120 days), CR-1009, CR-1018 for lowland (145 days) and introduced in the watershed for higher yield.

(C) Horticultural intervention

In the watershed, 400 banana plants , 1000 cashewnut plants, 100 *Acacia mengium*, 100

Photo-49 : Bumpercrop of banana in the watershed with harvested rainwater

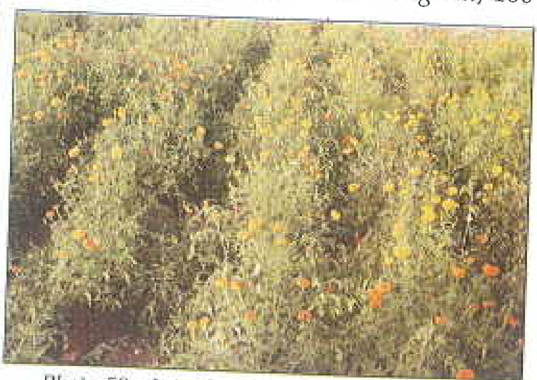


Photo-50 : Introduced marigold crop provides higher income to farmers drumstick were planted. Besides, this 50 rubber plants were also introduced in the watershed with the help of Samajik Seba Sadan (NGO) and Central Rubber Board, Dhenkanal. The mango, papaya, turmeric, ginger, lemon were also supplied to grow to the backyards of farmers. In the watershed marigold was found to grow suitable in upland areas and crop was grown in 1 ha area with the help of irrigation from created water resources inside the watershed (Photo 50).

(D) Interventions for enhancing water productivity of runoff recycling pond

After studying water balance of pond, to enhance the water productivity, the water was used as both consumptive and non consumptive ways. The low water requirement vegetables, oilseeds, pulses were grown in the field with supplemental irrigation, spices like ginger, turmeric were grown in shaded area, short term fruit like banana on pond bund and pisciculture with the remaining water of the pond. The fishes like catla, rohu and mrigal were reared in the ratio of 30%, 40%, 30% with seed rate @ 5500/ha (fry of 15-20 mm size) of the pond, where water remains 4-5 feet deep upto May.

7.0 DEVELOPMENT OF SOFTWARE FOR CROP WATER BALANCE STUDY IN THE WATERSHED

The amount of water supplied to a crop is dependent on several factors. These factors constitute the various components of the water balance equation. The root zone is represented by means of a container in which the water content may fluctuate from time to time. To express the water content at root zone it makes the adding and subtracting of losses and gains directly as the various parameters of the soil water budget are usually expressed in terms of profile stored water depth, rainfall, irrigation and capillary rise of ground water towards the root zone add water to the root zone and soil evaporation, crop transpiration (combined known as evapotranspiration), runoff and percolation losses remove water from the root zone. So the simple form of water balance equation can be written as:

$$\Delta R = (Peff + V_z + I + G_c)-(ETo + DP + RO)$$

Vz: water stored in the deeper layer of thickness (z) explored by the root after equivalent root growth or depletion(mm),

I : irrigation applied (mm), Peff: effective rainfall (mm)

Gc : ground water contribution (flux) (mm),

ETo : actual evapotranspiration (mm)

DP : deep percolation losses (mm),

RO : runoff (mm)

Development of software for computing soil water balance

In recent times, simulation modeling has become one of the most powerful tools for analyzing the interaction in the soil-plant-atmosphere system. With the advent of computer use in agriculture science, the importance of crop growth modeling using several meteorological, soil and plant physiological parameters has increased. Most of the crop yield simulation models, GROWIT (1983), SPAW (1984), O'leary (1985), Campbell and Diaz (1988), SOYGRO (1988), CERES-maize (1989), CERES-Wheat (1989) etc., use the information generated in a water balance model to estimate crop dry matter or yield.

The software package "**WATERBAL**" was developed by using **Visual Basic 6.0** as programming language for user interface and **MS Access** as backend for storing of data in the database. This software consists of three modules:

(A) Input Module: This is the first module and it consists of four sub-modules such as:

(i) *Daily climate data:* (temperature, humidity, sunshine hour and windspeed)

(ii) *Rainfall:* daily rainfall

(iii) *Crop data:* (crop name, date of sowing, maximum rooting depth, crop duration, duration of four development stages)

(iv) *Soil data* (number of soil layer, depth of each layer, bulk density, field capacity, permanent wilting point, soil moisture content with different days after sowing)

(B) Calculation Methods: This module consists of 4 sub-modules such as:

(i) ETo estimation method (Using Penman-Monteith method)

(ii) Runoff calculation (land use/cover, treatment/ practice, state, hydrological soil class)

(iii) Effective rainfall (fixed percentage, dependable rain, empirical formula and USDA soil conservation service method)

(iv) Irrigation scheduling

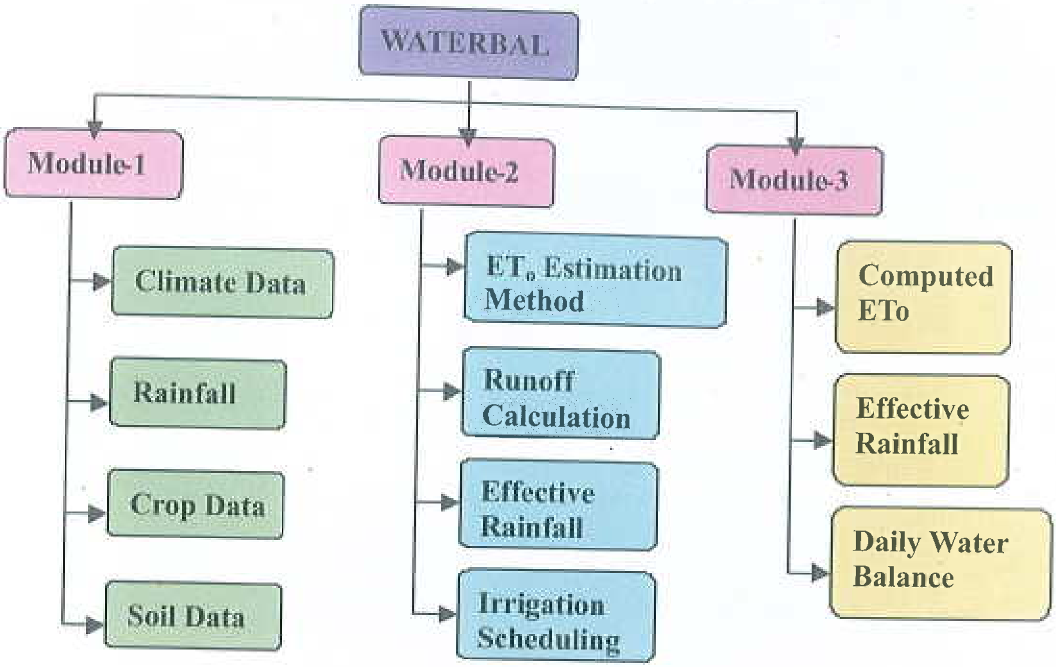
(C) Output Module: This module consists of three sub-modules such as

(i) ETo for specific period

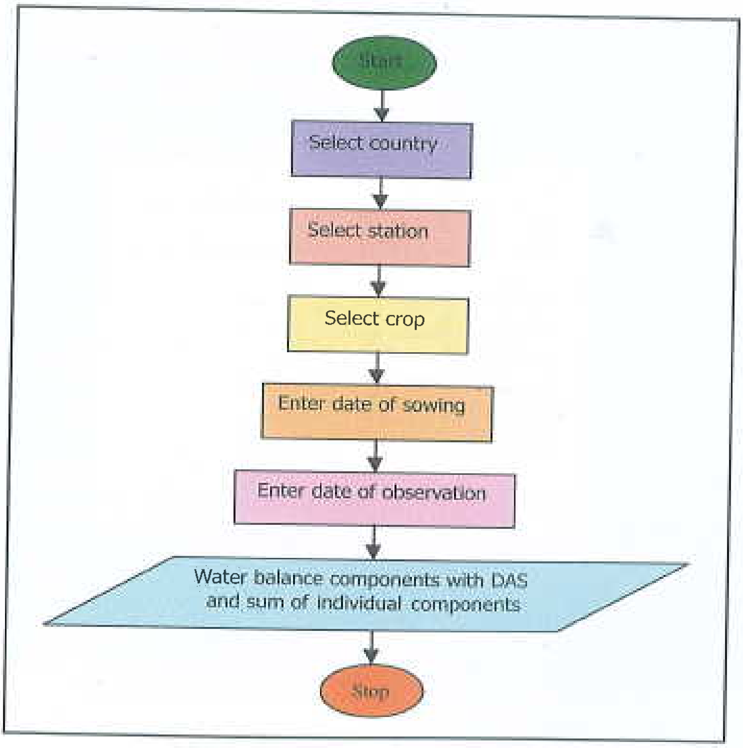
(ii) Effective rainfall with actual rainfall for a specific method

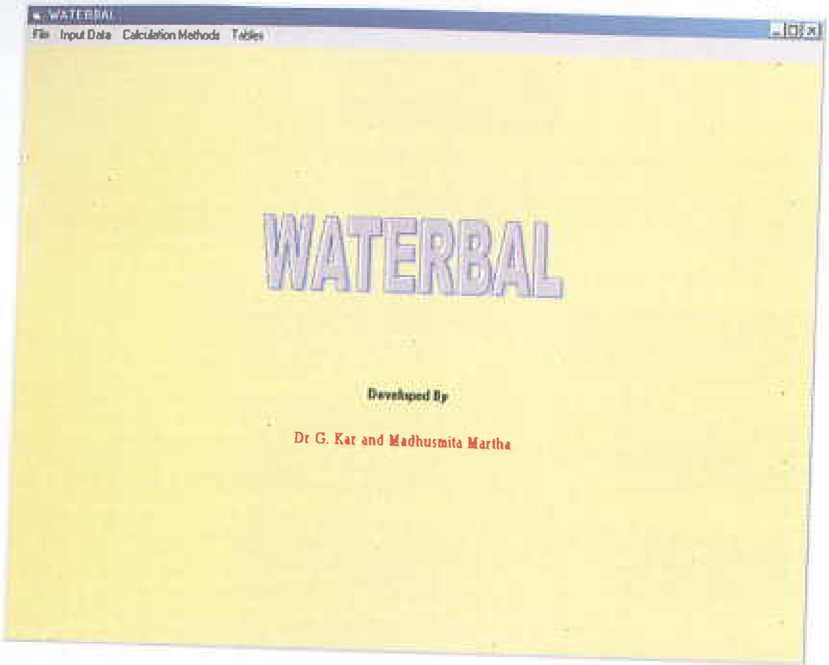
(iii) Daily water balance from the date of sowing to date of last observation with all the water balance components.

Block diagram of the developed software

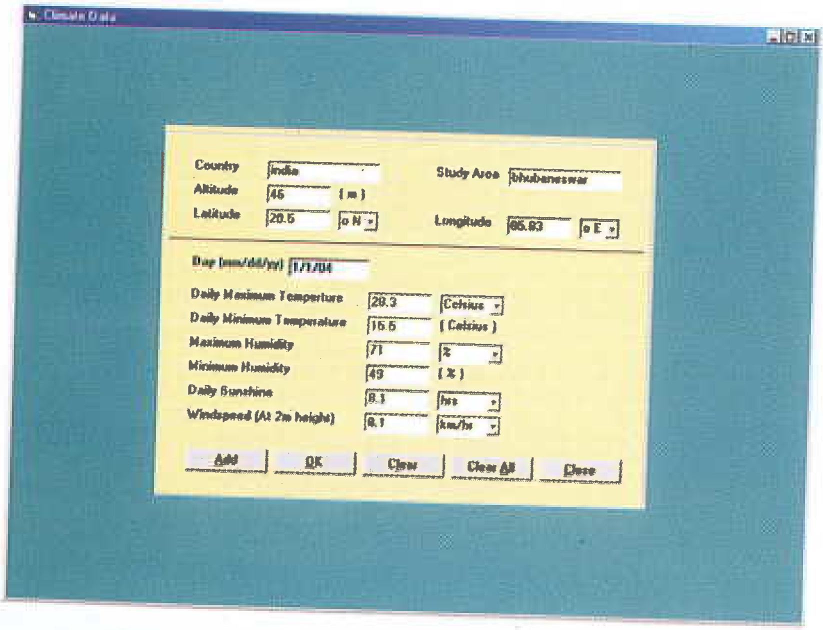


Flowchart of the computing all the components of water balance

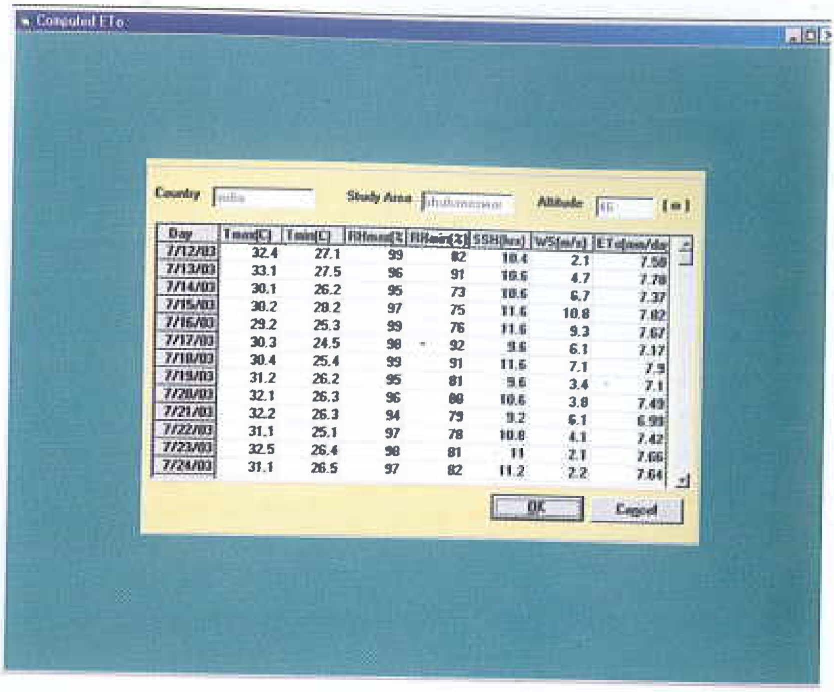




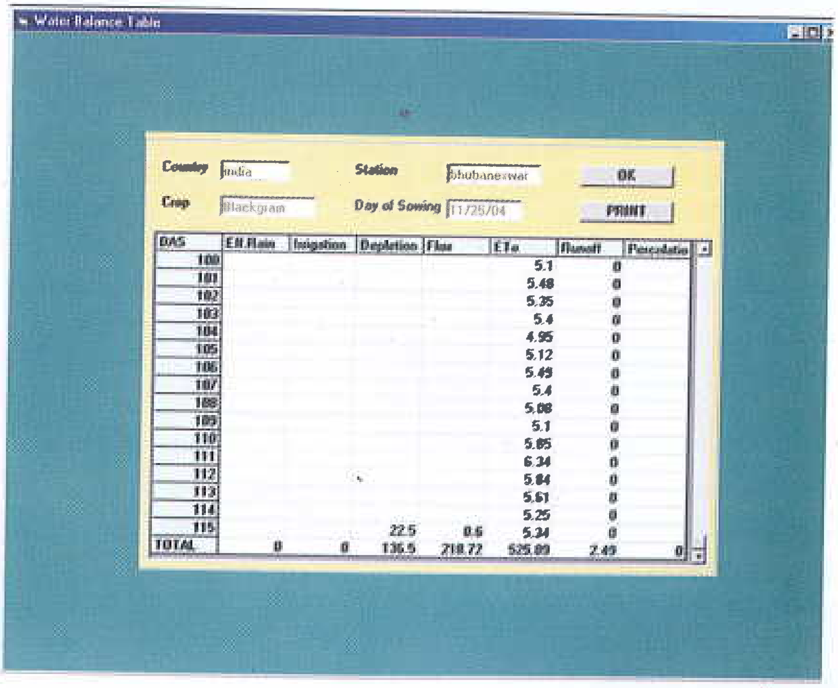
Front Page of the Software



Climate data base input in the software



Computation of ETo data base



Computation of water balance components

8.0 TECHNOLOGY DISSEMINATION AND CAPACITY BUILDING PROGRAMME ORGANIZED FOR WATERSHED MANAGEMENT

8.1 Tranning & field day organised

- A training programme on "Agricultural diversification options for drought mitigation" was organized on 11-12th October, 2004 where 100 tribal farmers and 12 NGOs were participated. In that training programme, different drought mitigation strategies were discussed. The resources persons for taining were eminent scientists from local ICAR institutes, agricultural universities, different departments of state government of Orissa .Some success stories were also briefed in that training programme. A training manual entitled " Drought mitigation through agricultural diversification in eastern India" was also prepared on that occasion and distributed to participants. Dr. G.Kar, Principal investigater of the project was the course co-ordinator for the training course.

Photo-51 (a & b) : Training programme on "Agricultura diversification options for drought mitigation in rainfed rice area"

- A national level training course on "Blending of modern and traditional technologies for watershed management" was organized at WTCER, Bhubaneswar from 5-11th September, 2005. This training was attended by 30 participants (scentists/ engineers/ planners) from different parts of the country. The training was designed to create awareness about usefulness of modern tools like remote sensing, Global Positioning System (GPS), Geographic Information System (GIS) by scientists, officers, planners, extension workers who are working at grassroot level for watershed management. A training manual on "Blending of modern and traditional technologies for watershed management " was also published on that occasion. Dr. G. Kar, principal investigator of the project was the course director of that training course.

Photo-52 : Scientists, Officers, extension officials from different parts of the country participated the training programme, on "Blending of modern and traditional technologies for watershed management'

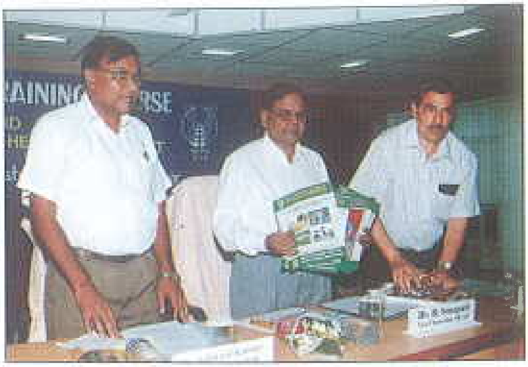


Photo-53 : Vice Chancellor of OUAT, Bhubaneswar Dr.B. Senapati releasing training manual in the inaugural programme of the training

Blend old & new tech to tackle water crisis

Changing crops answer to dry spells

EXPRESS NEWS SERVICE

Bhubaneswar, Sept 5: A blend of traditional and modern watershed technologies along with crop diversification can be the answer to the problems caused by extreme weather conditions for farmers, water technology experts feel.

With the threat of a drought looming large over 10 districts in the State, the suggestions seem to have come at an appropriate time.

Though major portions of Eastern India receive an average rainfall ranging from 1,000 mm to 2,000 mm, the region has one of the lowest farm productivity, said experts here on Monday.

At a meet organised by Water Technology Centre Eastern Region (WTCER), a body under Indian Council of Agricultural Research (ICAR), the experts deliberated on "Blending modern and traditional technologies for watershed management" to tackle dry spell conditions.

Of the 21.1 million hectare rain-fed rice area in eastern region, according to WTCER, about 20 percent is rain-fed upland rice land. Productivity is very low and unstable due to erratic rainfall and dry spells during the farming season. But farmers traditionally grow rice on such land.

The experts felt that crop diversification with low-water requiring and high value crops such as oil-seeds, pulses and cereals can be some of the options for the farmers.

HARVESTING MORE

- Eastern India receives good rainfall but farm productivity is the lowest
- Crop diversification with low-water requiring plants can boost productivity
- Fruit, high value oil-seed crops and cereals can be better options

The water technology experts also felt that low-water requiring dry land fruit crops can also play a major role in mitigating drought in rain-fed areas.

Besides mitigating drought, the crops will also meet the nutritional needs.

In fact, the WTCER has come out with a training course on watershed management for the officers, scientists, extension workers and planners. This will showcase the use of modern tools such as GIS, GPS, remote sensing and simulation models along with traditional knowledge.

During the next five days, case studies in alternative land and water resources planning, crop diversification and exposure to the modern tools will be explained to the trainees.

The Indian Express on 6.9.2005

- An on-farm training of tribal women was organized from 11 to 12th December 2005 for adoption of improved package of practices for vegetable cultivation during winter season. In that training programme tribal women from all the 75 households of Majhisahi and Banasahi villages of Bahasuni watershed were parcipated.

Photo-54 : On-farm training of tribal women

Majhi Sahi tomatoes find takers

WTCER scientists take up village for research programme

EXPRESS NEWS SERVICE

Dhenkanal, Sept 26: The tomatoes of Majhi Sahi finally have some takers. The village, which had been in the limelight for cultivating tomatoes for eight months in a year, has now been taken over by the scientists of Water Technology Centre for Eastern Region (WTCER) for its all round development.

Popularly referred to as tomato village, Majhi Sahi had found a mention in this paper last year after the 'crossbandh' on which the farmers depended for irrigation, collapsed. The 'bandh' was the source of livelihood for the villagers as they cultivated vegetables with the help of the 'bandh' water.

After this paper reported on the plight of the farmers of the village, Dhenkanal Sub-Collector Surath Chandra Mallick and Chairman, MADA (Modified Area Development Agency) sanctioned more than Rs. 1.5 lakh in phases for renovation of the 'bandh'.

While the 'bandh' got renovated, the tomato village caught the attention of a group of scientists of WTCER. They immediately held discussions with the district administration for adopting the village for their support and research programme. In fact, for the last seven months, they have been working on the village.

According to the scientists, they had first taken soil samples from the village for examination. This apart,

Farmers of the village cultivate tomatoes for eight months in a year

they had taken satellite images of the village with the help of the Indian Space Research Organisation.

Since the scientists were convinced about the bright prospects the village had in store for its farmers, they started supplying new and hybrid varieties of seeds of other vegetables including papaya and brinjal, to the farmers. They have also supplied the farmers with saplings of china teak and fish seeds for the bandh and ponds on an experimental basis.

For this, they have started imparting on-the-spot training to the farmers.

One of the scientists, G. Kar, disclosed that if their 'experiment' proves successful, they would also adopt the nearby villages for development purpose. He said they have planned to conserve the water of Saptasajya hill for farming activities throughout the year while a watershed management programme would be taken up during winter season.

WTCER director Ashwini Kumar will also visit the village soon to interact with the farmers, he pointed out. "Our objective is to encourage the poor farmers take up soil and water conservation measures and improve their livelihood," he remarked.

Meanwhile, the farmers and other villagers have resented the indifferent attitude of the district administration towards improving the condition of the road to the village. In absence of a concrete road, the farmers have been facing difficulties in selling their vegetables outside. Their repeated pleas to the administration in this regard have fallen on deaf ears, they alleged.

However, Dhenkanal Sub-Collector told this paper that he will soon apprise the administration of the matter.

The Indian Express on 27.9.2005

Cash crops bring bonanza to them

EXPRESS NEWS SERVICE

Farmers in their maize field in Dhenkanal.--Expressphoto

Dhenkanal, Sept 21: Neither heavy rains nor drought can stop them from achieving a bumper harvest. The farmers of Kadalipal and other villages of Kamakshyanagar sub-division have learnt scientific methods of growing crops even in extreme climatic conditions and reap profits too.

In 1999, the scientists of Water Technology Centre for Eastern Region (WTCER) came forward and provided on the spot training to the farmers. Seminars were also conducted to hone their skills.

Under the new method, which is a blend of modern and traditional techniques, the scientists suggested growing crops on laterite soil which is favourable for groundnut, maize, cowpea and other crops. Moreover, to sustain soil fertility crops are grown through inter-cropping, crop diversification and multi-crop farming in upland areas. Thanks to the new techniques, the farmers now prefer cash crops over paddy cultivation.

Gati Krushna Samal and Pramod Kumar Nayak, two farmers have successfully applied the technology and are reaping profits. Samal, who invested Rs 2,500 to grow maize on four acres earned Rs 10,000 within three months while Nayak invested around Rs 5000 for the maize crop and earned Rs 20,000 despite sporadic rain. "Our income has doubled in the last six years, thanks to the scientists," said the two farmers.

And while the farmers are ploughing profits from the modern know-how, it is the money lenders who are more happy. The lenders have started charging exorbitant interest. The farmers pay Rs 5 as interest against Rs 100 and Rs 50 against Rs 1000. Half of their profits often go to the money lenders. "They charge more interest if the repayment gets delayed, the farmers said.

Meanwhile, WTCER director, Indian Council of Agriculture Research, Ashwini Kumar visited Kadalipal village and interacted with the farmers. The farmers sought supply of quality seeds.

Assuring that he would to contact National Seeds Corporation, he said seeds will be supplied after a meeting with the corporation. On the otherhand, Collector Usha Padhee said she would work out a solution after a discussion with the agriculture experts and banks.

WTCER scientist G.Kar said the organisation plans to adopt more villages to promote the status of farmers.

The Indian Express on 22.9.2004

- An on-farm training of tribal youth was organized from 17th to 18th December 2005 at Majhisahi village of Bahasuni watershed of Dhenkanal, Orissa. In that training programme, different improved package of practices for vegetable cultivation were taught. A meeting was also organized to appraise tribal youth regarding rainwater harvesting, multiple use of harvested water for enhancing water productivity at Majhisahi village which was attended by 50 tribal youths.

Photo-55 : On-farm training of tribal youth

- An awareness programme cum field day was organized on 20.01.2006 at Dhenkanal on the theme"Agricultural diversification and value addition in watershed" where 500 farmers, 50 NGOs, state government extension officials were participated. District

Magistrate and Collector, Dhenkanal, Smt. Usha Padhee, was the chief guest on the occasion. Former Vice chancellor, OUAT, Dr. I.C. Mahapatra, Director, WTCER, Dr. Ashwani Kumar, Shri Surath Mallick, Sub collector, Dhenkanal are among the prominent speakers on that awareness programme. An exihibition of modern farm implements, improved cultivars, pesticides, biofertilizers, planting materials was organized by WTCER, Bhubaneswar on the occasion of awareness programme, where farmers showed much enthusiasm to interact with different agencies. Arrangement was also made for exposure visit of 200 farmers to different experimental sites of WTCER at Dhenkanal district.

8.2 Formation of water users association

Group of 20 tribal farmers each in Majhisahi and Banasahi whose lands fall in the command area was selected for creation of water users association. The members were responsible to settle conflicts, maintain the created assets like cross bundh, runoff recycling pond, underground pipline system and to use water judiciously and efficiently. They will also collect nominal water cess for maintenance of the irrigation system created by the project.

Photo-56: Lighting up lamp by Chief Guest, Mrs. Usha Padhee, Collector, Dhenkanal in the inaugural programme of awareness programme

Photo-57: Director, WTCER, Dr. Ashwani Kumar briefing about activities of watershed management carriedout by WTCER in an exhibition organised at the site

Photo-58: Large number of male and female farmers participated in the training cum awareness programme on 20.1.2006 at Dhenkanal

8.3 Establishment close interaction and linkage with NGO's and government organizations

- Besides creation of alternative land and water resources in the watershed, for technology dissemination and capacity building, strong linkage was established with many Governments and non-Government organizations (NGOs).

- The WTCER, Bhubaneswar has setup linkage with OUAT, Bhubaneswar for undertaking trials on integrated nutrient management in vegetable production in the watershed.
- The WTCER center also established close interaction with local District and Block authorities, forest departments for undertaking different development programme on soil and water conservations through food for work programme. The condition of approach road was very bad at the time of starting of the project, as a result farmers were facing problem to bring their agricultural produce to the market. Now after request to local district and block administration, they have made good approach road from the watershed to the local market.
- A meeting was also conveyed by Agricultural Production Commissioner (APC), Government of Orissa on 12.04.2006 for discussing possible adoption of dry land farming and crop diversification technologies of watershed management by the state Government. The APC wishes to disseminate the technologies of alternative land and water resources development of watershed through Orissa State Watershed Mission vid. the proceedings F No.FG-II 40/2006/6362/Ag., dated 6.5.2006 . The technologies of crop diversification for watershed management were submitted to Principal Secretary of Agriculture and Director of Agriculture, Government of Orissa.
- After implementing successfully the dryland crop diversification and soil and water conservation technologies in two watersheds of Dhenkanal *viz*., Kadalipal and Bahasuni, large number of farmers and NGOs have come forward to adopt the technology. To cater the seed requirements of non paddy crops in the Orissa state, the WTCER, Bhubaneswar has set up strong linkage with National Seed Corporation (NSC), Bhubaneswar for crop diversification and seed multiplication programme with buy back guarantee. The NSC, Bhubaneswar has made an agreement with WTCER for the same vid. Letter No.PRODN.2/NSC BBSR/06.07 Dt 7.6.06 and already initiated seed multiplication programme of groundnut and maize in 150 acres of land with the adopted farmers of WTCER in *kharif* 2006 at Dhenakanal and Balasore district, Orissa with buy back guarantee. It is expected that this mechanism will solve the problems of non-availability of seeds of non-paddy crops in the state.
- The institute identified a local NGO, Samajik Seva Sadan who is working on social aspects of tribal farmers at Dhenkanal.
- With the help of central Rubber Board Regional Station, Dhenkanal, 50 rubber plants were also planted as per the action plan map prepared by WTCER, Bhubaneswar.
- Through the project, the WTCER also established link with APICOL, Government of Orissa for demonstrating production of value added products from crop diversification.

9.0 TECHNOLOGICAL IMPACT, MEDIA COVERAGE AND FEED BACK

After two years of sincere and dedicated works in the watershed, a survey was made in *rabi* 2005 and *kharif* 2006 to study the socio-economic, scientific and technological impact of different interventions. After effective dissemination of different watershed management technologies, the recommendations to improve productivity, profitability and cropping intensity of rainfed rice area have been widely accepted by wider categories of farming community, state agricultural officials and NGOs. The technologies have ability to enhance production, profitability and sustainability as can be assessed from media reports, feedback from farmers etc.

(i) Increased cropping intensity after creating water resources in the watershed

After creating irrigation facilities by tapping perennial spring water from hill top at Majhisahi village, Dhenkanal, now the farmers are growing high value crops like vegetables, flower (marigold) and short duration fruits with that water and earning Rs.35,000 per hectare. A farmer, Rupee Baske of Majhisahi village did crop diversification in *rabi* 2005 with vegetables, flowers in 1 ha areas with the help of spring water and earned income as follows (Table-14). Other farmers have also come forward to adopt the same. Now irrigated areas of the village have been increased from 1.2 ha to 8.5 ha comprising of 20 tribal families due to installation of spring water collection system in the village.

Table-14: Adoption of diversified crops by Shri Rupee Baske

Crops	Area (acre)	Production (quintal)	Rate (Rs./quintal)	Gross Return (Rs.)
Marigold	0.24	8	500	4000
Cucumber	0.50	30	400	12000
Tomato	0.50	40	250	10000
Bean	0.26	10	600	6000
Couliflower	0.26	12	500	6000
Carrot	0.24	10	550	5500
Cowpea	0.26	10	400	4000
Raddish	0.26	10	400	4000
Total	**2.52**	**130**	**3600**	**51500**

Total area = 2.52 acre @ 1 ha., Cost of cultivation for 2.52 acre = Rs. 16,500/-
Net Return = Rs. 35,000/-, Cost : Benefit Ratio = Rs. 2.19

- Due to construction and renovation of runoff recycling pond and installation of underground pipe line of 1.1 km (PVC pipe: 110 mm, 4kgf) the availability of surface water got enhanced. The conveyance efficiency was increased upto 95%, as a result irrigated area of the Banasahi village of Bahasuni watershed increased from 2 ha .o 18 ha in 2005-06. Net return from second crops ranged between 13,808 to 22,810 per hectare. Highest net return was obtained from cob of winter maize (Rs. 30,000/ha) with 3 supplemental irrigations.

After out interventions farmers are growing double/triple crops in different rainfed rice ecologies. The cropping intensity (whole village was surveyed) has been increased from 105 % and 107% to 177 % and 171 %, in Majhisahiand and Banasahi villages of the study watershed, respectably of Dhenkanal district, Orissa in 2005-06. (Table-15).

Photo-59 : Maize crop with 3 supplemental irrigations

Photo-60 : Bean with 3 irrigations

Table-15 : Increase of cropping intensity (%) due to introduction of second crops in rainfed lowland rice fallow study villages (Based on survey in *rabi* 2005-06)

Water-shed villages	Area under crop (ha)	Double cropped area before project (ha)	Double cropping area after project (ha)	Cropping intensity (%) before project	Cropping intensity (%) after project	Adopted crops with limited irrigation scheduling and or with residual moisture
Majhisahi	12	1.2	8.5	108.1	177.2	Groundnut, pea, blackgram, wheat, potato, sunflower, winter maize, vegetables, marigold
Banasahi	23	2	18	115.2	170.8	Groundnut, pea, blackgram, wheat, sunflower, vegetables, banana

Photo-61 : *Farmers are now self sufficient to purchase vegetable seeds from market*

Photo-62 : *Farmers are happily growing vegetables by substituting rice in upland*

(ii) Shifting from traditional crop (rice) to sustainable productive system through crop diversification in rainfed upland.

The enhanced and stable productivity and profitability through crop diversification changed the outlook of all section of farmers (large, marginal, small, tribal, women) to shift from traditional cropping system (rice-fallow) to sustainable productive cropping system viz., groundnut + pigeonpea, maize-horsegrm/sesamum, sole groundnut, sole blackgram which is reflected from the increased trend of adoption of non paddy crops (Table-16).

Table-16: Increased trend of adoption of rainfed crop diversification technology in rainfed upland rice area (Surveyed in *kharif* 2004 and 2005)

Village	Small and marginal farmers			
		Kharif 2004		
	Total farmers	No. of farmers adopted	Adoption (%)	Area (ha)
Majhisahi	35	28	80	5
Banasahi	40	31	77.5	4
		kharif 2005		
Majhisahi	35	30	85.7	6
Jiral	40	35	87.5	8

(iii) Enhanced and stable productivity and income at household level

Through adoption of crop diversification and improved rainwater management technologies, the productivity and net economic return in rainfed rice area were enhanced and stabilized (Table-17).

(iv) Reduction of household property sale for food security

Due to yield and income stabilization, the property sale (land, livestock and other

Table-17. Increased and stable productivity through crop diversification rainfed rice upland.

Villages	Before adoption (2003)			After adoption (2005)		
	Crops	Productivity (kg ha^{-1})	Net return (Rs ha^{-1})	Crops	Productivity (rice equi-valent yield) (kg ha^{-1})	Net return (Rs ha^{-1})
Majhisahi	Only rice	1014	Nil	Gnut	4550	11700
				G.nut+PP	5980	17420
				BG	3720	8380
				M(c)+HG	7568	23772
				Rice+PP	2880	5020
Banasahi	Only Rice	1200	Nil	Gnut	4890	13060
				Gnut+PP	5460	15340
				M(c)+HG	6540	19660

**Gnut= Groundnut, PP= pigeon pea, M (c)= Maize (cob), HG= Horse gram, BG= Black gram, GG= green Gram*
The productivity and net return after adoption were analysed based on survey in 2005-06.

assets) at household level has been reduced (Table-18). Non farm activities were also reduced because of farm works. (Results based on survey of 35 tribal families).

Table-18: Average income (Rupees) per household before and after adoption.

Sources income	Before project, 2003 (Rs.)	After project (2005-06) (Rs.)
1. Crop	9560	45470
(a) Rice	7956	6065
(b) Non-rice crop	1609	39405
2. Farm labour	1185	0
3. Non-farm activities	8880	540
4. Other sources	1480	1010
5. Total income	**21105**	**47020**
6. Sale of livestock	1485	850
7. Sale of land	740	0
8. Sale of other assets	1010	0
9. Mortgage/ borrowings	2280	0
10. Total (asset sale+ borrowing)	**5515**	**850**

The data is based on survey of output of 30 households of Majhisahi village, Dhenkanal in the year (2005-06).

(v) Enhancing rainwater use efficiency of upland

More crop per drop' i.e. higher rainwater use efficiency was obtained with non-rice crops from farmers field as compared with that of sole rice. Study found that water use efficiency (in terms of rice equivalent yield) was much higher with maize cob, groundnut+pigeonpea, sole groundnut with the values being 7.3, 5.0, 6.3 kg ha^{-1} mm^{-1}, respectively, while the water use efficiency of sole rice was '2.4 kg ha^{-1} mm^{-1}.

Photo- 63 : Farmers of Majhisahi are harvesting fish in harvested rainwater.

(vi) Enhancing of water productivity of pond

As a case study a water harvesting pond of 2100m^3 of Majhisahi village of the study watershed was taken. From the pond Rs. 53,000 was obtained from field crops vegetables, and fishes, therefore, water productivity of the pond was achieved upto Rs.25/m^3.

(vii) Generating income in lean period and fastest return from rice substituted crops in rainfed upland

Rice substituted crops mainly from maize cob, fastest return per unit area per unit time was obtained that too in lean period (August-September), when farmers faced financial crisis. The average net return from maize cob was Rs. 23391 per ha in 70 days ie. Rs. 314/ha/per day net return was achieved. Whereas sole rice returned only Rs.50.1 ha^{-1} day^{-1}. The per ha per day net return was Rs.137.9, Rs.80.1 and Rs. 277 from groundnut, pigeonpea and fish, respectively in normal rain fall year.

(viii) Introduction of high yielding varieties and enhancement of productivity of rainfed lowland rice

Due to improved management with high yielding varieties, the productivity of rice in rainfed lowland was enhanced from 1.3-2.7 tha^{-1} to 3.5-4.3 tha^{-1} in different study villages of the watershed (Table-19).

(ix) Checked labour migration.

The effective rainwater utilization through crop diversification and runoff recycling ensured double cropping in different rainfed rice ecologies which kept the whole farm family busy for longer period, as a result desperate labour migration from the watershed got reduced.

Table-19: Improvement of rice yield through adoption of improved practices. (Average result of result of *kharif* 2004 & 2005).

Village	Area under medium and lowland (ha)	Average productivity (t/ha) before execution of the project	Area adopted (ha)	% of adoption	Average productivity after project execution (t ha^{-1})	Varieties adopted after project execution
Majhisahi	15	1.4-1.9	10	72.7	3.5-3.9	Lalat, Parijat, Swarna Gayatri, Savitri
Banasahi	19	1.3-1.8	14	85.1	4.1	Lalat, Swarna, Ramachandi Gayatri, Savitri, T-1242, CR-1030

(x) Inclusion of legumes in the cropping system improved soil physical conditions

Crop diversification with legumes in *kharif* and introduction of legumes in rice based cropping system improved physical conditions of soils. The soil porosity was enhanced from 31.6% in 2003 to 37.5% in 2006 after substituting rice with legumes (sole / intercrops). The hydraulic conductivity and available water capacity were enhanced by 46 and 22 %, respectively, after replacing rice in rainfed rice upland (Table-20).

Table-20: improvement of soil physical parameters after changing the cropping pattern in rice upland.

Physical parameters	Existing crops			
	Year 2003	Year 2006		
	Rice	Groundnut + Greengram	Groundnut + Pigeonpea	Groundnut + Blackgram
Soil porosity (%)	30.3	34.5	36.8	35.2
Available water capacity (m^3/m^3)	0.141	0.168	0.170	0.162
Hydraulic conductivity (cm hr^{-1})	1.20	1.45	1.50	0.148
Bulk density (mg m^{-3})	1.55	1.51	1.50	1.52
PH	6.1	6.2	6.0	6.1
Electrical conductivity (dS m^{-1})	0.12	0.10	1.12	0.13
Water stable aggregates (%)	18.8	2.21	21.8	20.9

(xi) Shifting from traditional cropping system to sustainable productive cropping system in different rainfed rice ecologies

Due to above mentioned impacts; the cropping system of the study villages has been changed from traditional cropping system to sustainable cropping system (Table-21).

Table-21 : Changed cropping system in the study villages (surveyed in 2005-06)

Village	Before project			After project		
	Upland	Medium land	Low land	Upland	Medium land	Low land
Majhisahi	Rice	Rice, tomato	Rice	Maize, horsegram, Groundnut +Pigeonpea,	Rice, Sunflower, Vegetables (cucumber,water melon, potato, groundnut, winter maize with limited irrigation). Fish in village pond, Papaya, Banana on pond bund.	Rice, blackgram, lathyrus and vegetables (cucumber, tomato)
Banasahi	Rice	Rice	Rice	Maize, horsegram, Groundnut +Pigeonpea,	Rice, groundnut, greengram	Rice, blackgram, lathyrus and vegetables

10.0 STRATEGIES ON LONG TERM SUSTAINABLE LANDUSE PLANNING IN THE BAHASUNI WATERSHED

(i) Agro-forestry

Agroforestry system aims at growing woody perennials along with agricultural crops on the same unit of land either in some form of spatial mixture or temporal sequence. It is defined as "Sustainable land management system which increases the yield of land, combines the production of crops and forest trees and / or animals simultaneously or sequentially on the same unit of land and applies management practices that are compatible with the cultural practices of the local population. The area of 62.8 ha has been recommended for agro-forestry in the watershed area. The forest species manly to be grown are *Acacia auriculiformis, Albizzia lebbeck, Azadiracta indica, Dalbergia sisoo, Eucalyptus spp.*, and *Leucaena leucocephala. Zizyphus mauritiana, Phoenix spp*, etc.which can be grown on field bunds, boundaries, and marginal lands.

The Orissa Bhaskar (Oriya) on 21.1.06

କୃଷି ବିବିଧତା ହିଁ ଖାଦ୍ୟ ସମସ୍ୟାର ଏକମାତ୍ର ସମାଧାନ : ଜିଲ୍ଲାପାଳ

English Translation

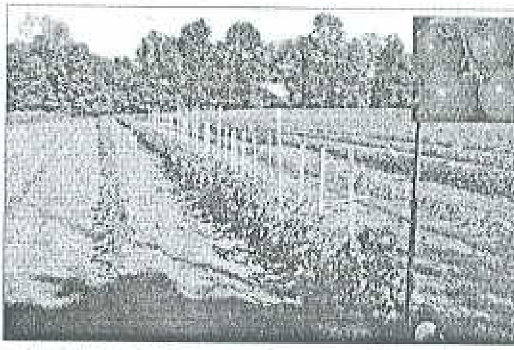
Agricultural diversification is the only solution for food scarcity: says Collector

Dhenkanal: Food is the only problem of ever-growing population. Number of agricultural dependant people has enhanced by four times within last decade. Agricultural diversification is the only option for feeding the vast population told, district collector, Mrs. Usha Padhee. Addressing a training-cum-awareness programme on "Agricultural diversification and value addition", organized by Water Technology Centre for Eastern Region, she told that almost all the farmers of the district depends on rainfall for agricultural operations. But due to erratic rainfall, rice cultivation is hampered. If the farmers adopt low water requiring crops, their economic condition will be improved. WTCER has already come forward to provide technical support. On this occasion, WTCER director, Dr. Ashwani Kumar told that now varieties and technology are available to face the adverse climatic conditions like flood, drought and cyclone. But due to lack of awareness, the farmers are not aware of modern technologies. Crop diversification is the only option to mitigate drought. In this programme, Dr. Gouranga Kar, Principal Investigator of the project advised that with the normal rainfall of 1000-1400 mm rainfall in Orissa, any crop can be grown. Farmers may adopt other cash crops replacing rice in upland and diversified crops by harvesting the rainwater in lowland. Dr. Kar told that farmers of Kamakhyanagar, Parjang and Bhuban block of Dhenkanal district, have been benefited by adopting agricultural diversification strategy. Besides this, WTCER is conducting agricultural research project in Majhi Sahi and Bana Sahi. WTCER is ready to deliver technical support to the farmers, if they need so. Among others, former vice-chancellor of OUAT Dr I.C. Mahapatra, Deputy Director of Agriculture Mr. P.K. Dash and sub-collector Mr. S.C. Mallick were present in this training-cum-awareness programme. Hundreds of farmers discussed their problems on that occasion.

The Sambad (Oriya) on 3.5.06

ଢେଙ୍କାନାଳର ଟମାଟୋ ଗାଁ 'ମାଝିସାହି'

ମାଝିସାହିର କେତୋଟି ଆଦିବାସୀ ପରିବାର ନିଜ ଉଦ୍ୟମରେ ଟମାଟୋ ଚାଷ କରି ଆଜି ସଫଳତା ଅର୍ଜନ କରିଛନ୍ତି। ଗାଁର କେହି ବେକାର ରହିନାହାନ୍ତି। ପିଲାଠାରୁ ବୁଢ଼ା, ମହିଳା ପର୍ଯ୍ୟନ୍ତ ସମସ୍ତେ ମିଶି ପରିବା ଚାଷ କରନ୍ତି।



English Translation

Tomato village of Dhenkanal "Majhisahi"

Majhisahi, a village consisting of 50 tribal families is situated just at a distance of 10 km from Dhenkanal town. It is now at far distance from modern facilities like electricity, proper communication facilities. Their children have never seen television or motorbike. Still then, through their dedicated effort, they now became example for others.

They first started cultivating tomato by cleaning the nearby jungle. The women also helped them a lot. Gradually they show interest in agriculture. Few years back they started cultivation of banana, maize, cauliflower, cabbage, ladies finger, onion, cucumber etc. Initially, they started cultivation in *rabi* season. But now, they are growing different crops through out the year. Now, they have completely substituted rice with different vegetables. WTCER, a central Government organization has started a project there. This organization has supplied water pumps, seeds etc. The cross bund prepared by the villagers was reconstructed. According to the villagers, WTCER has trained them about modern agro-techniques. But it is a matter of sadness that due to improper road, they are facing a lot of problem in marketing of their produce. They either take their produce on head to nearest market . Looking at the success of the village, people of nearest village, Banasahi has started vegetable cultivation. Anyway, now Majhisahi has become an example for others. They have shown that everything is possible through dedicated work.

The Indian Express on 10.2.2006

Tomato farmers have *multi-crop* reasons to cheer

By Biranchi Seth

Dhenkanal, Feb 9: Majhi Sahi, once known as the tomato village of the district, is back in news. This time not just for tomatoes but for several other vegetables and crops which the farmers can now grow thanks to the efforts of Water Technology Centre for Eastern Region (WTCER).

Majhi Sahi had grabbed attention last year after the cross bundh in the village collapsed posing problems for the farmers, for whom the bundh was the 'source' for getting water and thus growing tomatoes, the only vegetable cultivated there.

Following reports published in this paper, the administration came to the rescue of farmers and under the initiative of Sub-Collector Surath Chandra Mallick, the bundh was repaired and renovated with Modified Area Development Agency (MADA) funds sponsored by Centre. But this wasn't the only good thing to have happened then. WTCER heard of the village and decided to take it up on an experiment basis to find out whether other crops could also be grown there.

Following series of experiments and assessment, WTCER discovered that the soil was suitable for cultivation of multiple crops. In fact, it has now decided to develop Majhi Sahi as a model village in the State. WTCER scientists have also taken up the nearby Bana Sahi village.

At present, they are imparting on-the-spot guidance to the farmers. According to one of the scientists, Gaurang Kar, soil of the land is laterite acidic which is favourable for vegetables and flowers like beet, bean, marigold, cluster bean, tomatoes, cucumber, cowpea, banana and sweet potatoes, some of which are being grown successfully now.

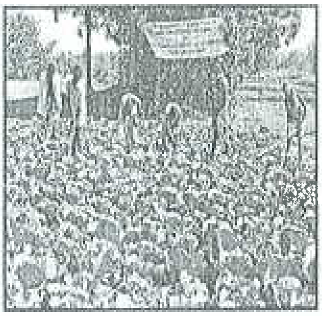
The scientists are now focusing on strengthening the existing sources of water. Kar disclosed the bundh will also be strengthened and new pipe lines erected this month to provide water facility to each patch of land. WTCER also has plans for fish production in the villages.

Kar said WTCER has sought cooperation from the district Agriculture and Horticulture departments for initiating awareness programmes among farmers. Recently, WTCER also organised an awareness programme on 'agricultural diversification and value addition in rainfed areas'. WTCER, Bhubaneswar, Director Ashwini Kumar said crop diversification with low water requirement but high value crops may be one of the options with farmers to improve productivity of upland rainfed ecosystem.

Later, Collector Usha Padhee inaugurated an exhibition of different modern technologies.

Director, WTCER and a team of officials from Ministry of Science and Technology have now decided to visit the villages this month to take stock of the situation.

WTCER's noble endeavour



Farmers of Majhi Sahi engaged in cultivation work – Expressphoto

The Pioneer on 21.1.2006

Awareness camp to boost land productivity

Pioneer News Service

Dhenkanal

THE WATER Technology Centre for Eastern Region, functioning as a branch of Indian Council of Agriculture and Research, on Friday organised a training and awareness programme on agriculture at Dhenkanal.

Inaugurating the programme at Gopabandhu Town Hall, district collector Usha Padhee urged farmers to adopt scientific method of cultivation as the population is growing whereas cultivable land is constant and water sources are diminishing.

Speaking on the occasion, principal investigator Dr Gournga Kar explained the achievement of agricultural projects executed at Kamakhya Nagar, Parjang and Bhuban blocks. He claimed that earlier villagers of Arnapur and Kadalipal were migrating for greener pastures as they could not earn enough to maintain their families. "Now after implementing the scientific method of diversification of crops, they earn at least Rs 50,000 to Rs 1 lakh from ground nut, maize, turmeric and bidi," he said.

'Now after implementing the scientific method of diversification of crops, they earn at least Rs 50,000 to Rs 1 lakh from ground nut, maize, etc'

Taking part in the discussion, the director of WTCER Dr Aswini Kumar said the Green Revolution though helped to increase food grains in assured water supply regions, out of 142 million hectares of cultivable land in India 67 per cent are under influence of rain-fed agriculture.

The Orissa Bhaskar (Oriya) on 15.9.05

ଜଳ ବିଭାଜିକା ପରିଚାଳନାକୁ କେନ୍ଦ୍ରର ଗୁରୁତ୍ୱ

English Translation

Centre gives emphasis on watershed management

Bhubaneswar: Managing-Director of APICOL, Dr. A.K. Behera said that central government is giving more emphasis on watershed management for rural development. In the closing ceremony of the six-day national level training programme on "Blending of modern and traditional technologies for watershed management" organized by Water Technology Center for Eastern Region, Dr. Behera informed that watershed development is also being given importance in the recently started "National Employment Guarantee Scheme" (NEGS). He said that, through blending of modern and traditional technologies for watershed development, it is possible to fulfill the ambition of farmers. The training programme conducted by WTCER is the first step in this regard. Dr. Behera advised the scientists and organizations engaged in watershed development programmes to motivate the local people to actively participate in this. WTCER Director, Dr. Ashwani Kumar informed the participants that, as the central government is giving emphasis on watershed management, the center will organize such kind of training programmes regularly. Among others, Dr. R. singh (principal scientist, WTCER) and scientist Dr. G. Kar (Course Director of the training programme) gave their views on the issue. This programme was conducted from 5th to 10th September 2005. Policy makers and professionals from different parts of the country participated in this training programme.

The Dharitri (Oriya) on 9.9.2005

ଜନ ଭାଗୀଦାରି ଦ୍ୱାରା ଜଳଛାୟା ପ୍ରକଳ୍ପ ସଫଳ ହେବ

ଜାତୀୟ କର୍ମଶାଳା

English Translation

Watershed projects will be a success with people participation

On the occasion of watershed training programme Dr. B. Senapati (VC-OUAT) told that the watershed development projects are running with a noble cause. It is also functioning in many places in Orissa. But it seems as if we are at far away from the goal. In future, in order to increase the agriculture production, we have to give importance on proper utilization of natural resources, technological advancement and improvement of agro-marketing structure. So we must give importance on use of modern tools like GPS, GIS and remote sensing techniques. On this occasion, chief guest, Dr. I.C. Mahapatra, who is a renowned agro-consultant, informed that the central government is giving emphasis on watershed development since last four decades. But this fails due to the political interference in the village and lack of interest of the villagers. Around 70 to 80% of land in Orissa is acidic in nature. Because rainwater washes away many soil nutrients like sodium, potassium and calcium etc. This problem can only be solved through proper rainwater management and watershed development projects. So, he emphasized on people participation for success of any watershed development project. Director of the institute Dr. Ashawani Kumar explained the causes of failure of different watershed development programmes of the state and also the remedy. He briefed success story of two such projects carried out by the institute. As approximate 70% of Orissa belong to upland, so the food security of the increasing population can only be meet through crop diversification and relay cropping. Dr. Gouranga Kar, scientist (S.S.) and Dr. R. Singh (Principal Scientist) were among the experts present on the occasion. Many scientists and officers from different parts of the country participated in the training programme.

(ii) Horticulture and Hortipasture

It is the combination of agricultural field crops with the growing of some fruit or flowering crops to increase the income of the farmers and stabilize the soil loss due to erosion. The area of 225.7 ha are recommended for practice of hortipasture in the watershed area. Orchards crops like mango, sapota, ber etc. can be tried depending upon the soil suitability.

(iii) Inter-cropping and intensive agriculture

The following criteria should be taken into account while practicing inter-cropping.

(a) The leguminous crop should be inter-cropped with non-leguminous crops, to restore fertility status of the soil.

(b) The deep rooted crops should be cultivated along with shallow rooted crops.

(c) The low water requirement crops are to be inter-cropped with moderate water requirement crops and both crops should have different growth habits.

Attempts should also be made to identify and introduce as much high yielding varieties a possible and package of practices in order to improve the productivity. Suitable contingent crop like 'cover crop', 'catch crop' like cowpea, horsegram may be recommended to combat aberrant weather situations.

(iv) Silvipasture

Sivipasture is the practice of growing of forest species with grass cultivation. The grasses and legumes vary in their root characters, which contributes ultimately get reflected on the soil aggregate stability and infiltration rate. These characters alter soil and water loss and also impart stabilization of soil structure and reduce erosion. Silvipasture development coupled with appropriate soil and water conservation measures may greatly improve the site and also the land productivity. The recommended tree species are Teak, Sal, *Albizzia lebbeck, Acacia nelotica, Leucaena leucocephala* etc. along with grasses like *Cenchrus ciliaris, Stylosanthes* hamata, (legume grass). In addition to that, soil conservation measures like contour terraces, stone walling on contour line, gully plugging etc. can be adopted on moderately slope areas to improve soil physical and physico-chemical properties, to augment the water holding capacity of the soil and to reduce soil erosion. The area of 527.3 ha is recommended for silvipasture in the study watershed area because most of the area of the watershed is upland degraded forest and grazing land .

(v) Horticulture

It is the practice of growing fruit crops and flowering plants (floriculture) according to land suitability and irrigability of the area. The fruit crops recommended for the area are mango, guava, banana, sweet orange, sapota, aonla, ber etc. The floricultural crops like Marigold, Roses, Chrysanthemum, Jasmines etc. may be propagated in some area to increase per capita income of farmers. The areas of 6562.8 ha are recommended for growing dryland horticultural crops.

(vi) Soil and water conservation practices:

Realizing the importance of in situ conservation of soil and moisture for better productivity, various soil moisture measures should be adopted in moderate to steep sloppy areas. Vegetative measures with Khus, Agave etc. can be introduced to check soil erosion. Farm ponds can be constructed wherever feasible in order to harvest rainwater and may be used for multipurpose activities like irrigation, aquaculture etc. The graded bunds, smoothing, land leveling, boulder checks etc. may be recommended in second or third order drainage of the watershed. These soil and moisture conservation measures will direct towards improved use and management of land and water resources in order to increase, stabilize agricultural production and arrest soil erosion.

କୃଷକମାନଙ୍କର ମତାମତ

ଭୁବନେଶ୍ୱରସ୍ଥିତ ଡବ୍ଲ୍ୟୁ.ଟି.ସି.ଇ.ଆର୍. ସଂସ୍ଥା ଦ୍ୱାରା ବିଗତ ଦୁଇ ତିନିବର୍ଷ ହେବ ଚାଲିଥିବା ଜଳଛାୟା ପ୍ରକଳ୍ପ ପରିଚାଳନା ଦ୍ୱାରା ଆମ୍ଭେ ଭୂଆସୁଣୀ ଜଳଛାୟା ଅଞ୍ଚଳର ମାଝିସାହି ଏବଂ ବାନାସାହିର ଚାଷୀମାନେ ବିଶେଷ ଉପକୃତ ହୋଇଅଛୁ । ଉନ୍ନତ ପନିପରିବା ଚାଷଦ୍ୱାରା ଆମ୍ଭମାନଙ୍କର କୃଷି ଉତ୍ପାଦନ ବୃଦ୍ଧି ହେବା ସଂଗେ ସଂଗେ ସାମାଜିକ ଏବଂ ଅର୍ଥନୈତିକ ଅବସ୍ଥାରେ ମଧ୍ୟ ଅଗ୍ରଗତି ଘଟିଛି । ଏପରିକି, ପୂର୍ବରୁ ଆମ୍ଭେମାନେ ଆମର ଚାଷଜମିରେ ଗୋଟିଏ ପ୍ରକାର ଫସଲ କରିବାରେ ମଧ୍ୟ ସକ୍ଷମ ନଥିଲୁ, କିନ୍ତୁ ବର୍ତ୍ତମାନ ସେହି ଜମିରେ ଦୁଇରୁ ତିନିପ୍ରକାର ଫସଲ ଉତ୍ପାଦନ କରିପାରୁଛୁ । ପ୍ରକଳ୍ପରୁ ଜାଣିବାପରେ, ଏଠାକାର ଚାଷୀମାନେ ଢ଼ିପ ଜମିରେ ଧାନ ପରିବର୍ତ୍ତେ ମକା, ଚିନାବାଦାମ୍ ଇତ୍ୟାଦି ଫସଲ ଚାଷକରି ଅଧିକ ଲାଭବାନ ହୋଇପାରୁଛନ୍ତି । ଡବ୍ଲ୍ୟୁ.ଟି.ସି.ଇ.ଆର୍. ସଂସ୍ଥାଦ୍ୱାରା ଜଳଛାୟା ଅଞ୍ଚଳରେ ଝରଣା ପାଣିକୁ ସଂଗ୍ରହ କରାଯାଇ, ପଥର ବନ୍ଧ ନିର୍ମାଣ କରି ଏବଂ ବୋହି ଯାଉଥିବା ପାଣିର ପୁନଃଉପଯୋଗ କରି ଚାଷୀମାନଙ୍କର କୃଷି, ମତ୍ସ୍ୟ ଚାଷ ଏବଂ ଗୃହ ଆବଶ୍ୟକତା ପୂରଣ ହୋଇପାରୁଛି ।

[After 2-3 years of watershed project management activities by WTCER, Bhubaneswar at Majhisahi and Banasahi villages of Bahasuni watershed, we the farmers of those villages are highly benefited. Our agricultural income was enhanced, socio-economic conditions were improved through improved vegetable cultivation. Earlier we were not able to grow even one crop in our agricultural land, now growing 2-3 crops in the same land. After learning from the project, farmers are now emphasizing non paddy crops like maize, groundnut, vegetables in upland and getting higher return (Rs. 10,000-25,000/ha). The water resources created by WTCER, Bhubaneswar in the watershed like spring water collection system, construction of cross bundh and runoff recycling pond have help the farmers of the watershed to meet water requirements for agriculture, fisheries and domestic purposes.]

Dulgu Marndi
Dukhia Tudu
Bhanja Tudu
Lidi Tudu
Swaraswati Tudu
Chaitan Baskey
Arjun Baskey
Lanubha Marndi
Sakro Marndi

Laxman Tudu
Durga Hembram
Sunia Champia
Mamina Champia
Malati Murmi
Sukurmani Murmu
Hisi Tudu
Salga Tudu
Mani Marndi