Forty Years of Water Management Research in Hirakud Command

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FOREWORD

Water is the single most important natural resource affecting mankind. The area that needs most attention is the management of water, which is going to be probably the most scarce factor in the twenty first century. Technologies for conservation of water and increasing its use efficiency need to be aggressively promoted. It is essential that the available water resources are managed efficiently and efforts are made to strengthen them further. Our irrigation efficiency is estimated to be around 35% which needs to be raised to at least 50% in view of the declining trend of water availability for irrigation. This will contribute immensely to increase agricultural production and availability of water for other uses.

The book on "Forty Years of Water Management Research in Hirakud Command" is based on the research and development work undertaken during the last four decades under the AICRP on Water Management located at Chiplima in the Hirakud Command. It contains information on innovative water management technologies which are tested in farmer's field and have the potential to reshape crop productivity in the command areas. I congratulate all the scientists who are involved in generation of technology and compilation of this useful database on water management. I believe this book will benefit the researchers, scholars and the farming community in enriching their knowledge in the field of efficient water management.

I wish this publication all success.

(D.P. Ray)

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Dr. Madan Mohan Panda, Ph.D
DEAN OF RESEARCH

PREAMBLE

Water, the finite and vulnerable natural resource, has multifarious uses for mankind. At present different parts of the world are facing water crisis. The share of water for irrigation is declining day by day due to increasing population, urbanization, industrialization and growing environmental concerns. On the other hand, irrigated area has to be increased to produce enough food to ensure food and nutritional security. All these necessitate increasing water productivity for which the All India Coordinated Research Project (AICRP) on Water Management was initiated at Chiplima in 1969 to develop effective water management practices in the Hirakud Command Area. During last 40 years a lot of research information has been generated due to the concerted efforts of the scientists of the project. Few of these have been field tested by the project and through the Agricultural Intensification Programme in irrigation commands in the State. The outcome of such research findings has been reflected in enhancement of cropping intensity, crop productivity and so on.

I appreciate the endeavour of the Chief Scientist of the AICRP on Water Management and his team, who have compiled all such valuable information generated and field tested in the Hirakud Command Area into a Book entitled "**FORTY YEARS OF WATER MANAGEMENT RESEARCH IN HIRAKUD COMMAND**" in 14 Chapters. I hope this book will be of immense use to the scientists, teachers, extension workers, planners, policy makers, students and all those interested in agricultural development in irrigated areas.

(M. M. Panda)

PREFACE

Water is the most important element of the universe and is the basis for life. It is a finite and vulnerable natural resource, which is being depleted and degraded very fast. At present the world is facing severe water crisis. Water abundant regions have become water scarce and water scarce regions face water famines. It is claimed that water will be more precious than oil and future wars will be fought over water issues. The demand of water for irrigation, industry, energy and household uses in India is increasing day by day due to rapid growth of population, urbanization and industrialization. Water must have to be used efficiently, economically, environmentally and judiciously to derive maximum benefit from it.

About 85% of total fresh water in India is used in agriculture. As a thumb rule, about one litre of liquid water gets converted to water vapour to produce one calorie of food. Every person normally drinks 2 to 5 litres water while consumes about 2000 to 5000 litres of water per day depending upon the food habit. While availability of water for agriculture is decreasing day by day, gross irrigated area in India needs to be increased from present level of about 100 m ha to 140 m ha in order to produce 400 to 450 million tonnes of food grains to meet the requirement of 160 crore people by 2050. Hence, there is an urgent need for improving irrigation water productivity *i.e.,* efficiency of canal irrigation system from 40 to 60% and that of ground water from 60 to 75%. As per an estimate 10% increase in irrigation water use efficiency can bring about water availability by 40% for other sectors.

To address the irrigation related issues of Orissa, an All India Coordinated Research Project (AICRP) on Water Management was started by the ICAR, New Delhi in the State Government Agriculture Farm at Chakuli of Sambalpur district during January,1969 which was shifted to Regional Research and Technology Transfer Station, Chiplima of Orissa University of Agriculture and Technology during June, 1979. The AICRP on Water Management, Chiplima is operating in the command area of Hirakud Canal System which is the largest one in Orissa with a Gross Command Area of 1,85,000 ha out of which the Culturable Command Area is 1,59,093 ha. The project work aimed at generating knowledge, database and technology with respect to the water management issues in the agro-hydrological situations of Hirakud Command for enhancing water use efficiency and scaling up of water productivity in agriculture.

We gratefully acknowledge the ICAR for opening a Centre of Water Management Research at Regional Research and Technology Transfer Station, Chiplima of Orissa University of Agriculture and Technology. We extend our sincere thanks and gratitude to

Prof. D.P. Ray, the Hon'ble Vice-Chancellor, OUAT for his guidance and encouragement in functioning of the project and compiling this manuscript. We are thankful to the Directorate of Water Management (DWM), Bhubaneswar for effectively coordinating the project activities and the present Director, Dr. Ashwani Kumar for inspiring us in effectively implementing the project work. Special thanks are due to Dr. P.Nanda and Dr. R.Singh, Principal Scientists of the DWM for their timely suggestion and co-operation for management of the Project.

This publication is based on the data generated by different scientists working in the project during the last forty years. The book is divided in to fourteen chapters dealing with different aspects of water management including water resources in the state, water requirement of important crops, irrigation scheduling in crops and cropping systems, water balance studies, micro-irrigation, water conservation techniques, water use efficiency, drainage techniques, multiple use of water in chronically water logged areas, transfer of technology and its impact, future thrust area, success stories and literature published.

We are glad to put on record our gratitude to our senior colleagues Dr. D. Lenka, Dr. N.K. Tyagi, Dr. S.C. Panda, Dr. N. Hati, Dr. S.K. Samantray, Dr. JML Gulati, Dr. B. Panigrahi for their pioneering work in the project. Their wisdom not only laid the strong foundation of the project, but also set guidelines for future work on water management at the Centre. We acknowledge the role of the successive Deans of Research of OUAT and the Associate Directors of Research, RRTTS, Chiplima for their guidance and cooperation for successful functioning of the project over years. The inspiration and suggestion of Dr. M.M. Panda, Dean of Research, OUAT in writing this book is worth mentioning.We are also thankful to the Professor and Head, Department of Agronomy and Professor and Head , Department of Soil Science & Agril. Chemistry, College of Agriculture, Bhubaneswar for their constructive suggestions and timely guidance for working out the technical programme of the project. We are thankful to Dr. L.M. Garnayak, Professor, Agronomy and Dr. D.K.Dash, Associate Dean, College of Agriculture , Chiplima for their suggestion and help for preparation of this manuscript. The efforts of all the scientists and staff of RRTTS, Chiplima who were directly or indirectly involved in this project and the cooperation of the farmers of the state who helped us for testing the technologies generated by the scientists on their farms are gratefully acknowledged.

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CHAPTER - 1

WATER RESOURCES AND DEVELOPMENT OF WATER MANAGEMENT RESEARCH IN HIRAKUD COMMAND

Water is a prime natural resource and a basic necessity for sustaining life on earth. Supplying adequate amount of portable water to the global population is a gigantic task in the wake of growing industrial and domestic needs. India is endowed with a rich and vast diversity of natural resources, water being one of them. Its development and management plays a vital role in agriculture production. Water resource management is critically important in India because the incomes and employment of 60-70 per cent of Indians depend on agriculture. Irrigation is a key feature of India's agricultural strategy, but it is not being used to its potential. In fact, the excessive and indiscriminate use of water has often resulted in substantial harm to the soil and reduced productivity. Unfortunately, water resource management in India is suffering. Surface water management requires heavy investment including meeting technical needs and environmental concerns. Groundwater management must reduce excessive pumping and address inadequate recharge of the water table. There are simple, well-known technical and economic solutions to the problems.

A network of several Water Technology Centres and sub-research centres in different institutions in the country under All India Coordinated Research Project (AICRP) on Water Management and establishment of a full fledged Directorate of Water Management by the Indian Council of Agricultural Research have given a qualitative and quantitative boost to strengthen water management research in the country. The Directorate of Water Management located at Bhubaneswar and the AICRP on Water Management operating in Orissa University of Agriculture and Technology at Regional Research and Technology Transfer Station, Chiplima are conducting research on various aspects of water management in Orissa.

1.1 Agriculture in Orissa

Agriculture contributes about 26% to the State Gross Domestic Product (SGDP). About 65% of the workforce depends on agriculture for their employment. The average size of holding in the State is 1.25 ha. The small and marginal farmers constitute about 83% of the farming community. The state is divided into ten Agro-climatic zones on the basis of soil, humidity, elevation, topography, vegetation, rainfall and other agroclimatic situations. The average rainfall in the state is 1482 mm, of which about 80% is confined to monsoon months (June-September). The total food grain production in the State during 2007-08 is estimated to be 92.13 lakh tones which is 4.06 percent of national food grain production. Rice is the main crop of the state. Agriculture in Orissa is characterized by low productivity on account of various factors. These factors include problematic soil (acidic, saline and waterlogged), lack of assured irrigation, low seed replacement rate, low level of fertilizer consumption, low level of mechanization etc. The serious gaps in yield potential and the technology transfer provide an opportunity to the state to increase production and productivity of different crops in different parts of the state substantially.

1.1.1 Physiography

The state of Orissa is situated between 17°47' to 22°33' N latitude and 81°21' to 87°30' E longitude. The state covers an area of 15.57 million hectares representing 4.7 per cent of the total geographical area of the country. The state is endowed with wide variations in climate, geology, landforms and vegetation, which are reflected by the large variety of soils. Based on tectonic history and relief features along with erosional processes, the state presents four broad and well defined physical regions *viz.*

- Northern plateau (23%)
- Central table land (26%)
- Eastern gnats (36%)
- Coastal plains (15%)

These four physiographic regions are further subdivided into several micro units on the basis of variations in geographical, physical, climatic and edaphic conditions.

1.1.2 Geology

The geological sequences responsible for the present topography are the Archaean to Pleistocene and Recent age. The Archaeans dominate the rock system with other systems like proterozoic, cretaceous and carboniferous.

1.1.3 Agro-climatic zones

Integrating the effects of land, topography, climate, soil and crop adaptability the state has been divided into ten agro-climatic zones (Table 1.1).

Table 1.1 Agro-climatic zones, area and broad soil groups of Orissa

Sl. No.	Agro-climatic zones	Area (m ha)	Broad Soil Group	Districts and locations of RRTTS (OUAT)
1.	North Western Plateau	1.20	Mixed red and yellow	Sundargarh, Deograrh, parts of Sambalpur and Jharsuguda, **Kerai**
2.	North Central Plateau	1.72	Red, mixed red and balck	Mayurbhanj, Keonjhar **Keonjhar**
3.	North Eastern Coastal plain	0.95	Coastal alluvial, saline	Balasore, Bhadrak, Jajpur, **Ranital**
4.	East and South Eastern Coastal Plain	2.04	Deltaic alluvial, lateritic	Kendrapara, Jagatsinghpur, Khurda, Puri, Nayagarh, parts of Cuttack and Ganjam, **Bhubaneswar**
5.	North Eastern Ghat	2.85	Red loam, brown forest soil	Gajapati, Phulbani, Rayagada, parts of Ganjam, **G. Udayagiri**
6.	Eastern Ghat High land	0.96	Red, laterite	Koraput, Nawarangpur, **Semiliguda**
7.	South Eastern Ghat	0.97	Red, black	Malkangiri, **Kalimela**
8.	Western Undulating land	1.24	Red, black	Kalahandi, Nuapada, **Bhawanipatna**
9.	West Central Table land	2.41	Laterite , mixed red and black	Bolangir, Boudh, Sonepur, Baragarh, parts of Jharsuguda and Sambalpur, **Chiplima**
10.	Mid Central Table land	1.23	Red, laterite, alluvial	Dhenkanal, Angul, parts of Cuttack, **Mahishapat**

1.2 Water resources of Orissa

Taking into account the geographical area (15.57 m ha) and average annual rainfall (1482 mm), the total water resources of Orissa is 23.076 m ha m out of which only 47% is utilizable. About 8.7 m ha m is the utilizable surface water and 2.1 m ha m is the ground water resources. The total irrigation potential of the state is estimated to be 5.9 m ha. But irrigation potential created so far (2006-07) from all sources is only 4.05 m ha (68.6% of total possible irrigation potential) *i.e.*, 2.72 m ha during *kharif* and 1.33 m ha in *rabi* season. Contribution of major and medium projects, minor projects (flow), minor projects (lift) and other sources to the total potential created is 45, 14, 16 and 25%, respectively. The gross irrigated area during 2006-07 was about 3.16 m ha (2.00 m ha during *kharif* and 1.15 during *rabi* season) which was roughly 78% of the potential created. Considering the topography and geological limitations, 75% of the average annual flow (12.04 m ha comprising of 8.28 m ha m from own drainage boundary and 3.76 m ha m through interstate rivers) can be utilized. But till date a storage capacity of only 1.7 m ha m has been created through completed major (7 nos.), medium (38 nos.) and minor (2340 nos.) projects and an additional 0.147 m ha m will be through ongoing projects. Moreover, we have so far exploited only about 18% of replenishable ground water, although 60% is safe and usable. Orissa largely depends upon monsoon for its water resources. Southwest monsoon triggers rainfall in the state. About 78% of total annual rainfall occurs during the period from June to September and the balance 22% in the remaining period. In addition to seasonal availability, the rainfall in the state also shows spatial variation *i.e.*, from about 1200 mm in southern coastal plain to about 1700 mm in northern plateau. This has resulted in causing droughts in some parts of the state and floods in some others. The long-term average annual rainfall in the state is of the order of 1482 mm. Under normal condition, the state receives annual precipitation of about 230.76 billion cubic meters (BCM) of water. Of the total precipitation, a part is lost by evaporation, transpiration and deep percolation and a part stored in the form of ground water reserve and the remaining appears as surface runoff. The groundwater reserve and surface runoff constitute the water resources of the state. The water resources scenario of Orissa and India are given below.

Table 1.2 Water resources of India and Orissa (in BCM)

Description	India	Orissa*
Annual Precipitation	4000	230.76
Average Annual Water Resources	1869	141.41
Utilizable Water Resources (Surface and Ground)	1122	108.15
Utilizable Resources (% of precipitation)	28%	47%

* include water available from outside state

1.2.1 Surface water resources

The state is endowed with an extensive network of rivers and streams. As per an assessment made in 2001, the average annual availability of surface water is estimated as 120.397 BCM. Out of the above, the yield from its own drainage boundary is 82.841 BCM and inflow from neighboring states through interstate rivers is 37.556 BCM. Considering the topography and geological limitations, 75% of the average annual flow can be utilized. Due to increasing demands for water for various uses, an attempt has been made to assess the availability of water. The assessment reveals that the surface water availability from its own drainage boundary remains more or less fixed but the inflow of surface water from neighboring states will be reduced from 37.556 BCM to 25.272 BCM. The following table shows the assessed inflow of surface water pertaining to the years 2001 and 2051.

Table 1.3 Assessed inflow of surface water scenario: 2001

Basin Name	Average Annual flow (in BCM)			75% dependable flow (in BCM)		
	Own	Outside State	Total	Own	Outside State	Total
Mahanadi	29.90	29.255	59.155	25.508	23.225	48.732
Brahmani	11.391	7.186	18.577	8.849	5.521	14.011
Baitarani	7.568	-	7.568	5.434	-	5.434
Rushikulya	3.949	-	3.949	2.782	-	2.782
Vamsadhara	5.083	-	5.083	3.881	-	3.881
Budhabalanga	3.111	-	3.111	2.521	-	2.521
Kolab	11.089	-	11.089	8.885	-	8.885
Indravati	6.265	-	6.265	4.451	-	4.451
Bahuda	0.438	-	0.438	0.213	-	0.213
Nagavali	2.853	-	2.853	2.322	-	2.322
Subernarekha	1.193	1.115	2.308	1.193	1.115	2.308
Total	**82.841**	**37.556**	**120.397**	**65.679**	**29.861**	**95.540**

Table 1.4 Assessed inflow of surface water (Future Scenario: 2051)

Basin Name	Average Annual flow (in BCM)			75% dependable flow (in BCM)		
	Own	Outside State	Total	Own	Outside State	Total
Mahanadi	29.90	21.039	50.939	25.508	16.702	42.210
Brahmani	11.391	3.118	14.509	8.849	2.395	10.884
Baitarani	7.568	-	7.568	5.434	-	5.434
Rushikulya	3.949	-	3.949	2.782	-	2.782
Vamsadhara	5.083	-	5.083	3.881	-	3.881
Budhabalanga	3.111	-	3.111	2.521	-	2.521
Kolab	11.089	-	11.089	8.885	-	8.885
Indravati	6.265	-	6.265	4.451	-	4.451
Bahuda	0.438	-	0.438	0.213	-	0.213
Nagavali	2.853	-	2.853	2.322	-	2.322
Subernarekha	1.193	1.115	2.308	1.193	1.115	2.308
Total	**82.841**	**25.272**	**108.113**	**65.679**	**20.212**	**85.891**

1.2.2 Ground water resources

The natural recharge of ground water takes place through percolation from land after rain events. The quantum of dynamic ground water, which can be annually extracted, is generally reckoned as ground water potential. As per the assessment made in 2001, the total annual replenishable ground water resource of the state is 21.011 BCM, out of which 60% *i.e.*, 12.607 BCM is safe and usable.

1.2.3 Per-capita water availability

The per-capita water availability is reducing progressively owing to increase in population. In 2001, the average per-capita water availability (both surface and ground) in the state was around 3359 cubic meter (cum) per year, as compared to the national average of1820 cum. With the projected future population, the per-capita water availability in the state will reduce to 2218 cum in 2051. Per-capita water availability less than 1700 cum is termed water stress condition while if it falls below 1000 cum, it is termed as water scarce condition. Though per-capita availability of water resources in our state is relatively favorable in the aggregate, the Rushikulya basin will experience a scarcity condition and basins like Budhabalanga and Bahuda will be close to scarcity condition by 2051.

1.2.4 Water requirement

Water has always played an important role in providing livelihood, hygiene and environmental securities since the dawn of civilization. The demand pattern is changing rapidly with increase in population, urbanization and rapid industrialization. Keeping the constraints of water availability in view and the variety of its uses, water allocation issues need to be addressed in a wise manner. Considering this, the present and future requirement of water for all purposes have been assessed, which is given in the following table.

Table 1.5 Water requirements for different uses (in BCM)

Uses	Year-2001			Year-2051		
	Surface	Ground	Total	Surface	Ground	Total
Domestic	0.798	1.198	1.996	1.202	1.803	3.006
Agriculture	18.00	4.688	22.688	40.00	9.408	49.408
Industry	0.606	0.100	0.706	1.750	0.20	1.950
Environment	21.00	8.40	29.40	21.00	8.40	29.40
Others	0.10	0.10	0.200	0.20	0.20	0.40
Total	**40.504**	**14.486**	**54.99**	**64.152**	**20.01**	**84.463**

1.2.5 Water storage

A storage capacity of 17.00 BCM has so far been developed through completed major, medium and minor(flow) projects. Besides, the projects under construction will contribute to an additional 1.47 BCM. The details are given in the table below.

Table 1.6 Reservoir Storage Status as on 31.03.2008 (in BCM)

Category	Completed projects		Projects under construction	
	No	Capacity	No	Capacity
Major	7	14.86	4	1.04
Medium	38	1.30	9	0.43
Minor	2340	0.85	-	-
Total	**2385**	**17.01**	**13**	**1.47**

1.3 Irrigation in Orissa

Orissa is primarily an agrarian state. Irrigation sector holds the key to Orissa's economic development and poverty alleviation. The state has a cultivable land of 61.65 lakh ha. It has been assessed that 49.90 lakh ha can be brought under irrigation through major, medium and minor (flow and lift) irrigation projects.

Irrigation development has not made much headway in the state in the pre-independence era. Hardly 1.83 lakh hectare of net irrigation potential was created. After introduction of Five Year Plan by Govt. of India in 1951, attempts were made for rapid harnessing of water resources and much emphasis was laid to accelerate the irrigation potential creation. By the end March 2009, net irrigation potential of 23.02 lakh hectare has been created through major, medium and minor irrigation projects executed by Department of Water Resources. In addition to the above, 5.33 lakh hectare of net irrigation potential created through other sources like dug-well, water harvesting structures, small check dams etc. Sector wise created irrigation command up to end of March 2009 is given in the Table 1.7.

Table 1.7 Created Net Irrigation Potential (lakh ha.) in Orissa as on 31.03.2009

Sector	Pre-Plan Period	Plan Period (end of March 2009)	Total	Executing Agency
Major & Medium	1.83	11.03	12.86	WR Deptt.
Minor (flow)	-	5.42	5.42	WR Deptt.
Minor (lift)	-	4.74	4.72	WR Deptt.
Other Sources*	-	5.33	5.33.	WR Deptt., Agril Deptt., Private
Total	**1.83**	**26.52**	**28.35**	

1.3.1 Irrigation potential and utilization

The State's achievement in irrigation potential creation during last five decades is considerable, but its utilization is not very encouraging. The irrigation potential creation and utilization corresponding to the year 2000-01, to 2007-08 is given in the following table. The potential utilization has shown an increasing trend from 59% in 2000-01 to 81% in 2007-08. The gap between potential creation and utilization is attributed to many factors, but the main reasons are defunct LIPs, MIPs and deterioration of distribution systems in the irrigated commands.

Table 1.8 Status of irrigation potential created and utilized

Year	Irrigation potential created ('000 ha)			Irrigation potential utilized ('000 ha)			% utilization
	Kharif	*Rabi*	Total	*Kharif*	*Rabi*	Total	
2000-01	2533.83	1071.99	3605.82	1589.88	535.84	2125.72	58.59%
2001-02	2554.26	1117.63	3671.89	1752.27	793.64	2545.91	69.33%
2002-03	2608.59	1123.75	3732.34	1246.81	465.21	1712.02	45.86%
2003-04	2674.12	1161.21	3835.33	1737.49	780.87	2518.36	65.66%
2004-05	2707.27	1266.22	3973.49	1845.79	844.87	2690.66	67.71%
2005-06	2731.50	1294.92	4026.42	1922.70	1042.79	2965.49	73.65%
2006-07	2720.46	1318.52	4038.98	2001.98	1147.47	3149.45	77.97%
2007-08	2765.73	1342.06	4107.79	2027.00	1281.46	3308.46	80.54%

1.4 General information on Hirakud Command

The state is endowed with a wide range of macro and microclimates, land forms, geology and vegetation which influence the genesis of the soils. The variation in soil formation occurs with one change in any of these soil-forming factors. Recently the soil resource mapping was carried out (NBSS & LUP, 1998) following climatic, physiographic and geological studies of the terrain. The soils have shown a definite relationship with the physiography/ land form. Accordingly the state is divided into 6 physiographic regions

- Soils of Eastern Ghat
- Soils of Dandakaranya
- Soils of Mahanadi Basin
- Soils of Garhjat Hills
- Soils of Utkal Plain
- Soils of Mahanadi Delta

The soil characteristics significant for efficient water utilization are depth, slope, texture, available water capacity, drainage and permeability. The generalized and dominant characteristics of the physiographic region to which the study area belongs and the characteristics of the soils in this region are briefly described below.

1.4.1 Soils of Mahanadi basin

Mahanadi basin comprises of western part of Sundargarh, western part of Sambalpur, Jharsuguda, Sonepur, Boudh, Bolangir and central part of Kalahandi districts of Orissa. It is composed of unclassified crystalline rocks which include granite gneisses, limestone and other magmatic rocks. It experiences hot and moist sub-humid climatic condition with mean summer temperature of 31°C and mean winter temperature of 15°C and average rainfall of 1600 mm. Rice is the principal crop of the zone constituting approximately 80 % of the cropped area and the rest cropping with pulses, millets and oilseeds.

The major constraints of the region are steeply slopping terrain, shallow soil depth, severe erosion and stoniness. The general characteristics of soil in soil scapes are presented in Table 1.9.

Table 1.9 Generalized soil scape characteristics of Mahanadi basin

Soil scape	Dominant soil characteristics	Land use	Constraints
i) Hill slopes	Moderate to steeply slopping, depth moderately to very shallow, excessively drained, loamy skeletal / loamy, acidic , *Litihic Ustorthents*	Forest	Severe erosion, rock out crops, low to medium AWC.
ii) Undulating uplands	Undulating, moderately deep to deep, well drained, slightly acidic, loamy skeletal / fine , medium to high AWC, *Typic Rhodustalfs, Aeric Haplaquepts*	Castor, niger, arhar	Moderate to severe erosion, moderate stoniness.
iii) Very gently slopping uplands	Very gently slopping, moderately to very deep, well drained, acidic, fine loamy, medium AWC, *Rhodic Paleustalfs, Typic Ustochrepts*	Paddy, mustard, linseed, cotton	Moderate erosion
iv) Very gently slopping valleys	Very gently slopping , moderately deep to deep, poorly to imperfectly drained, neutral to slightly alkaline, clayey, medium AWC, *Typic Ustochrepts*	Paddy, bengal gram, lentil	Medium AWC.

1.4.2 Soils of Mahanadi delta

The area represnting Mahanadi delta includes part of Bhadrak, Jajpur, Kendrapara, Jagatsinghpur, Cuttack, Puri and parts of Khurda districts of Orissa. The region is covered with deltaic sediments of the river Mahanadi formed in recent times. Pleistocene alluvium occurs at several places along with the coastal tract. The region exhibits a hot tropical climate and high humidity. The mean maximum and mean minimum temperatures are 35°C and 22°C respectively with annual rainfall of 1482 mm. Crops like paddy, sugarcane, pulses, oilseeds, jute are grown in this area. The major constraints of the area are flooding, salinity and high clay content. The generalized characteristics of the soil scape are given in Table 1.10.

Table 1.10 Generalised soil scape characteristics of Mahanadi delta

Soil scape	Dominant soil characteristics	Land use	Constraints
i) Uplands	Very gently slopping, moderately shallow to moderately deep, well drained, acidic, loamy. *Typic Ustochrepts, Typic / Ultic Ustorthents*	Paddy, cotton, wheat, pulses	Gravels on the surface, low AWC
ii) Gently slopping coastal plains	Gently slopping, very deep, imperfectly drained, slightly acidic, clayey, *Vertic Tropaquepts*	Mustard, arhar	Medium AWC, slight salinity
iii) Lower delta	Very gently slopping, moderately deep to very deep, poorly drained, neutral to slightly alkaline, saline, fine to medium, *Aeric Tropaquepts*	Paddy, pulses, wheat, sugar cane, oil seeds	Moderate flooding, moderate erosion, salinity, high AWC
iv) Sand dunes	Very gently sloping, very deep, excessive drainage, sandy, neutral, *Typic Ustipsamments*	Casuarina plantation at places	Severe erosion, low AWC

1.4.3 Hydrologic information of Hirakud command

The Hirakud dam is a multipurpose Project built across Mahanadi river about 14 km upstream of Sambalpur town in Orissa having a culturable command area (CCA) of

157018 ha and irrigation intensity about 170% (100% in Kharif and 70% in Rabi). The area has been divided into four sectors with ridge canals and major rivers, viz. Mahanadi and Ong as boundaries of the sectors.

1.4.3.1 Hydrogeology

The weathered residuum (average thickness 15m) and fracture zones form the principal repository of ground water which occur under phreatic condition in weathered residuum and under semi confined to confined conditions in the fracture zones. Aquifer parameters of the phreatic aquifer reveals that specific yield varies from 0.7 to 11 lps average being 5 lps. The specific capacity value ranges from 2.317 lpm per meter of drawn down to 142.9 lpm per mt of draw down. The discharge of deeper borewells tapping the fractured aquifer varies from 2.7 to 10 lps for drawdown varying from 3.89 to 21 mt. The transmissivity values (T) ranges from 5.8 m^2/d to 125 m^2/d. Similarly the storage coefficient (S) ranges from 1.96×10^{-4} to 6.9×10^{-4}. Depth to ground water level varied from 0.8 to 9.7 m bgl during pre-monsoon period and 0.3 to 4.03 m bgl during post-monsoon period. During the month of August major part of the command area remains within a depth to water level range of 0 to 2 m bgl. The ground water flow direction in general is towards southeast .Hydraulic gradients varied from 1/300 to 1/500.

1.4.3.2 Water logging

It has been found that water logging conditions (DTW <2m) exist in an area of 174 sq.km during Pre-monsoon (May'94) and it was 1494 sq.km during Post-monsoon period (Nov'94). Topographic set up, unlined canals, over irrigation and predominant paddy cultivation during kharif and rabi are mainly responsible for water logging conditions in the command area.

1.4.3.3 Availability and demand of water

As per GEC norms, 1984, the utilisable ground water resources during *kharif* season have been estimated as 508.04 MCM and net draft through existing structure worked out to be 2.35 MCM leaving a balance of 506.09 MCM for further development. Similarly utilisable G W resources during Rabi season have been estimated on 764.44 MCM with a net draft of 4.35 MCM leaving a balance of 760.09 MCM for future development.

Availability of surface water during the Kharif season have been estimated as 1360.8 MCM and during the *rabi* season it is 1494.8 MCM. The Projected annual domestic water demand for the year 2025 was computed as 49.89 MCM. and the projected water demand for industrial purposes have been computed as 261 MCM.

Conjunctive use planning

During the *kharif* season paddy coverage is 98% and sugarcane is 2%. During Rabi season, five major crops like paddy, pulses, oil seeds, vegetable and sugarcane have been considered. Demand of water for 200% irrigation intensity can be met from surface water (90%) and ground water (10%) for both the seasons. The surface water irrigation being cheaper an attempt has been made to determine optimal cropping pattern for the maximum use of available surface water in conjunction with groundwater to get maximum return. Various possible conjunctive use strategies have been tested with the ground water simulation model and it has been found that the above scenario of 90% surface water and 10% ground water use appears to be the most viable one. In Hirakud command area development of groundwater is feasible through dug wells and borewells. Dugwells are the most suitable ground water structure in the area. For meeting the additional demand of water a total of 17,526 dug wells are required which should be installed in the identified area within a period of two years. The simulation studies also indicates that water logging reduces with increase in the use of ground water. The financial analysis of the development plan show that with an additional investment of Rs.953.99 million the B.C. ratio worked out to 1.66 and the internal rate of return (IRR) of 55%.

1.5 Genesis of the All India Coordinated Research Project on Water Management in Orissa

The All India Co-ordinated Research Project on Water Management is one of the ICAR aided research projects operating in Orissa University of Agriculture and Technology under Regional Research and Technology Transfer Station (RRTTS) Chiplima. The All India Coordinated Research Project on Water Management started at Chakuli in Sambalpur district of Orissa under the control of Agriculture Department, Govt. of Orissa from January 1969 and then got transferred to Orissa University of Agriculture and Technology during June 1969 and continued at Chakuli up to 20th June 1979 and then shifted to Regional Research and Technology Transfer Station, Chiplima, Sambalpur and continuing there.

The RRTTS is situated at a distance of 35 km from the district headquarter, Sambalpur, the western most district of Orissa lying between 20° 43' N to 20° 11' N Latitude and 82° 39' E to 85° 15' E Longitude and is under West Central Table Land Zone of Orissa. This zone spreads over 17,190 sq km accounting for 11.06% of the total geographical area of the state. This zone consists of 23 out of 29 Blocks of earstwhile Sambalpur District and 20 Blocks of undivided Bolangir District, 492 grampanchayats and 4978 revenue villages. It is surrounded by the undivided Sundargarh, Dhenkanal, Bargarh and Kalahandi districts of Orissa in North, East, South and West directions, respectively. Along the North Western and Western boundaries lie the Raigarh and Raipur districts of Chhattisgarh. The AICRP on Water Management, Chiplima is located in the command area of Hirakud Canal system which is the largest canal system in Orissa with a Gross Command Area (GCA) of 1,85,000 ha out of which the Culturable Command Area (CCA) is 1,59,093 ha. The topography of the Hirakud command is undulating and inter sparse with hills, dales and valleys. The topography of the command area is rolling in nature with slope ranging between 1 to 3%. In the table land 62.03%, 28.4% and 4.53% of the soils are acidic,neutral and alkaline, respectively. In the plain land 56.4%, 39.32% and 4.24% of the soils are acidic, neutral and alkaline in nature, respectively. The cropping pattern of the Hirakud command area is presented below.

Table 1.11 Cropping pattern of the Hirakud command area

Crop	Present pattern (% of total)			As envisaged (% of total)		
	Kharif	***Rabi***	**Total**	***Kharif***	***Rabi***	**Total**
Paddy	75	35	110	75	30	105
Vegetable	15	15	30	15	10	25
Oilseed	7	16	23	7	10	17
Pulses	3	4	7	3	5	8
Total	100	70	170	100	55	155

Efficient management of water in Hirakud command area is the main objective of AICRP on water management centre at Chiplima of Sambalpur district in Orissa. Due to indiscriminate application of irrigation water in the *att* and *mal* lands and inadequate drainage facilities, water logging is a major problem for the *bahal* lands. The low lands at many locations have become permanently water logged and become unculturable. The area under this type of land is increasing day by day. The *berna* land, though quite productive, have been used for cultivation of rice only.

1.5.1 Mandate of the Project

The mandate of the All India Coordinated Research Project on Water Management, Chiplima centre are :

- To identify the water management problems in the Agro-hydrological situations of Hirakud Command
- To suggest remedy through problem oriented research in order to enhance water use efficiency and crop productivity.

1.5.2 Objectives of the project

In view of the different agricultural situation of the region, the AICRP on water management, Chiplima is working with the following broad objectives.

1. To determine the consumptive use of water, irrigation requirement of different crops and cropping pattern.
2. To study the irrigation and nutrient interaction in relation to crop yield.
3. To design and evaluate irrigation methods to increase irrigation efficiency.
4. To study the short and long term effects of irrigation on the rise of water table, salt distribution and the quality of ground water.
5. To study drainage aspects in high water table areas in different types of soils and to devise methods of managing water logging.
6. To take up on design and development of farm ponds in tail end of canal systems for storage of run off water and it's recycling for use in crop production.
7. To study "On Farm Water management" through operational research in farmer's field.

1.5.3 Brief description of study area

1.5.3.1 Topography

The topography of the Hirakud command is undulating and interspersed with hills, dales and valleys. Locally the land is classified as *att* (unbunded upland), *mal* (bunded upland), *berna* (medium land) and *bahal* (low land). The distribution of land types are 23.42% *att*, 40.72% *mal*, 21.53% *berna* and 14.33% *bahal.*

1.5.3.2 Soil characteristics

As per the comprehensive system of soil classification (Soil Taxonomy, USDA) which is being adopted in India since 1960, the soils of Orissa as well as Hirakud command area come under 4 orders. Average physico-chemical properties of the surface soil at the AICRP on water management, Chiplima are given below.

Table 1.12 Soil taxonomic orders and area under each order

Orders	% of Total Geographic Area	
	Orissa	Hirakud Command
Inceptisols	48	11
Alfisols	36	63
Entisols	10	19
Vertisols	6	7

Table 1.13. Soil physical and chemical characteristics of RRTTS, Chiplima

A. Physical characteristics

Texture	Sandy Loam to Clay Loam
Particle density	2.50 to 2.70 g/cc
Bulk density	1.66 to 1.72 g/cc
Upper plastic limit	16.8 to 4% (Weight basis)
Lower plastic limit	9.3 to 26.8% (Weight basis)
Kc (disturbed soil)	1.5 to 6.2 cm/hr
Infiltration rate	0.3 cm/hr
Field Capacity	19.6 to 20% (Weight basis)
Maximum WHC at Saturation	24.0 to 27% (Weight basis)
Puddling	30.0 to 35%
Wilting point	7.0 to 10.0%

B. Chemical characteristics

pH	5.3 to 7.5
EC (at 25°C)	0.06 to 0.25 mmhos/cm
Organic carbon	0.30 to 0.50%
Total Nitrogen	0.03 to 0.05%
Available P_2O_5 (Olsen)	9.0 to 25.0 kg/ha
Available K_2O (Amm. Acct)	100 to 112 kg/ha
C.E.C.	9.8 to 15.6 me/100g soil
Ca^{++}	6.1 to 8.2 me/100g soil
Mg^{++}	1.8 to 6.2 me/100g soil
K^{+}	2.1 to 6.2 me/100g soil
Na^{++}	0.1 to 0.2 me/100g soil

1.5.3.3 Climate

Orissa largely depends upon monsoon rain for its water resources. Southwest monsoon triggers rainfall in the state. About 78% of total annual rainfall occurs during the period from June to September and the balance 22% in the remaining period. In addition to seasonal availability, the rainfall in the state also shows spatial variation i.e. from about

1200 mm in southern coastal plain to about 1700 mm in northern plateau. This has resulted in causing droughts in some parts of the state and floods in some others. The long-term average annual rainfall in the state is 1482 mm.

District of Sambalpur is characterized by hot and moist sub-humid climate. Mean weather data (mean of 29 years) indicated annual rainfall of 1459.2 mm received in 89 rainy days. The mean monthly maximum and minimum evaporations are recorded as 79.7 mm during December and 225.1 mm during May respectively. Variations of mean monthly rainfall and evaporation are presented in Fig. 1.1. It is observed that except the monsoon period the average monthly evaporations are very high compared to the average rainfall received during each month which necessitates effective irrigation and water management practices for better utilization of water for crop growing. The monthly average number of rainy days and average rainfall during each month are depicted in Fig. 1.2. It is evident from the figure that although rainy days are observed during the non-monsoon months, the rainfalls during these months are very less. Highest atmospheric temperature is recorded in May (44°C) while the lowest (5°C) occurred in December. Mean minimum and mean maximum temperatures are recorded to be 12.5°C (December) and 40.2°C (May). The variation of mean monthly maximum and minimum temperatures are presented in Fig. 1.3. The range of variation is found to be minimum during August and September. Relative humidity varied from 42.9% in the afternoon (May) to 94.15% in the morning (November). The variations of mean monthly relative humidity at different hours of the day are presented in Fig. 1.4. All the average monthly weather parameters recorded at the observatory of the project.

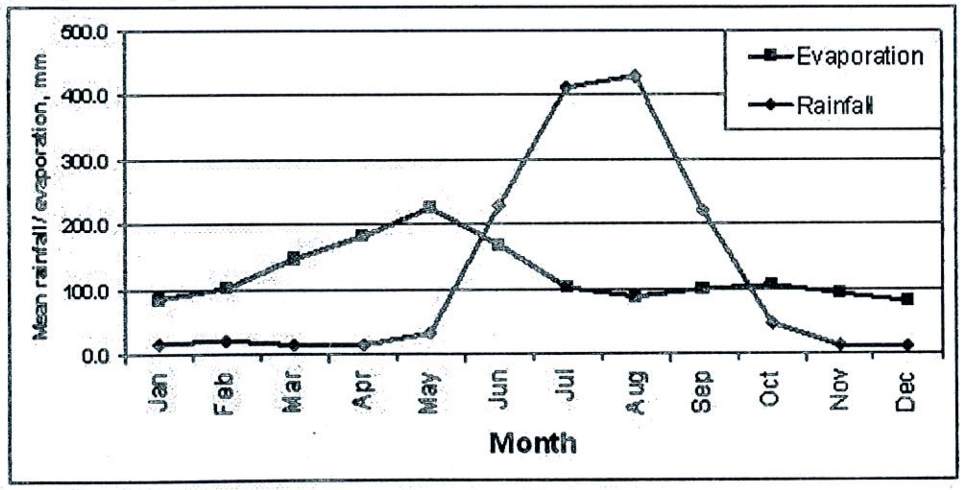

Figure 1.1. Variation of 29 year mean monthly rainfall and evaporation at chiplima

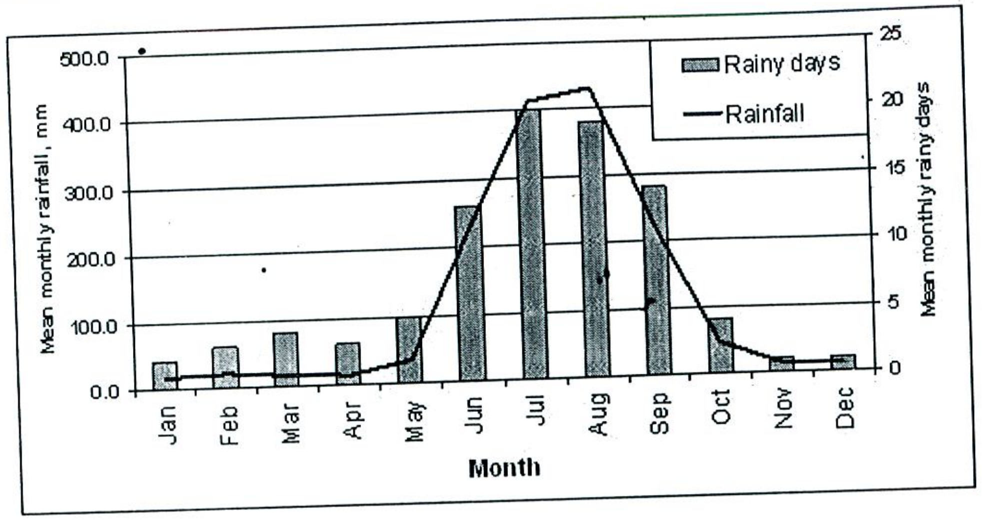

Figure 1.2. Variation of 29 year mean monthly rainy days and rainfall at Chiplima

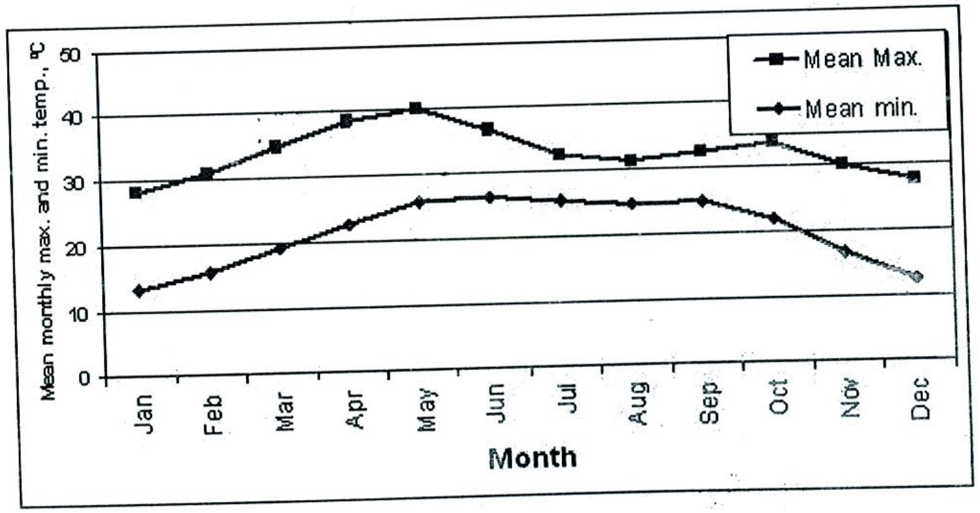

Figure 1.3. Variation of 29 year mean monthly maximum and minimum temperature at Chiplima

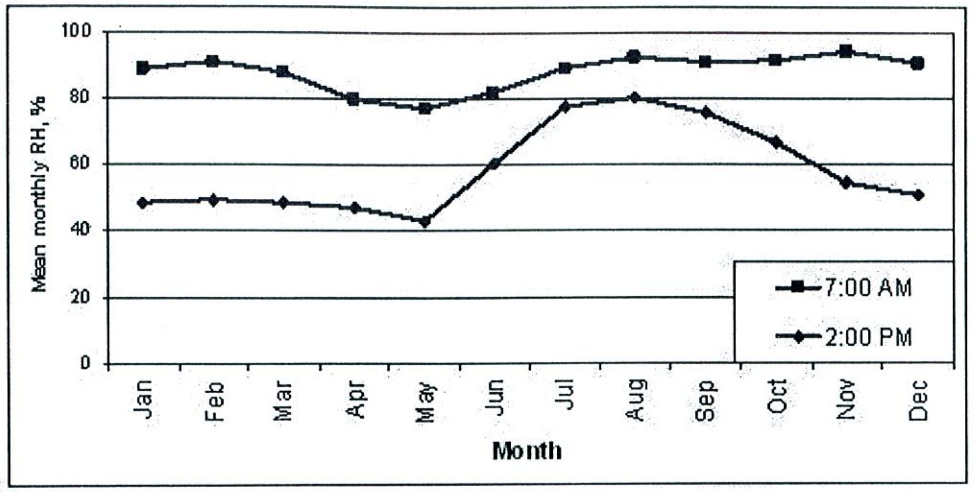

Figure 1.4. Variation of 29 year mean monthly relative humidity at different hours of the day

Table 1.14 Average Weather condition at Chiplima (1981 to 2009)

Month	Evaporation (mm)	Rainfall (mm)	Rainy days	Atmospheric temperature (°C)				Relative humidity (%)	
				Max.	Min.	Mean Max.	Mean Min.	7.00 AM	2.00 PM
January	86.1	16.1	2	36.4	9.0	28.1	13.1	88.6	48.4
February	102.5	19.9	3	34.7	11.7	30.8	15.7	90.8	49.2
March	147.0	14.8	4	38.1	15.3	34.7	19.1	87.9	48.6
April	181.1	14.5	3	42.0	19.8	38.5	22.5	79.7	46.9
May	225.1	32.9	5	44.0	20.9	40.2	25.7	77.0	42.9
June	168.2	228.3	13	42.7	22.6	36.7	26.3	81.9	60.1
July	101.4	412.0	20	36.4	23.5	32.6	25.3	89.2	77.3
August	88.6	430.4	19	34.1	22.6	31.3	24.7	92.5	80.1
September	98.6	220.8	14	35.1	22.8	32.6	24.8	91.1	75.6
October	105.8	45.6	4	34.3	17.5	33.6	21.9	91.5	66.3
November	92.1	12.5	1	35.8	11.6	29.9	16.6	94.1	54.3
December	79.7	11.4	1	30.1	8.6	27.6	12.5	90.4	50.5

1.5.3.4 Groundwater table

The water table in different parts of the year fluctuates from 0.44 to 5.35m below ground level. Water table remains at deeper depth (2.0 - 5.35 m) near the canal but at shallow depth (0.44 to 1.1 mbgl m) in irrigated fields during the canal opening period. The rise is however, rapid due to unlined canal, undulating topography and intensive irrigation.

1.5.3.5 Irrigation water and its quality

The average quality of water of two sources of irrigation water viz; canal and pond is categorized as good.

Table 1.15 quality of canal and pond water at Chiplima

Quality Parameters	Canal Water	Pond Water
pH	8.60	8.30
EC (dSm^{-1})	0.14	0.16
Anions (me l^{-1})		
$CO_3^{=}$	0.12	0.15
HCO_3^-	2.50	2.30
Cl^-	4.56	3.20
NO_3^-	0.06	0.06
$SO_4^{=}$	Trace	Trace
Cations (me l^{-1})		
$Ca^{++}+Mg^{++}$	123	1.70
K^+	0.09	0.05
Na^+	0.19	

1.6 Water management problems

Many water related problems have cropped up due to faulty water management practices followed in the area. The important water management problems are:

a. Rise in ground-water table in upper reach region of the canal system
b. Limitations in crop diversification due to wet -wet canal scheduling
c. Formation of hard pan at plough sole layer due to regular puddling
d. Drainage congestion due to lack of natural drainage at lower end of terrace land
e. Low water use efficiency due to field to field irrigation and conveyance losses
f. Lack of awareness in farmers on effective water use

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CHAPTER - 2

WATER BALANCE STUDIES IN DIFFERENT CROPS

Assesment of water availability and basic studies on water balance on regional basis are highly essential to devise appropriate interventions in crop planning and water management techniques so that the demand of water will match the water supply. Under AICRP on water management some selected studies have been conducted to determine the regional availability of water in the Hirakud Comand and interventions were demonstrated in farmers fields for reducing water demand. Some selected studies are presented below.

2.1 Assessment of water availability in Hirakud Command

Study was made to assess the irrigation water balance situation of the Hirakud Command taking total water available from different sources and crop water demand of the area into consideration. Hirakud Dam which is situated about 16 km up stream of Sambalpur district commands five blocks in Sambalpur, six blocks in Bargarh, two blocks in Sonepur and one block in Bolangir through four canal systems such as Bargah Main Canal(133391.4ha), Sason main canal (21467.6ha), Sambalpur distributory (3,947.6 ha) and Hirakud distributory(151.4ha) with a total command area of 158958 ha.Water availability, crop water demand and period of surplus and deficit for all 4 canal systems and that of Hirakud command for the period from1994 to 2003(Mean of 10years) were computed and presented in Table 2.1 and Table 2.2.

2.1.1 Water availability

Total water availability in Hirakud command is 3713.22 m m^3 with contribution from rainfall being 21.80.3 m m^3(58.7%) and from canal water at field levelbeing 1532.9 m m^3 (41.3%). On an averagerai water availability to total water availabilityat field levelwas 21.6, 79.3 and 21.6% during pre monsoonand post monsoon period respectively.

2.1.2 Crop water demand

Kharif : Estimated total crop water demand in *kharif* (June-October) is 18.02 m ha.cm with paddy being the major consumer (99%). The demand trend was similar under different canal sectionswith 15.13,2.44,0.45 and 0.002 m ha.cm at Bargarh, Sasan, Sambalpur and Hirakud Canal system, respectively. Demand is maximum in July and minimum in June.

Rabi - Summer : During Nov to May the crop water demand is 10.16 m ha.cm with rice share being 89.7%.On monthly basis the maximum demand is in March (2,88 m ha cm) and minimum of 0.069 m ha-cm in the month of May.

Water Balance

Total crop water demand for Hirakud command is 28.198 M ha-cm and the total water availability at field level is 37.13 M ha-cm. Thus, there is net surplus of 8.93 M ha –cm on yearly basis.

Table 2.1 Total crop water demand in Hirakud command(Ha-cm x 10^6)

Crops	Kharif		Rabi	
	Area (ha)	Demand	Area (ha)	Demand
Paddy	154203	17.87	73978	8.929
Pulses	992	0.02	9218	0.185
Oilseeds	694	0.03	13548	0.430
Sugarcane	714	0.04	2004	0.252
Vegetables	2358	0.06	12704	0.366
Total	158961	18.02	111272	10.162

Table 2.2 Total water balance in Hirakud Command (ha-cm)

Month	Water Demand	Water available	Water Balance	
			Surplus	Deficit
January	2187132.7	1691800.3	--	495332.4
February	2218571.7	1818805.6	--	399766.1
March	2885995.9	2102508.5	--	783487.4
April	2428219.5	2346911.5	--	81308.0
May	69392.7	1194308.6	1124915.85	--
June	188133.5	4028100.3	3839966.80	--
July	5445587.5	7824701.3	2379113.8	--
August	4359958.6	7795909.6	3435947.0	--
September	4640601.6	4383205.5	--	257396.1
October	3463712.9	2711206.8	--	762506.1
November	113310.0	529205.5	415895.5	--
December	197802.7	705505.6	507702.9	--
Total	28198419.0	37132165.1	1170354.2	2769796.1
Net surplus/Deficit	--	--	8933745.8	

2.2 Evaluation of moisture retention, release and transmission characteristics of different soils of Hirakud command

A profile was dug out in the medium land of RRTTS, Chiplima. Depth wise soil samples at an interval of 15cm up to a depth of 120cm were collected in core as well as polythene bags.The soil moisture retention, release and transmission characteristics of each undisturbed core samples were determined at the tension of 1/3bar and 15 bar using pressure plate apparatus and the available moisture content was determined from the difference.Results revealed that maximum available soil moisture of 11.88% was found at a dsoil depth of 60-75cm and 11.87% at 45-60cm which might be due to higher clay content in that layer(Table 2.3).The maximum water holding capacity (41.24%) of the layer also signifies the available moisture content of 11.86% at 60-75cm. The bulk density of surface soil increased with increase in soil depth which might be due to greatest compactness of the layers below the surface.The porosity of the soil also decreased with increase in depth.

Table 2.3 Available soil moisture(ASM) and maximum water holding capacity (WHC) of a soil in Hirakud command at different soil depths

Soil depth(cm)	Moisture at 1/3bar (%)	Moisture at 15bar (%)	ASM (%)	Maximum WHC (%)	Clay (%)	Porosity (%)
0-15	19.95	9.17	10.76	39.10	26.7	37.8
15-30	19.76	9.76	10.00	37.20	26.7	35.6
30-45	19.10	8.61	10.49	36.30	26.7	34.0
45-60	22.66	10.79	11.87	45.40	36.7	30.2
60-75	21.67	9.79	11.88	43.60	34.2	41.5
75-90	20.80	7.14	11.66	40.50	30.4	31.1
90-105	19.78	9.26	10.52	40.40	30.3	27.8
105-120	19.88	9.28	10.60	40.30	30.4	27.6

2.3 Lysimetric studies on water balance and consumptive use of important crops

During 1976 to 1984 lysimetric studies were conducted at Chiplima on maize, wheat, rice, mustard, Jowar and groundnut in a sandy loam soil with bulk density of 1.52 g/cc, FC 18&, wilting point 7.2%, pH 6.4, EC 0.4 millimhos/cm and organic carbon 0.45%. Floating type Lysimeters with depth 120 cm and diameter 90 cm were used for the study. The soil of the Lysimeter was the same as that of the field surrounding. Crops were grown both in Lysimeter and the plot.

The evapo transpiration (ET) of the crops was computed as :

$$ET = (P+I)-\{(R+D) + \{\pm S\}\}$$

Where, P = Precipitation, I= Irrigation

R = Run off D = Deep percolation

S = Change in soil storage

2.3.1 Loss of water from fields under different crops

During *kharif* season there was substantial loss of water through deep percolation that varied with crops which were in the order groundnut(63.79cm)> maize(51.39cm)> paddy (45.24cm)> jower (29.36cm). But for *rabi* /summer season crops this component of loss was minimum (4.12-8.64cm). The evapotranspiration *(ETc)* values of 7different crops calculated using the water balance equation are: Jower (96.85 cm, summer groundnut (59.33cm), *rabi* groundnut(45.26cm), *kharif* rice (43.74cm), *kharif* groundnut (39.41cm), wheat (29.61cm), maize(24.41cm) and *rabi* mustard (22.22cm).

2.3.2 Losses of water through different components from a field

The deep percolation, evaporation and transpiration losses in case of paddy variety Pusa 2-21 were found to be 50.5 , 24.3 and 23.2% of total water requirement.

2.3.3 Reduction of percolation losses in paddy field

Application of Bentonite clay reduced the hydraulic conductivity of soils under rice with continuous shallow submergence(5±2cm) from 0.024cm/hr in a control plot to 0.004 and 0.002 cm/hr when the clay was applid at the rate of 250 and 500 kg/ha, respectively.

Table 2.4 Water balance for crops as measured in lysimeter

Crop	Season	Precipitation (cm)	Irrigation (I) (cm)	Run off (R) (cm)	Deep Porcolation (D) (cm)	Change in soil storage ± (S) (cm)	ET= (P+I)-{(R+D) ± S} (cm)
Jowar	Kharif	105.71	18.00	15.98	29.36	6.45	96.85
Groundnut	Summer	18.42	42.00	2.06	-	-3.46	59.33
Groundnut	Rabi	3.57	36.00	-	-	5.69	45.26
Groundnut	Kharif	106.57	-	13.07	63.79	9.00	39.41
Paddy	Kharif	79.74	9.30	5.83	45.24	5.02	43.74
Wheat	Rabi	98.54	29.27	-	4.12	1.27	29.61
Maize	Kharif	74.29	6.50	6.00	51.39	1.00	24.41
Mustard	Rabi	3.06	24.00	-	8.64	3.00	22.22

2.3.4 Field water balance study in groundnut

The field water balance for *kharif* with one pre sowing irrigation and for *rabi* and summer with irrigation at 1.2 IW/CPE was worked out. Evapo-transpition (ET) of crop during *kharif* was 27.54 cm and it varied from 32.5 to 54.5 cm in *rabi* and 37.78 to 50.97 cm in summer under different irrigation level. Runoff and percolation components were 25.6 and 47.1% of the total precipitation, respectively during *kharif*. The surface runoff loss was not observed during dry season. Change in soil moisture storage was almost similar in all the seasons. It was 2.49 cm in *kharif* and varied from 1.55 to 2.22 cm in *rabi* and from 1.52 to 2.97 cm in summer. The pod yield was significantly highest at 1.2 IW/ CPE during *rabi* and summer with a pod yield of 17.85 q/h and 34.85q/ha, respectively.

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CHAPTER- 3

IRRIGATION SCHEDULING IN DIFFERENT CROPS

Application of irrigation water at right time and in right amount as per the needs of the crop coupled with the use of other crop production inputs at or near optimum level is essential for efficient utilization of water for crop production. Where water resources are deficient as compared to land resources the objective should be to obtain maximum production per unit of water used. In such cases water may either be supplied at optimum level during the critical physiological stages of crops or alternate source of water should be tapped and used conjuctively for crop production. During last 40 years many basic and applied research have been made at AICRP on water management on various aspects of water management. Irrigation scheduling works related to some important crops are covered here.

3.1 Rice

Rice is the most important cereal crop of Orissa. The water requirement of rice is much greater than most other arable crops. Irrigation scheduling in rice depends upon many factors such as crop water requirement, moisture holding capacity, climatic situation of the area , water quality and its availability, depth of ground water table etc. Many research works on its water requirement and various methods of irrigation scheduling taking different factors into consideration have been done over the years. Some important studies are only reported in this book.

3.1.1 Water Management in rice in relation to ground water table

Ground water contributes to plant root zone through capillary rise. As fluctuation in depths of water table has a strong bearing on water management of rice which requires more water through out its growth. A field trial with varying depths(0,20,30,45,60cm) of controlled water table was conducted at Chakuli farm in Sambalpur district during 1976-77 to find out depth of water table under which submergence is required for rice cultivation and to determine critical water table depth under which maintenance of soil moisture at saturation through out the crop growth is adequate. At a particular water table depth rice (cv: Shakti) was grown under three moisture regimes; continuous saturation(irrigation at hair cracking),saturation till tillering followed by submergence(5±2cm) upto maturity and continuous submergence(5±2cm) upto maturity.Water tables were maintained at most of the time with a variation of ±2cm in all the blocks of the water table.

Results revealed that the grain yield decreased significantly with increasing depth of water table . At higher depths of water table (60 cm) the grain yield was less because of higher percolation and leaching losses of plant nutrients which ultimately inhibited the tiller production and reduced the grain yield. Highest grain yield (5716 kg/ha) was obtained at 0 water table depth. When averaged over the water table depths highest yield of 5834 kg/ha was obtained with shallow submergence (5±2cm) where as lowest of 4559 kg/ha was obtained at continuous saturation.

Interaction between water table depth and irrigation schedules was not significant. However, highest grain yield of 6214 kg/ha was obtained at '0' water table depth under continuous shallow submergence that inhibited weed growth and induced more number of effective tillers/m^2 in contrast to continuous saturation that allowed dense weed population resulting in less number of tillers/m^2. The critical water table depth appeared to be 30 cm, below which maintenance of adequate soil moisture is difficult.

Table 3.1 Yield of grain (kg/ha) as affected by the depth of water table and irrigation schedules

Irrigation Schedule	Water table depth (cm)					
	0	20	30	45	60	Mean
Continuous saturation	5043	4757	4629	4614	3700	4559
Saturation upto tillering followed by submergence	5872	5457	5372	5000	4814	5303
Continuous submergence	6214	6114	6000	5529	5314	5834
Mean	5716	5443	5334	5048	4608	—
CD(0.05)	Water table (W) = 442.87 Irrigation (I) = 357.15 Interaction (W x I) = NS					

3.1.1.2 Frequency of irrigation and irrigation requirement in different growth stages as affected by the depths of water table and irrigation schedules

Measurement of water requirement from the results of the some experiment revealed that irrigation requirement increased with increasing depths of water table. Generally continuous saturation treatment required less number of irrigation and consequently less amount of irrigation that varied from 46.65 cm to 121.70 cm within the

range of '0'cm to 60 cm depth of water table. The corresponding values of irrigation requirement under continuous submergence varied from 148.92 cm to 320.93 cm.

Continuous submergence under normal water table condition(0 cm) that gave the highest yield required 30 irrigations with application of 148.92cm of irrigation water. However, saturation till tillering followed by submergence that produced the next highest grain yield saved 16-20% of irrigation water.

Table 3.2 Irrigation requirement (IR) as affected by depths of water table and irrigation schedules

Irrigation schedule	Water table depth (cm)									
	0		20		30		40		60	
	No. of irrigations	IR (cm)	No. of irrigations	IR (cm)	No. of irrigations	IR (cm)	No. of irrigations	IR (cm)	No. of irrigations	IR (cm)
Continuous saturation	8	46	15	72	17	85	21	109	23	121
Saturation upto tillering followed by submergence	26	133	44	231	46	235	50	256	53	231
Continuous submergence	30	148	50	257	52	272	56	295	61	320

3.1.2 Effect of irrigation schedules on the growth and yield of rice

In order to find out a suitable irrigation schedule for rice a field experiment was conducted continuously for three years on an acidic (pH 5.0) sandy loam soil at Chiplima from 1979-80 to 1982-83 in both *kharif* and *rabi* seasons taking variety Jagannath grown in *kharif* and Jaya in summer with 6 irrigation schedules viz; continuous shallow submergence with 5±2cm water from establishment of seedling to maturity, 7 cm irrigation at 1day after the disappearance of ponded water (ADP), 7 cm irrigation at 2 days ADP,7 cm irrigation at 4 days ADP, 5±2 cm during tillering and reproductive stages and rain fed in *kharif* with life saving irrigation and 7 cm irrigation at 6 ADP during summer.

Results (Table 3.3) revealed that continuous shallow submergence of 5 ± 2cm gave significantly higher yield of grain and was at par with 5±2 cm irrigation provided only at tillering and reproductive phases, with the variety Jagannath in *kharif* and Jaya during both the seasons. Among the phasic submergence treatments 7 cm irrigation at one day ADP gave highest yield.

The water requirement for Jagannath (155 days) during *kharif* was 175, 161 and 156 cm with respect to continuous submergence during tillering and reproductive stage and 7 cm irrigation at 1 ADP, respectively. The water requirement at the corresponding irrigation levels in Jaya (145 days) during summer was 130, 119 and 121 cm, respectively. Thus highest saving of water with irrigation at 5±2 cm submergence provided at tillering and reproductive phases as compared to continuous shallow submergence of 5±2cm during both the seasons without significant reduction in yield. Irrigation at one day ADP also saved 19 cm water during *kharif* and 9 cm water during summer without much yield reduction.

Table 3.3 Grain yield, water requirement (WR) and field water use efficiency (FWUE) of rice under different irrigation schedules during *kharif* and *rabi* season

Irrigation schedule	*Kharif* Rice (cv: Jagannath-155 d)			Summer Rice (cv- Jaya-146 d)		
	Grain yield (q/ha) (Pooled Mean of 1979-81)	WR (cm)	FWUE (kg/ha-cm)	Grain yield (q/ha) (Pooled Mean of 1979-81)	WR (cm)	FWUE (kg/ha-cm)
5±2 cm Continuous submergence	44.9	175	25.55	72.1	130	55.12
7cm at 1ADP	39.8	156	25.42	66.0	121	54.46
7cm 2ADP	38.8	143	27.06	64.7	107	60.48
7cm 4ADP	35.0	133	26.26	58.4	99	58.74
5±2 cm at tillering and reproductive phases	44.0	161	27.27	70.8	119	59.11
Rainfed in Kharif and 6 ADP in summer	34.9	105	32.90	56.2	97	57.70
CD(0.05)	3.56			4.12		

3.1.3 Phasic submergence vs continuous submergence

In an experiment conducted with two rice varieties Jajati (Summer) and Daya (*kharif*) at Chiplima demonstrated that application of 7 cm irrigation at 3 days ADP during *kharif* and one day ADP during summer through channel to field method of irrigation on an average saved 12 to 15% water, improved water use efficiency by 15 to 20% over continuous submergence and helped in maintaining better soil health besides realizing good yields (Table 2.4).

Table 3.4 Grain yield, water requirement and water use efficiency as influence by irrigation schedule

Treatment	Season	Yield (t/ha)	WR (cm)	WUE (kg/ha-cm)
5 ± 2 cm continuous submergence	*Kharif*	3.7	142	25.7
	Summer	4.6	140	32.5
7 cm irrigation at one day ADP	*Kharif*	3.5	124	27.9
	Summer	4.1	122	33.8
7 cm irrigation at three days ADP	*Kharif*	3.3	113	29.1
	Summer	3.7	93	39.9
7 cm irrigation at five days ADP	*Kharif*	3.0	100	30.7
	Summer	3.6	87	41.7

3.2 Wheat

3.2.1 Effect of depth of irrigation and irrigation schedules on growth and yield of wheat

A field experiment was conducted on a sandy loam soil at Chiplima during Rabi 1982-83 to study the effect of depth of irrigation (6 cm and 8 cm) and levels of irrigation (0.6, 0.8,1.0 IW/CPE) grain yield of wheat (cv: Sonalika). The level of ground water remained below 2m during the entire crop growth period.

The result revealed that maximum grain yield of wheat was obtained when irrigation was applied at IW/CPE ratio of 1.0 (6cm CPE) Table 3.5. At this condition the water requirement (WR) and consumptive use (CU) were 33 and 26.2 cm, respectively, with the corresponding water use efficiency (FWUE) of 71.6 kg/ha-cm. No significant difference in yield was observed with variation in depth of irrigation water. The interaction effect between the depth of irrigation water and level of irrigation was also not significant.

Table 3.5 Grain yield (kg/ha) of wheat (cv : Sonalika) as affected by irrigation and depth of irrigation

Irrigation level (IW/CPE)	Grain yield (kg/ha) at different depth of irrigation (cm)			WR (cm)		Consumptive use (cm)		FWUE (kg/ha-cm)	
	6cm	8cm	Mean	6cm	8cm	6cm	8cm	6cm	8cm
0.6	1270	1095	1184	26.33	25.13	23.67	20.58	43.89	39.06
0.8	1400	1427	1412	26.73	31.53	24.04	24.70	47.31	40.88
1.0	2005	1750	1876	31.63	31.93	26.198	25.32	60.68	49.82
Mean	1560	1424	-	-		-			
CD(0.05)	Irrigation Level(I)=312,Depth of Irrigation (D)=NS; I×D=NS								

The effect of various irrigation schedules on wheat(cv: Sonalika) was studied during *rabi* 1983-84 and 1984-85. The treatments consisted of three sowing conditions (sowing at optimum moisture followed by 1 irrigation 7 days after sowing, farmer practice, and dry sowing followed by irrigation) and four irrigation levels (0.6, 0.8, 1.0, 1.2 IW/CPE ratio) with uniform depth of irrigation water (6 cm). The soil of the experimental site was sandy loam with bulk density of 1.7 g/ cc. Results (Table 3.6) showed that dry sowing followed by irrigation produced highest mean grain yield of 18.2 q/ha which was significantly higher than that with other sowing conditions. The grain yield also increased significantly with increasing levels of irrigation from 0.6 to 1.0 IW/CPE. The interaction effect between the sowing condition and irrigation levels was however, not significant. With increasing level of irrigation both water requirement and consumptive use also increased.

Table 3.6 Water requirement of wheat (var. Sonalika) as affected by different irrigation schedules under different sowing conditions

Sowing Conditions	Irrigation Schedules (IW/CPE)	Yield (kg/ha)	Duration (days)	WR (cm)	CU (cm)	FWUE (kg/ha-cm)
Pre sowing irrigation	0.6	1179	84	20.51 (1)	20.25	57.48
	0.8	1237	84	23.41 (1)	21.83	52.84
	1.0	1413	84			
	1.2	1196	84	32.05(2)	31.34	37.31
Pre sowing irrigation + one irrigation at 7 DAS	0.6	1221	84	26.04(2)	24.63	46.88
	0.8	1263	84	28.90(2)	26.03	43.70
	1.0	1430	84	32.47(3)	28.71	44.04
	1.2	1118	84	37.54(4)	32.84	29.78
Post sowing irrigation dry sowing followed by irrigation	0.6	1673	84	22.45(2)	20.61	74.52
	0.8	2057	84	24.60(2)	23.24	83.61
	1.0	2214	84	28.91(3)	26.33	76.58
	1.2	1914	84	34.09(4)	30.67	56.14
CD (0.05)	Yield : Irrigation level – 74, Sowing conditions – 86, Interaction effect - NS					

3.3 Groundnut

3.3.1 Growth and yield of groundnut under varying moistures regimes

A field experiment with nine irrigation treatments consisting of application of irrigation at two stages of crop growth, pegging and pod filling with different combinations

of three types of irrigation levels viz; IW/CPE of 0.9,0.75 and 0.60 (Table 3.7) was conducted during *rabi*, 1980 in a sandy clay soil having pH,6.2 ,0.38% total N ,21.28 kg available P_2O_5 132.5 kg available K_2O/ha and 0.42% organic carbon.

Results indicated that irrigation at 0.9 IW/CPE (66.7mm CPE) throughout the crop growth period produced highest pod yield of 10.2 q/ha with significantly higher content of important biochemical constituents such as chlorophyll (6.81.mg/g),sugar (41 mg/g) and amino acids (125.33 mg/g) which have a bearing on the seed quality (Table 3.7). The water requirement of the variety Kishan(136 day) at this level of irrigation was about 38 cm with the corresponding water use efficiency of 47.3 kg/ha-cm.

Table 3.7 Pod yield, water requirement, water use efficiency and biochemical constituents as influenced by irrigation schedules in groundnut

Irrigation schedul (IW/CPE)		Pod Yield (q/ha)	WR (cm)	FWUE (kg/ha-cm)	Biochemical constituents of fresh leaf		
Pegging stage	Pod filling stage				Chlorophyll (mg/g)	Sugar (mg/g)	Aminoacid (mg/g)
0.90	0.90	10.2	38.0(5)*	26.73	6.81	41.0	125.3
0.90	0.75	8.3	33.2(4)	24.99	6.31	35.0	85.3
0.90	0.60	6.8	32.0(4)	21.33	5.95	29.0	48.0
0.75	0.90	8.6			6.67	39.0	95.3
0.75	0.75	7.4	33.0(4)	22.41	6.31	30.0	80.0
0.75	0.60	5.5	27.6(3)	19.81	5.95	20.0	41.5
0.60	0.90	7.1	33.2(4)	21.46	6.27	34.0	77.3
0.60	0.75	4.3			5.75	21.5	48.0
0.60	0.60	4.0	27.4(4)	14.48	5.32	10.0	37.3
CD(.05)		2.4					

*Figures in Parenthesis indicate number of irrigations

Measurement of chlorophyll, sugar and amino acid of fresh leaves revealed that during earlier stages the groundnut crop can resist moisture stress to some extent but not at later stages.

In another experiment scheduling of irrigation in groundnut(cv:TG-3) with 10 irrigation treatments was studied during summer 1982. The water table was below 1.75 m throughout the growing season. Among the treatments irrigation at 1.2 IW/CPE with IW of 6cm produced highest pod yield of 33.69 q/ha which was significantly higher than those at other treatments except the schedules where 15 and 11 irrigations were applied. Total water requirement for highest yield was 70.9 cm with FWUE of 47.51kg/ha-cm.

3.3.2 Response of groundnut to irrigation schedules under different water table conditions

A field experiment was conducted with OG-85-1 a spanish bunch groundnut during summer 1992 and 1993 on a slopy terraced field having clay loam texture where water table fluctuated within 50±10, 90±10 and 110±10 cm below the surface. In each water table condition, the crop was irrigated at 0.2,0.4,0.6,0.8,1.0 and 1.2 IW/CPE ratio(IW=60mm).

Results showed that the pod yield increased significantly from 11.6 q/ha at stress (0.2 IW/CPE) to 22.5 q/ha at wettest regime of 1.2 IW/CPE and from 14.7 q/ha in 50±10cm to 20.3 q/ha in 110±10 cm water table condition. Response to irrigation was quadratic under 50±10 cm and 90±10 cm water table conditions. With optimum irrigation and water requirement of 8,10,48.4 cm and 66.8 cm respectively. In 110±10 cm water table condition the response was linear. Optimum water table depth was estimated to be 118.5 cm. Irrigation and water table interaction effect was significant.

3.3.3 Influence of irrigation on yield and moisture utilization of groundnut

A field experiment was conducted during 1994-97 on clay loam soil of medium land with winter groundnut. The pod yield increased with increasing IW/CPE with 52.5 cm evapo transpiration, 76.1 cm water requirement (WR) and 42.8 kg/ha-cm crop water use efficiency (CWUE). It required12 irrigations of 6cm depth each with ET/PE ratio of 0.87. Most of the ancillary characters however, showed increasing trend upto IW/CPE of 1.2 which also gave pod yield of 21.91q/ha which was at par with that of IW/CPE of 1.4. The value of ET, WR, runoff and percolation at 1.2 IW/CPE were 46.95, 65.39, 3.25 and 21.39 cm, respectively. The crop water use efficiency and field water use efficiency were 46.69 and 33.81kg/ha-cm respectively with ET/E pan value of 0.78 at this moisture regime.

3.3.4 Moisture extraction pattern, phasic water use and phasic growth in groundnut under varying moisture regime and ground water table condition

An experiment conducted during summer 1992 and 1993 with groundnut on moisture extraction pattern, phasic water use and growth at Chiplima showed that moisture extraction increased with lowering of ground water table. On an average, crop extracted 18.6 cm water from 60 cm profile 50±10 cm water table depth which increased to 25.2 cm and 26.7 cm at 90±10 and 110±10 cm water table depth respectively. Extraction was maximum (9.12 cm) at surface layer of 0-15 cm which accounted for 39.9% of the

total extraction. It reduced to 7.31 cm (31.6%), 4.13cm (18.7%) and 2.45 cm (9.8%) with increase in profile depth by 15cm up to 60cm profile, respectively. Groundnut used the maximum water of 3.11 cm/day with maximum growth in terms of crop growth rate (10.18g/m^2 per day) and net assimilation rate (3.31g/m^2 per day) during 56-90 days of its growth. Water use showed significant positive correlation with pod yield at lowest water table depth, 'r' value of 0.994 being the maximum.

3.4 Mustard

3.4.1 Scheduling of irrigation in mustard based on altered physical conditions of soil

Experiment was conducted with eight treatments *viz.*, soil: sand in 1:1 ratio, sunflower as indicator plant , polythene at 30 cm depth, polythene at 45cm depth ,IW/CPE of 0.9, two times plant population, four times plant population and tin containing soil with free percolation which were imposed in small test plots in side main plots of mustard crop for assessing effect of water stress and suitability of irrigation schedules. The soil of the experimental site was sandy loam with a sandy clay sub soil having pH 6.0, organic carbon (0.40%). The level of ground water was below 100 to 130 cm during the crop growth period. No significant difference in yield was noticed due to various treatment though the highest yield of 13.6 q/ha was recorded at 0.9 IW/CPE ratio with water requirement of 30 cm and WUE of 44.9 kg/ha-cm.

3.4.5 Effect of moisture stress on *rabi* potato

A field experiment was conducted to study the effect of moisture stress on potato grown during *rabi* in a moderately well drained sandy loam soil underlain with a sandy clay loam soil at Chiplima in order to study the effect of moisture stress on *rabi* potato(cv: Kufri Chndramukhi) during 1977-78. Results (Table 3.8 and Table 3.9) revealed that application of irrigation between 0.9 to 1.5 ratios of IW/CPE influenced yield of potato which increased significantly up to IW/CPE of 1.05 and then reduced at higher IW/CPE. More frequent irrigation at IW/CPE ratio of 1.5 reduced the yield significantly by spoiling the tubers in higher moisture condition. Similarly at 0.75 and 0.6 ratios of IW/CPE, water stress produced significantly lower yield because of less frequent irrigation which inhibited the tuber formation.

The yield of potato was also influenced by the depth of irrigation. It is kobserved that 3cm depth of irrigation was superior to 4.5 cm depth of irrigation as the latter was applied at longer interval which was not conducive for tuber formation. Highest tuber yield of potato of 210 q/ha

Table 3.8 Yield of potato (kg/ha) as affected by soil moisture stress and different depths of irrigation

Irrigation level (IW/CPE)	Tuber yield (kg/ha) Depth of Irrigation		Mean
	3 cm	4.5 cm	
1.50	12158	12638	12398
1.20	17918	20160	19039
1.05	20962	18398	19680
0.90	17428	17122	17275
0.75	10882	10238	10560
Mean	15870	15711	15791
CD(0.05)	Moisture Level (M) = 3177 Irrigation depth (I)= NS M x I= NS		

Table 3.9 Total water requirement potato at different levels and depths of irrigation

Irrigation Level (IW/CPE)	CPE (mm)	Soil contribution (cm)	No. of irrigation	Irrigation application (cm)	Effective rainfall (cm)	Total water requirement (cm)
3 cm depth of irrigation						
1.50	20.0	0.5	8	24.0	Nil	24.5
1.20	25.0	0.2	7	21.0	Nil	21.2
1.05	28.6	1.2	6	18.0	Nil	19.2
0.90	33.3	1.7	5	15.0	Nil	16.7
0.75	40.0	0.3	5	15.0	Nil	15.5
4.5 cm depth of irrigation						
1.50	30.0	0.5	6	25.5	Nil	26.0
1.20	37.5	1.9	5	21.0	Nil	22.9
1.05	42.9	0.4	5	21.0	Nil	21.4
0.90	50.0	1.7	4	16.5	Nil	18.2
0.75	60.0	0.4	4	16.5	Nil	16.9

was recorded from the treatment IW/CPE 1.05 under 3cm depth of irrigation which received six irrigation having mean irrigation and water requirement of 18.0 cm and 10.2 cm, respectively.

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CHAPTER-4

IRRIGATION SCHEDULING IN DIFFERENT CROPPING SYSTEMS

Crops vary in their performance with the ground water table and water regimes in different soils of a particular region. Depending on the changes in water regimes and available moisture, crops are to be selected judiciously so that the cropping system is most productive and profitable.

4.1 Evaluation of suitable crop rotation in medium land

The experiment was conducted on sandy loam soil during 1982-83 with three dates of sowing (early, normal and late) of crops in rice-mustard-rice, rice -wheat-mung, rice –potato-til sequence under two levels of irrigation. The soil was acidic (pH 5.8) with 0.5% organic carbon, 17.9 kg/ha available P_2O_5, 199 kg/ha available K_2O and total nitrogen 0.035%. The ground water remained between 1.5 to 2.0 m.

Table 4.1 Irrigation schedules for different cropping systems

Crop	Irrigation schedule		IW (cm)
Rice *(kharif)*	Rain fed with life saving irrigation (I_1)	Continuous submergence (I_2)	
Rice (Summer)	Saturation	-do-	
	IW/CPE		
Mustard	0.75	0.9	6.0
Wheat	0.9	1.05	6.0
Potato	0.9	1.5	3.0
Mung	0.6	0.8	6.0
Till	0.75	0.9	6.0
Dates of sowing /planting			
	D_1	D_2	D_3
Rice*(kharif)*	9.7.82	25.7.82	10.8.82
Mustard	29.11.82	5.12.82	13.12.82
Rice(Summer)	5.2.83	16.2.83	26.2.83
Wheat	1.12.82	7.12.82	15.12.82
Mung	19.3.83	31.3.83	10.4.83
Potato	29.11.82	5.12.82	13.12.82
Til	4.3.83	9.3.83	14.3.83

Table 4.2 Net return and water requirement of crop sequences under different dates of sowing and irrigation levels

Date of sowing / Irrigation level	Rice –mustard -rice		Rice –wheat-mung		Rice-potato-til	
	Net return (Rs/ha)	WR (cm)	Net return (Rs/ha)	WR (cm)	Net return (Rs/ha)	WR (cm)
D_1I_1	3430	249.9	2953	182.0	6766	188.7
D_1I_2	7757	306.1	4077	231.4	12230	235.9
D_2I_1	3857	213.9	3229	151.9	6950	156.1
D_2I_2	6922	286.2	4443	222.5	11736	223.8
D_3I_1	3036	211.1	2904	149.6	6158	143.8
D_3I_2	5640	264.2	4060	201.3	9473	193.5
Mean	5107	255.2	3611	189.8	8885.5	190.3

Higher net return was obtained from all the sequences when frequent irrigation (I_2) was applied irrespective of sowing dates. Rice-potato-til sequence gave the highest net return of Rs.12230/ha under early sowing with frequent irrigation (WR-236 cm) (Table 4.2). On an average, rice-potato-till was the most profitable sequence both in terms of economics and water use. It saved about 34% water over the sequence rice-mustard-rice.

4.2 Evaluation of suitable crop rotation for medium land under constraints of irrigation water

The experiment was conducted with three crops grown in a sequence in three seasons, *kharif*, *rabi* and summer during 1983-84 and 1984-85 . It consisted of four crop sequences; rice-mustard-rice, rice-wheat –mung, rice-potato-til and rice-black gram – groundnut. The details of irrigation treatments are presented in Table 4.3.

Table 4.3 Irrigation schedule for different crops

Crops	Duration	Irrigation levels		Depth of irrigation (cm)
		K_1	K_2	
Rice (*kharif*)	111	Rain fed with live saving irrigation	Shallow submergences with 5 ± 2cm irrigation	
Rice (Summer)	128	Saturation	-do-	
		IW/CPE		
Mustard(M-27)	75	0.75	0.9	6.0
Wheat (Sonalika)	93	0.80	1.0	6.0
Potato (K.Ch.)	82	0.9	1.2	4.5
Black gram (T9)	88	0.6	0.8	6.0
Mung (TT 9 E)	63	0.6	0.8	6.0
Til (S 14)	91	0.75	0.9	6.0
Groundnut (Kissan)	115	0.9	1.2	6.0

The soil of the experimental site was sandy loam with pH 5.8, Organic carbon 0.405%, available P_2O_5 17.92 kg/ha ; K_2O 199.2 kg/ha and total nitrogen 0.035%.

Table 4.4 Net return (NR) and water requirement (WR) of crop sequences under varied levels of irrigation

Irrigation schedule	Rice-mustard-rice		Rice-wheat-mung		Rice-potato-til		Rice-blackgram-ground nut	
	NR(Rs/ha)	WR(cm)	NR(Rs/ha)	WR(cm)	NR(Rs/ha)	WR(cm)	NR(Rs/ha)	WR(cm)
$K_1R_1S_1$	2996	224.5	3711	150.2	7061	162.9	4964	183.1
$K_1R_1S_2$	5028	231.9	4574	152.0	7789	169.3	5712	186.3
$K_1R_2S_1$	4709	237.0	5201	159.2	9877	166.5	5299	191.4
$K_1R_2S_2$	6662	244.7	5768	160.8	10309	171.7	6948	194.1
$K_2R_1S_1$	5270	237.3	5796	163.0	8910	175.1	6572	195.9
$K_2R_1S_2$	6559	245.0	6308	164.7	9384	180.4	7519	198.7
$K_2R_2S_1$	6619	249.6	6217	171.6	11376	178.9	7479	204.1
$K_2R_2S_2$	7500	257.4	7062	123.2	12748	184.1	8786	206.3
Mean	5618	240.9	5579	161.8	9682	173.6	6660	195.0

Maintenance of optimum irrigation levels in all the three crops in sequence produced the highest net return/ha, irrespective of the crop sequences followed. Rice-potato-til sequence gave the maximum net return of Rs.12748/ha with a total water requirement of 148 cm. Thus, by adopting the sequence rice-potato-til, an extra income of about 70% can be obtained besides a saving of about 73 cm water over rice-mustard-rice sequence which stood least remunerative among the sequences grown in Hirakud command.

4.3 Evaluation of suitable crop rotation under constraints of irrigation water

To determine the most suitable cropping pattern for medium land in Hirakud Command, field experiment was conducted with five crops such as maize, groundnut, wheat, potato and mustard each in sequence with *kharif* rice under three irrigation schedules of optimum, sub optimum and stress conditions in a sandy loam soil of Chiplima for four years during 1985-86 to 1988-89. Rice was grown in *kharif* with 7 cm irrigation each at 1, 3 and 5 ADP, groundnut with 6 cm water at 0.6, 0.9, and 1.2 IW/CPE, mustard at 6 cm irrigation in 0.5, 0.7, and 0.9 IW/CPE, maize with 6 cm at 0.5, o.7, and 0.9 IW/CPE, wheat with 6 cm, at 0.5, 0.75, and 1.0 IW/CPE and potato under 4.5 cm at 0.5, 0.7 and 0.9 IW/CPE ratio.

Table 5.5. Irrigation schedules in different cropping systems

Crop	Irrigation schedule			Depth of water applied (cm)
	I_1	I_2	I_3	
Rice	7 cm irrigation at 1 ADP	7 cm irrigation at 3 ADP	7cm irrigation at 5 ADP	7.0
	IW/CPE ratio			
Maize	0.5	0.7	0.9	6.0
Groundnut	0.6	0.9	1.2	6.0
Wheat	0.5	0.75	1.0	6.0
Potato	0.5	0.7	0.9	4.5
Mustard	0.5	0.7	0.9	4.5

Table 4.6 Net return of cropping sequence, yield, water requirement and water use efficiency of the component crops as influenced by different irrigation schedules

Cropping sequence	Net return (kg/ha)	Irrigation schedule	Crop	Yield (kg/ha)	WR (cm)	WUE (kg/ha-cm)
Rice-maize	5843	I_1I_3	Rice	3740	135.0	27.70
			Maize	2940	41.6	70.67
Rice-groundnu	10157	I_1I_3	Rice	3940	135.0	29.19
			Groundnut	2190	74.2	29.51
Rice-wheat	2862	I_1I_3	Rice	4000	135.0	29.63
			Wheat	1590	35.1	45.29
Rice-potato	6901	I_3I_3	Rice	3383	94.6	35.76
			Potato	11210	24.2	463.22
Rice-mustard	2656	I_1I_2	Rice	3850	135.0	28.52
			Mustard	430	19.0	22.63

Rice -groundnut sequence was the most profitable one with a net profit (average of 4 years) of Rs.40,147/- per ha under the irrigation levels of I_1 I_3. On an average, 39.4 q/ha of rice (water requirement 135 cm) and 21.9 q/ha of groundnut (7.4.2 cm of water) was obtained. The corresponding water use efficiency was 29.2 and 29.5 kg/ha-cm, respectively. It was followed by rice-potato sequence (Rs.6901/ha) where the I_3 I_3 level of irrigation was maintained. The mean yield of rice under this irrigation level was 33.8 q/ha with water requirement of 94.6 cm and that of potato was 112 q/ha with water requirement of 24.2 cm .The water use efficiency for rice and potato being 35.7 and 463.2 kg/ha-cm, respectively.

Examination of the data on the net return under each sequence and their corresponding irrigation schedules revealed that the treatments I_1 I_3, I_3 I_3, I_1 I_2 taking all the rotations in to consideration, were rated in the order of first, second and third, respectively. But, the ratings assigned to net return obtained from each sequence under above irrigation schedules revealed that the differences among these treatments were not statistically significant.

With respect to net returns, I_1 I_3 was rated first among all the treatments except I_3 I_3 which was at par with the former and was rated second. Irrigation to rice at I_1 (1 ADP) level and to *rabi* crops at I_3 levels gave maximum net return and yield advantages, and thus is considered to be a common standard irrigation schedule for all the sequences.

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CHAPTER-5

WATER –NUTRIENT INTERACTION STUDIES

Water and fertilizers are two important inputs that stear plant growth and development. Their efficiency depends upon the way they interact under a particular soil, climate and crop condition. Studies on interaction are important in managing the inputs for increasing productivity and use eficiency.Following are some of the studies made at Chiplima.

5.1 Effect of various water regimes on the yields of rice under varying levels of nitrogen

In order to determine optimum water regime for rice in relation to nitrogen levels a field experiment consisting of four nitrogen levels (0,40,80 and 120 kg N/ha) and four irrigation schedules(5±2 cm of continuous submergence,7 cm irrigation at 1day after disappearance of ponded water(1ADP),7 cm irrigation at 3ADP and 7 cm irrigation at 5ADP) was conducted for two years (1985-86 and 1986-87)in both *kharif* and summer seasons with Lalat as the test variety of rice .

Pooled analysis of the season wise data of two years on grain yield of rice revealed that maintenance of continuous submergence with 5±2 cm water through out the growth period produced maximum yield of 36.5q/ha which was at par with the yield(34.6q/ha) obtained with 7 cm irrigation at 1ADP. In summer continuous submergence also produced highest yield(36.1q/ha) which was however significantly more than that in other treatments.

At Chiplima Lalat variety of rice significantly responded to nitrogen application up to 40kg N/ha in *kharif* and upto 120kg in summer. The response curve was quadratic ($y= 29.1+ 4.05x -0.45x^2$) in *kharif* and linear in summer. Interaction between N levels and irrigation schedules was not significant (Table 5.1).

Table 5.1 Grain yield of rice as affected by irrigation and nitrogen level

Irrigation Level	Grain yield (q/ha)				
	Pooled mean of *kharif*	Pooled mean summer	Nitrogen level (kg/ha)	Pooled mean of *kharif*	Pooled mean summer
5±2 cm submergence throughout	36.5	36.1	0	29.1	26.9
7 cm irrigation 1 ADP	34.6	32.0	40	32.7	30.7
7 cm irrigation 3 ADP	32.9	31.8	80	35.4	35.5
7 cm irrigation 5 ADP	30.4	29.1	120	37.2	37.7
CD(0.05)	3.19	2.20	CD (0.05)	3.19	2.20
S x N	NS				

5.1.1 Direct, cumulative and residual effect of applied nitrogen under different moisture regimes

Direct, cumulative and residual effect of applied nitrogen (0,40,80 and 120 kg/ha) was studied on sandy clay loam soil under two moisture regimes(saturation in *rabi*/rain fed in *kharif* with life saving irrigation and submergence with 5± 2 cm throughout) during wet and dry seasons of 1982, 83 and 84 (Table 5.2).

Result showed higher direct effect of nitrogen during *rabi* than *kharif* whereas the trend was reverse in case of residual effect. The cumulative effect was significantly higher in *rabi* only at higher doses of N. The response equations that best described the relationship between N applied and grain yields was $Y=21.51 + 15.19x - 2.06x^2$ for direct application in *rabi* followed by residual in *kharif* with optimality at 88.17 kg and 134.27 kg N/ha and yields of 33.95 q/ha and 49.3q/ha in *kharif* and *rabi* season, respectively.

Similar quadratic response equations were also obtained for describing the cumulative effect of applied nitrogen both in wet season ($Y=23.77 + 9.0X-10.87x^2$) and dry season ($y=20.86+15.56x - 2.06x^2$) and the optimum level of nitrogen was 81.96 and 136.5 kg N/ha with corresponding estimated yields of 34.4 and 49.7 q/ha respectively. In both the season continuous submergence produced significantly higher yield at all levels of N. Interaction between the nitrogen and irrigation was not significant.

Table 5.2 The direct, residual and cumulative effect of nitrogen on grain yield in rice-rice sequence

Nitrogen level (kg/ha)	Grain yield of rice (q/ha) - *Kharif*									
	Direct				Residual			Cumulative		
	1982	1983	1984	mean	1983	1984	mean	1983	1984	mean
0	23.3	21.2	25.9	23.5	23.1	24.5	23.8	22.0	26.2	24.0
40	29.4	29.6	28.5	29.2	24.1	26.3	25.2	32.5	30.5	31.5
80	33.8	34.4	34.2	34.1	24.6	22.2	33.4	35.8	33.8	34.8
120	34.1	33.6	33.3	30.7	24.1	23.6	23.9	24.6	33.2	33.9
Mean	30.2	29.7	330.5	30.13	24.0	24.2	24.1	31.2	30.9	31.05
Grain yield of rice (q/ha) - *Rabi*										
0		22.5	22.4	22.5	17.3	20.5	18.9	21.9	22.6	22.3
40		32.7	34.0	33.4	183	20.8	19.6	34.0	33.8	33.9
80		48.2	43.3	45.9	24.1	22.1	23.1	45.2	43.0	44.1
120		51.8	44.8	48.3	19.6	21.3	20.5	53.8	43.6	48.7
Mean		38.8	36.1	37.45	19.8	21.2	20.5	38.7	35.8	37.25

5.1.3 Effect of different sources of nitrogen under varying moisture regimes in rice

A field experiment consisting of four nitrogen sources (urea, ammonium sulphate, rock phosphate coated urea, groundnut cake coated urea) and three irrigation schedules (rainfed, 5±2 cm submergence through out and 7 cm irrigation at 1 ADP) was conducted with rice cv: Lalat in a sandy clay loam soil during *kharif* 1984 under the fluctuating ground water table condition (from surface flow to 40 cm below the ground level) in order to determine optimum water regime for rice in relation to nitrogen levels.

Results on yield showed no significant differences among the various sources and irrigation schedules. An effective rainfall of about 74 cm was adequate for rice variety Lalat of 95 days duration under shallow water table condition in sandy clay loam soil.

5.1.4 Effect of various water regimes under varying levels of fertility on yield of rice

An experiment was conducted on a sandy loam soil at Chiplima in wet and dry seasons of 1982 to 1984 with five levels of fertility (0:0:0, 30:15:15, 60:30:30, 90:45:45 and 120:60:60 kg $N:P_2O_5:K_2O$ /ha) and three levels of water management practices (continuous shallow submergence, submergence at tillering and reproductive stage and rainfed in *kharif* followed by saturation in *rabi*) to study the response of rice. The ground water table remained in between 1.5 m to more than 2.0 m during the course of investigation. Results revealed that grain yield of Jajati increased significantly with the increasing fertility levels up to 120:60:60 kg/ha but it was at par with 90:45:45 kg $N:P_2O_5:K_2O$ /ha in both dry and wet seasons. The fertilizer use efficiency and profit per unit of fertilizer applied was higher during dry season than wet season.

Significant increase in yield was also observed with increase in irrigation frequency in both the seasons. An increasing trend in uptake of N P and K was also noticed with the increase in irrigation frequency. The leaf area index (LAI) that increased between 15 and 45 DAT and declined there after showed positive relationship with fertility level and irrigation frequency. The rate of increase in LAI was higher in dry season than that of wet season. Almost similar trend was observed with respect to chlorophyll concentration (kg/mg of fresh weight) in the third leaf from top.

5.2.1 Effect of irrigation schedules and nitrogen levels on wheat

The experiment was conducted on a sandy loam soil with four levels of nitrogen (0,40,80,120 kg N/ha) and three levels of irrigation(0.6,0.8 and1.0 IW/CPE ratio) for

three years 1980-81, 1981-82 and 1982-83.The soil was moderately acidic (pH 5.3), low in organic carbon (0.369%), medium in available phosphorus (24.64kg/ha) and low in available potassium (100 kg/ha). Total nitrogen content was 0.032%. Water table remained below 2 m from the ground surface during the study period.

Grain yield of wheat (cv:Sonalika) increased significantly and almost linearly with the increasing levels of nitrogen up to 120 kg/N/ha (20.8 q/ha) and so also with increase in IW/CPE ratio from 0.6 to 1.0 .Water requirement at 1.0 IW/CPE was found to be 33 cm and consumptive use was 28.6 cm with the corresponding water use efficiency of 66.5 kg/ha-cm (Table 5.3). The interaction between irrigation and nitrogen level was statistically non-significant.

Table 5.3 Grain yield of wheat as influenced by irrigation schedules and nitrogen levels

Particulars	Grain yield (q/ha)			Pool of three seasons
	1981	1982	1983	
Irrigation Schedules at IW/CPE				
0.6	16.91	11.33	12.67	13.64
0.8	18.58	15.86	16.67	17.11
1.0	20.00	18.00	20.15	19.02
CD (0.05)	1.45	3.59	2.82	1.297
Nitrogen levels (kg/ha)				
N0	13.20	14.40	11.56	11.45
N40	17.60	14.13	15.73	15.61
N80	20.28	16.66	18.28	18.54
N120	22.32	19.06	20.49	20.77
CD (0.05)	1.70	3.99	3.29	1.49
Interaction (I x N)				
CD (0.05)	NS	NS	NS	

5.2.2 Effect of irrigation schedules and levels of potash on the growth and yield of wheat

The experiment was conducted during *rabi* 1982-83 with four levels of potash (0,30,60,90 kg K_2O/ha) and three levels of irrigation (0.6, 0.8, 1.0 IW/CPE ratio) under a common depth of 6 cm. The soil of the experimental site was acidic in reaction (pH 5.8), low in organic carbon (0.405%), low in available P_2O_5 (17.92 kg/ha) and medium in Potash (199 kg K_2O/ha). The total nitrogen content was 0.035%.

No significant difference in yield was recorded due to various levels of potash although linear increase was observed up to 90 kg K_2O/ha . Significantly higher yield of 20.8 q/ha was obtained where irrigation was applied at 1.0 IW/CPE ratio. The water requirement and consumptive use under this treatment were 31.3 and 25.6 cm, respectively, with the corresponding water use efficiency of 81.15 kg/ha-cm. The interaction between the levels of potash and irrigation was not significant.

5.3 Response of mustard to nitrogen under different water regimes

Experiment conducted with four levels of nitrogen (0,20, 40 and 60 kg N/ha) and two irrigation levels of 0.75 and 0.9 IW/CPE ratio during *rabi* 1981-82 revealed that the yield was significantly increased with N levels upto 60 kg N/ha that produced highest yield of 8.96q/ha which was at par with that of 40 kg N/ha (6.9 q/ha).Irrigation levels however, had no significant effect on grain yield. For highest yield, water requirement and consumptive use of mustard (M-27) were found to be 22 cm and 19 cm, respectively.

5.4 Effect of phosphorus levels on summer groundnut at different moisture regimes

The experiment was carried out in summer 1983 and 1984 on a sandy loam soil having 0.035 % total nitrogen, 199 kg available P_2O_5/ha, 0.405% organic carbon with pH value of 5.8 .The ground water fluctuation was below 2.0 m during the crop growing period.

Pooled analysis of two years revealed that a phosphorus level of 40 kg P_2O_5/ha produced significantly higher yield of 18.3 q/ha. Application of 6 cm irrigation at 1.2 IW/CPE ratio through out the crop growing period produced highest yield (18.8 q/ha) with water requirement of 68 cm and consumptive use of 57 cm having water use efficiency of 33 kg/ha-cm.Moisture regime showed no interaction effect on P level.

5.5 Effect of various irrigation schedules and levels of nitrogen on sesamum

The experiment was conducted during summer 1985, 1986 and 1987 on a sandy loam soil at Chiplima revealed that grain yield of sesamum increased significantly with the increasing level of nitrogen up to 60 kg/ha (8.6q/ha).More frequent irrigation at 1.05 IW/CPE was not conductive for sesamum. Irrigation at 0.9 IW/CPE produced significantly

higher yield of 8.1 q/ha with water requirement of 45 cm and crop water use efficiency 35 kg/ha-cm.

5.6 Effect of irrigation schedules and nitrogen levels on the growth and yield of potato

A field experiment was conducted during *rabi* 1982 on sandy loam soil with a pH of 5.8, 0.405% organic carbon, available P_2O_5 17.92 kg/ha, available K_2O 199.2 kg/ha and total nitrogen 0.035% . The treatment consisted of three irrigation levels of 0.9, 1..05 and 1.20 IW /CPE with 3.0 cm depth and four nitrogen levels of 0, 50,100,150 kg/ha. Ground water remained below 2.0 m during the study period.Interaction effect was not significant.

Highest tuber yield of 136.5q/ha was recorded with irrigation at 1.2 IW/CPE. This yield was at par with that obtained at 0.9 IW/CPE ratio (126.75 q/ha). The water requirement and consumptive use under these two levels of irrigation were 27.8, 25.8, 24.3 and 23.9 cm with the corresponding crop water use efficiency of 562 and 491 kg/ha-cm, respectively. The tuber yield significantly increased with N levels up to 100 kg/ha that produced 142.70 q/ha. Interaction between irrigation and N level was non significant.

5.7 Effect of nitrogen and irrigation schedules on sugarcane

The experiment was conducted for two years during 1986 to 1988. The treatment consisted of four levels of N (100, 150, 200 and 250 kg N/ha) and three levels of irrigation (0.8, 1.0 and 1.2 IW/CPE). The depth of water applied during each irrigation was 6.0 cm. The soil of the experimental site was sandy clay loam up to a soil profile of 30 cm. The soil contained 0.45% organic carbon with a pH value of 6.5. The ground water table remained between 1.5 m during first two seasons but during 3rd season because of change in site, the groundwater was more than 2 m from the ground surface during the dry months.

The data on yield of cane for the 1st two seasons have been pooled but that of 3rd year has been discussed separately. Pool of two season revealed a significant increase in yield up to 200 kg N/ha (66.74 t/ha) though the highest yield was obtained at 250 kg N/ha. The response was quadratic.

$$Y=35.611+23.875x-4.402x^2$$

The optimum and maximum dose of nitrogen was observed to be 245 and 271 kg N/ha with the corresponding cane yield of 67.68 t/ha, respectively. Significantly highest yield of cane 66.24 t/ha was recorded at 1.2 IW/CPE (5cm CPE) but it was at par with that of irrigation at 1.0 IW/CPE ratio. The mean water requirement under irrigation level of 1.2 and 1.0 IW/CPE was found to be 204 and 189 cm with corresponding water use efficiency of 330.68 and 353.12 kg/ha-cm. Interaction between N × I was not significant.

During 3rd year the response to nitrogen was quadratic and the optimum dose was found to be 236.5 kg N/ha with an estimated yield of 111.42 t/ha. The response curve, $Y=74.91+14.34x-1.4x^2$ was almost similar to that of 1st two years. The interaction between nitrogen level and irrigation was significant. Highest yield of 118.9 t/ha was recorded with irrigation at 1.2 IW/CPE ratio with nitrogen level of 250 kg /ha. which was at par with that of 1.2 IW/CPE at 200 kg N/ha.

5.8 Long term effect of nitrogen and irrigation management on yield sustainability of sugarcane ratoon

A three year long experiment was conducted on a ratoon sugarcane crop with 200, 250 and 300 kg N/ha applied with or without organic manure and biofertiliser materials under three levels of irrigation(20% and 30% depletion of ASM and irrigation at 1.2 IW/CPE) at Chiplima from 2005 on a neutral sandy clay soil with low N level. Observation on third year of ratoon revealed that irrigation at 1.2 IW/CPE produced significantly higher cane yield of 54.5 t/ha when applied in combination with 300 kgN/ha. which was more by 51.1 and 43.8% over 200 and 250 kg N/ha, respectively under similar irrigation regime.However, the ratoon crop showed a declining trend in cane yield with a mean reduction of 59.3%.

5.9 Effect of irrigation and nitrogen on yield and quality of sunflower

A field experiment was conducted on fine loamy soil at Chiplima to evaluate the effect of irrigation and nitrogen on sunflower for three consecutive summer seasons from 1992 to 1994. Four irrigation frequencies at 0.6, 0.8, 1.0 and 1.2 IW/CPE were taken in the main plots and four nitrogen doses of 0, 30, 60 and 90 kg N/ha in sub-plots. The results indicated that application of N at the rate of 60 kg/ha and irrigation at IW/CPE of 1.0 significantly increased the seed yield (1391.7kg/ha) and N uptake (37.6 kg/ha) in sun flower. The nitrogen use efficiency of the crop was also significantly increased (11.9 kg seed/kg N) by supplying irrigation at IW/CPE of 1.0 and nitrogen fertilizer at 60 kg/ ha.The interaction effects of irrigation and nitrogen on yield and yield attributing characters were also found significant. When considered independently, the response of plant height, thallus diameter, number of seeds per thallus and seed weight of sun flower were found to be linearly related to the amount of irrigation water or N dose.

5.10 Study on sulphur use efficiency in rice-oilseed cropping system under different water regimes

A field experiment was conducted during 2008-2009 with four sulphur levels (0, 20, 30, 40 kg/ha) under three moisture regimes (0.6, 0.7 and 0.9 IW/CPE ratio) on a moderately well drained soil with rice –groundnut cropping system to assess the effect of sulphur on crop yield at a particular moisture regime.

Rice crop (cv: Surendra) responded significantly to the application of sulphur. During 2008 *kharif* application of 20 kg S/ha in the form of phospho-gypsum produced maximum grain yield of 50.75 q/ha which was 11.12% more than that with no application of sulphur. But when the dose increased to 40 or 60 kg S/ha no additional advantage rather slight negative response was noticed. During 2009 *kharif* similar result was obtained. At this level sulphur use efficiency was highest (25.40 kg/kg) that decreased with increasing level of sulphur to 60 kg/ha (Table 5.5). At 40 and 60 kg levels the sulphur use efficiency was 9.32 & 6.83 kg/kg, respectively. Irrigation levels however, did not influence the crop yield. Similar response was also obtained in groundnut.

Table 5.4. Effect of level of sulphur on grain yield of rice

Sulphur level (kg/ha)	Grain yield (q/ha)		
	Kharif 2008	*Kharif* 2009	Mean
0	45.67	35.79	40.73
20	50.75	43.82	47.29
40	49.40	42.68	46.04
60	49.44	42.54	45.99
CD (0.05)	3.22	4.88	

Table 5.5. Effect of level of sulphur and irrigation on yield of groundnut

Sulphur level (kg/ha)	IW/CPE			Mean	Sulphur use efficiency(kg/kg)
	0.6 (I_1)	0.7 (I_2)	0.9 (I_3)		
0	15.52	17.39	16.25	16.39	-
20	17.52	20.73	19.56	19.28	14.45
40	17.83	19.51	20.69	19.35	7.40
60	15.54	17.98	17.80	17.06	1.10
Mean	16.58	18.90	18.50	18.02	-
CD (0.05)	Irrigation -NS Sulphur- 2.02 Interaction (S x N) - NS				

Pod yield was highest at 20 kg level of sulphur but irrigation did not have any significant influence, Thus application of 20 kg S /ha was appropriate for yield increase in each of the two crops in Hirakud command.

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CHAPTER - 6

OPTIMISING WATER USE EFFICIENCY

For food security the gross irrigated area is to be increased from the present level of 100 m ha to 140 m ha to produce food grains of 400-450 mt to feed 1640 m people by 2050. There is need to increase the efficiency of canal irrigation system from 40 to 60% and that of ground water from 60 to 75%. Increase in efficiency by 10% in irrigation will increase the availability of water by 40% for other sectors like industry, energy and domestic use.

6.1 Effect of puddling implements on percolation losses and water use efficiency in rice field

Field experiments were conducted during the winter season of 1972-73 and *kharif* season of 1973 at Chiplima to study the effect of different puddling implements on the percolation losses and water use efficiency in the rice field. The implements used were local plough, mould board plough, disc harrow, power tiller with rotavator and tractor with cage wheel. The efficiency of puddling implements was judged in terms of percolation losses, water use efficiency and cost of puddling.Power tiller with rotavator was found to be most efficient in terms of percolation losses and water use efficiency, followed by tractor with cage wheel and disc harrow. The cost was least when puddling was done with disc harrow followed by powertiller and tractor.

6.2 Effect of irrigation and mulching on growth and yield of rajmash

To study the performance of rajmash under deficit irrigation a field trial was conducted for two years 2007-08 to 2008-09 on a medium land with moderately well drained soil at Chiplima with four mulching treatments (M_1=Sugarcane Trash @5 t/ha; M_2=Paddy straw @5 t/ha; M_3 = Plastic mulch (LDPE film of 0.5 m thickness) and M_4 = no mulch) under three irrigation levels(I_1= 30 % depletion of ASM; I_2 = 50 % depletion of ASM and I_3 = 60 % depletion of ASM).The study included evaluation of mulching materials in relation to crop performance and effect on soil health.

6.2.1 Crop yield

The study revealed that in both the years when averaged over the irrigation levels, paddy straw mulch resulted in 66.7% higher yield of over the un mulched control treatment. The corresponding values were 51.9% and 11.6% with plastic and sugarcane trash, respectively. When averaged over the mulching treatments the three irrigation treatments viz; 30, 40 and 50% depletion of available soil moisture(DASM) were at par in influencing the yields in both the years. Among the mulching materials, application of 3t paddy straw per ha created the most favourable soil environment measured in terms of bulk density, soil pH, SOC, available N, P, K and microbial respiration and enzyme urease, phosphatase and dehydrogenase. Irrigation levels were at par in influencing the microbial properties. When considered on the basis of the effect on soil properties and crop yield, paddy straw mulch can be used as suitable mulching materials for winter rajmash crop for higher the yield in water deficient areas of Sambalpur district which have large acreage under rice.

6.2.2 Water requirement

Water requirmenet of rajmash as measured on the basis of sources remained almost same during both the years. It varied from 24.34 to 30.03 cm during 2007-08 and 22.99 to 29.60 cm during 2008-09. The average water requirement for different mulching treatments and irrigation schedules are presented in Table 6.1 which reveals that the water requirement did not vary much among the mulching treatments. Among the irrigation treatments, irrigation at 30% depletion of soil moisture had lowest water requirement in both the years.

6.2.3 Water use efficiency

Water use efficiency (WUE) varied from 20.67 to 29.66 kg/ha-cm during 2007-08 and 28.21 to 57.06 kg/ha-cm during 2008-09. Higher WUE during 2008-09 was due to higher yield at same water requirement. As evident from Table 6.1, paddy straw mulch recorded maximum yield and WUE in both the years. The mean water use efficiency of two years was 37.68 kg/ha-cm as compared to 3387 kg/ha-cm with plastic mulch. Lowest WUE of 26.81 kg/ha-cm was recorded in unmulched treatment.

Among the irrigation treatments, highest WUE was obtained with irrigation at 30% depletion of ASM followed by 50% and 60% depletion. This indicates more frequent irrigation with less water in paddy straw mulched plants always recorded maximum yield with higher WUE followed by plastic mulch. sugarcane trash mulch had minimum effect. Irrigation at 50% and 60% depletion with straw mulch also produced almost same yield and WUE.

Table 6.1 Effect of different mulching and irrigation schedule on yield, water requirement and water use efficiency of rajmash

Treatment	Pod Yield(q/ha)			Water Requirement(cm)			Water use Efficiency (kg/ha-cm)		
	Y_1	Y_2	Mean	Y_1	Y_2	Mean	Y_1	Y_2	Mean
Effect of Mulch									
Sugarcane Trash mulch	6.37	7.65	7.01	28.29	27.34	27.82	22.50	38.64	30.57
Paddy straw mulch	7.26	13.69	10.47	27.27	27.02	27.15	26.77	48.59	37.68
Plastic mulch	6.30	12.78	9.39	27.59	27.03	27.31	22.93	44.81	33.87
Unmulched	6.00	6.56	6.43	27.91	27.66	27.79	22.27	31.35	26.81
CD(0.05)	0.83*	3.01*	1.92						
Effect of Irrigation Schedules									
30% DASM	6.25	10.98	8.62	24.89	23.38	24.14	25.16	46.18	35.67
50% D ASM	6.58	9.92	8.25	29.48	29.28	29.38	22.84	39.59	31.22
60% D ASM	6.61	9.62	8.12	28.92	29.14	29.03	22.86	36.76	29.81
$CD_{(0.05)}$	1.25	1.946	0.79						

Y_1 and Y_2 =crop years 2007-08 and 2008-09, respectively, DASM=Depletion of available soil moisture;

Figure 6.1 Rajmash under different mulching treatment

6.2.4 Effect of mulching at different irrigation levels on soil properties

Effect of different irrigation and mulching treatments on soil properties measured after harvest of second crop are presented in Table 6.2 The result revealed that irrigation treatments had significant influence on soil pH and soil organic carbon (SOC) but not on bulk density, available nutrients and soil microbial activities. Application of irrigation water with more gap at 50% or 60% depletion of ASM recorded higher and more favourable soil pH and lower SOC in the surface soil than 30% depletion of ASM. Higher organic carbon with relatively more frequent irrigation might be due to less mineralization but this effect was not reflected in available content of N. P and K and microbial activities measured in terms of respiration and enzyme activities.

On the other hand, mulching treatments significantly influenced various soil parameters except bulk density during both the years. Paddy straw mulch had most favourable effect with respect to soil pH, soil organic carbon, available nutrients, microbial respiration, enzyme activity such as urease, phosphatase and dehydrogenese. The effect of mulching treatments on soil enzyme activities are presented in Fig. 6.2. It was observed that plastic mulch was at par with paddy straw mulch with respect to all the microbial properties but not with respect to SOC, pH, available nitrogen and available phosphorus. Sugarcane trash had least effect on these properties. As compared to plastic mulch and sugarcane trash, the soil was more porous with paddy straw mulch. There was also significantly higher content of organic matter and available nutrients with higher microbial activity with the latter. This might be the reason why paddy straw mulching registered highest yield in both the years.

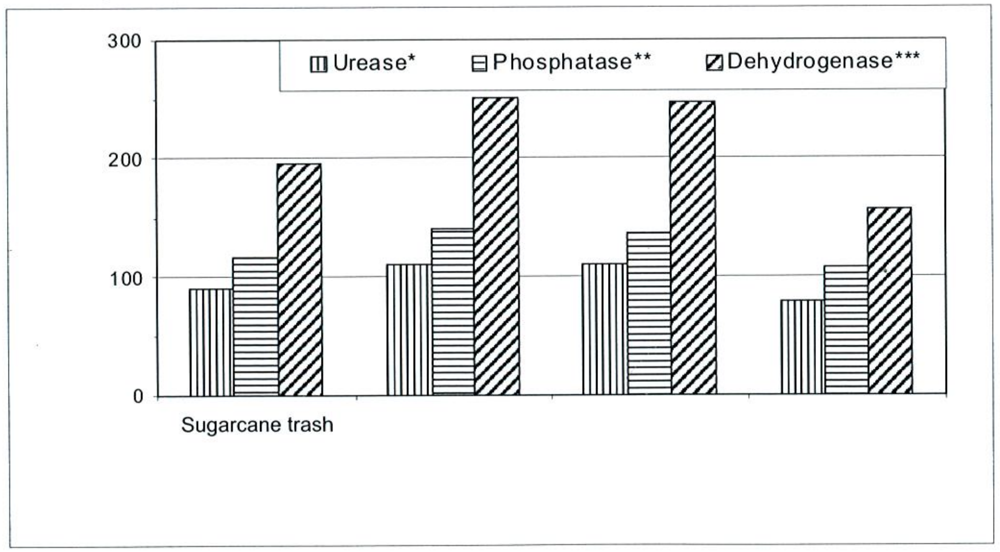

Figure 6.2 Effect of different mulching treatments on enzyme activities

6.4 Water and nutrient use efficiency under organic vis-à-vis integrated nutrient management (INM) practices in rice-tomato cropping system

To determine the water requirement and WUE under both organic and INM system in rice-vegetable (tomato) cropping system a field experiment was conducted for two years(2007-08 to 2008-09) with twelve treatments comprising of four nutrient management practices (N_1 100%organic, N_2 : 100% RD (80:40:40 kg N,P_2O_5, K_2O/ha), N_3 : 75% RD + 2.5 t FYM/ha and N_4 : 50% RD + 5.0 t FYM/ha) and 4 irrigation levels imposed in *rabi* tomato (I_1 : 0.8 IW/CPE, I_2 : 1.0 IW/CPE, I_3 : 1.2 IW/CPE and I_4 : 1.4 IW/CPE). Rice crop during *kharif* was grown with shallow submergence.

Result on yield of rice crop grown with shallow submergence and four nutrient management practices, revealed that the grain yield was maximum with 100% recommended dose of nutrients followed by 75% RD of fertilizer + 25% through organic sources during both 2008 and 2009. During 2009 the differences due to various nutrient combinations were not significant. With regards to straw yield similar response was also obtained as that of grain yield (Table 6.2 and Table 6.3)

Table 6.2 Effect of different nutrient management practices on grain and straw yield of rice

Nutrient management practices	Grain yield (q/ha)			Straw yield (q/ha)			Harvest Index
	2008 (cv: Surendra)	2009 (cv: Swarna)	Pooled Mean	2008	2009	Pooled Mean	
N_1 – 100% organic	39.79 (6.82)*	45.56 (3.52)	42.68	46.26	47.76	47.01	0.48
N_2 – 100% inorganic	42.70 -	47.22	44.96	45.86	53.69	49.78	0.47
N_3 – 75% inorganic + 25% organic	42.58 (0.29)	46.38 (1.78)	44.48	43.34	52.50	47.92	0.48
N_4 – 50% inorganic + 50% organic	41.18 (3.57)	46.07 (2.44)	43.63	43.89	47.64	45.77	0.49

*Values in parenthesis indicate percentage decrease from the maximum.

Table 6.3 Effect of different nutrient management practices and irrigation levels on yield of tomato

Nutrient management practice	Irrigation level				
	I_1: IW/CPE = 0.8	I_2: IW/CPE = 1.0	I_3: IW/CPE = 1.2	I_4: IW/CPE = 1.4	Mean
N_1 – 100% organic	54.13	59.64	69.30	63.75	61.71
N_2 – 100% inorganic	71.85	64.27	67.02	69.80	68.24
N_3 – 75% inorganic + 25% organic	75.80	76.48	86.48	79.39	79.54
N_4 – 50% inorganic + 50% organic	76.37	74.49	83.09	66.52	75.12
Mean	69.54	68.72	76.47	69.87	71.15
CD (0.05): Irrigation levels = NS, Nutrient management = 6.82 (S), Interaction = NS					

Table 6.4 Effect of irrigation levels on water requirement and water use efficiency in tomato

Irrigation level	Tomato yield (kg/ha)	Water requirement (cm)	Water use efficiency (kg/ha-cm)
I_1 : IW/CPE=0.8	6954	25	278.16
I_2 : IW/CPE=1.0	6872	30	229.07
I_3 : IW/CPE=1.2	7647	35	218.49
I_4 : IW/CPE=1.4	6987	40	174.68
Mean	7115	32.5	218.92

6.4.1 Tomato yield

Irrigation levels did not significantly influence the tomato yield in the very first season, but nutrient management practices had significant impact. Integrated use of 75% inorganic along with 25% organic and 50% inorganic in combination with 50% organic produced maximum fruit yield of 8648 kg and 8309 kg, respectively at I_3 level of irrigation (IW/CPE = 1.0). Among the irrigation levels, irrigation at IW/CPE of 1.0 was found to be

the best in influencing the crop yield. The results thus suggest for growing tomato crop in the moderately well drained, light textured soils of Hirakud command with provision of irrigation at IW/CPE of 1.0 and integrated use of nutrients through 75% inorganic in combination with 25% organic sources.

6.4.2 Soil properties

Irrigation schedule at IW/CPE of 0.8, 1.0, 1.2 and 1.4 were found to have negligible effect on soil properties except the available potassium content which showed an enrichment of soil. Highest available K was found in the soil irrigated at IW/CPE of 0.8. Nutrient enrichment of soil was highest in plots which received 100% RD through fertilizers followed by integrated use of inorganic and organic sources in the ratio of 75:25 of the recommended dose.

6.4.3 Water use efficiency

Water requirement varied from 25 to 40 cm depending on the irrigation scheduling. Water use efficiency as calculated from water requirement and crop yield varied from 174.08 to 278.16 kg/ha-cm and the crop that received irrigation at IW/CPE of 1.0 registering a highest mean water use efficiency of 229.07 kg/ha-cm (Table 6.4).

Thus, in Hirakud command growing tomato crop with integrated use of inorganic and organic at the ratio 75:25 of recommended dose and providing irrigation at IW/CPE of 1.0 results in better plant growth and crop yield with highest water use efficiency. It also maintains a better soil health.

6.5 Performance of potato under furrow irrigation at different irrigation levels

A field experiment was conducted in sandy loam soil during *rabi* season of 1991-92 and 1992-93 at Chiplima comprising four furrow methods of irrigation and two levels of irrigation. Irrigation in furrow with paired row planting proved to be superior over other furrow irrigation methods with irrigation at 1.2 IW/CPE (41.6mm CPE) producing 17% higher yield and 12.4% higher water use efficiency over the common practice of irrigation in all furrows.

6.6 Autumn planting of sugarcane

Yield potential of sugarcane has been found to be the maximum when planting was done during October-November instead of February-March giving an yield advantage of over 40%.Autumn planted crop can be made more remunerative by growing mustard as an intercrop in 2: 2 ratio. It needs 5-6 irrigations during October to January at an interval of 18-20days whereas 14-15 irrigations during February to May, the frequencies being 12-14days in February and 7-9days towards May. Monsoon months required adequate drainage.

6.7 Planting method and level of irrigation in banana-ginger intercropping

Field experiment was conducted with banana + ginger intercropping system in a sandy loam soil at Chiplima during *kharif* 2004 with three irrigation levels (1.0,1.2 1.4 IW/CPE and four types of planting (raised and flat bed system with either FYM + sand or straw mulching). The crop of ginger was planted in between two rows of banana (1.8m x 1.8m). Yield of banana was maximum (21.45 t/ha) under the irrigation treatment of 1.2 IW/CPE requiring 216 cm irrigation water. Significantly higher ginger yield of 16.58 q/ha was obtained under the lowest IW/CPE level of 1.0. Raised bed + mulching resulted in highest ginger yield of 13.35 q/ha and it closely followed the flat bed+ mulching type planting. Raised bed + mulching also resulted in highest B: C ratio of 1.68.

6.8 Interaction effect of nutrient and water use under micro irrigation system in papaya

A field experiment was conducted on a poorly drained soil at Chiplima in order to evaluate three methods of irrigation (Drip, basin with straw mulch and basin without mulch) in relation to increasing productivity and maintaining better soil environment under three systems of plant nutrition *viz;* organic, inorganic and integrated nutrient management(INM).

A count on the number of fruits revealed that although irrigation methods significantly differed in influencing the plant height it was not reflected in the number of fruits per plants. Maximum number of fruits (11.66 per plant) was recorded due to drip method; on the other hand nutrient management practices significantly influenced the fruit number. Integrated nutrient management with 75% RD through inogranics and 25% through organics resulted in maximum number of fruits followed by 100% RD through inogranic alone. Application of nutrients through organics only was inefficient in enhancing the number of fruits per plant.

Both irrigation methods and nutrient management practices significantly influenced the total yield of matured fruits. Organically manured plants and basin irrigation without mulch recorded lowest yield. Basin irrigation with straw mulch manured with INM recorded maximum yield of green and marketable fruits.

Within six months of planting root zone soils found to be influenced by irrigation methods with respect to bulk density and soil organic carbon. Irrigation with paddy straw mulch maintained a better soil health with more porosity and organic matter. It also maintained highest microbial activity (0.48 mg CO_2/g soil per day) as measured in terms of microbial respiration.

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CHAPTER - 7

GROUND WATER STUDIES

The thrust on ground water use is increasing exponentially to support the growing population for the domestic, irrigation and industrial needs.A comprehensive understanding of the ground water regime, its recharge and discharge characteristics is very important to evolve strategy for its optimal utilization.Studies were undertaken by AICRP on water management at Chiplima to regularly monitor the ground water fluctuation and assess the quality for its optimal utilization in crop production with appropriate technology adoption.

7.1 Contribution of ground water table to evapotranspiration in groundnut

Study was conducted to assess the contribution of groundwater table to groundnut production during 1991. Three different water tables(50±20cm,70±20cm and 90±20cm) found in situ under different topo system were taken in main plot and six different levels of irrigation (0.2, 0.4, 0.6, 0.8, 1.0 and 1.2 IW/CPE ratio) were taken in sub-plots.The ground water contribution was estimated by computation of evapotranspiration under field condition as well as inside drums which were installed in different irrigation treatments under various water tables.The soils of the sites were clay loam in texture.Pod yield of groundnut showed a significant reduction when ground water table became shallow (50±20cm) as compared to deeper layers (70±20cm) because of less pods per plant and 100 pod weight. Inreasing the irrigation frequency from 0.2 IW/CPE to 1.0 IW/CPE ratio resulted in significant increase in pod yield which was associated with higher number of mature pods per plant, 100 pod weight and 100 kernel weight. A yield of 35.5 q/ha of groundnut pod was recorded when irrigation was applied at 60 mm CPE under a water table of 70±20cm with field water use efficiency of 70.1 kg/ha (Table - 7.1)

7.1.1 Soil moisture studies

Soil samples were collected at sowing, harvest and before and after each irrigation for computation of moisture utilization by the crop and evapotranspiration. Data revealed that the moisture utilization decreased with increasing depth of soil profile irrespective of irrigation scheduling and depth of groundwater table. An increase in moisture utilization was also observed with increasing irrigation frequency irrespective of depth of ground water table.

However, comparatively higher moisture was utilized under stress treatment of irrigation when the crop was grown under the shallow ground water table of 50±20 cm which decreased with the increasing depth of water table. On an average, the crop utilized 69.3% of the total moisture under stress (0.2 IW/CPE) condition and 72.3% under frequent irrigation (1.2 IW/CPE). The evapotranspiration also increased with increasing level of irrigation irrespective of ground water table.

7.1.2 Ground water contribution

The contribution of ground water ranged from 1.5 cm to 5 cm. The contribution was higher when the ground water table was shallow (50±20 cm) and reduced there after at 70±20 cm depth and was becoming negative at 90+20 cm. The contribution was higher under stress condition and decreased with increasing irrigation frequency.

Table 7.1 Pod yield of groundnut and ground water contribution under various water table depths and irrigation levels.

Irrigation level	Water table depth(50±20cm)		Water table depth(70±20cm)		Water table depth(90±20cm)	
IW/CPE ratio	Pod yield (q/ha)	Contribution of ground water (cm)	Pod yield (q/ha)	Contribution of ground water (cm)	Pod yield (q/ha)	Contribution of ground water (cm)
0.2	14.5	5.03	19.1	3.05	23.4	-0.71
0.4	17.2	4.51	19.7	2.47	24.0	-0.82
0.6	21.0	3.33	26	2.62	25.0	-0.83
0.8	25.3	2.75	28.5	1.59	25.5	-0.50
1.0	21.1	2.68	35.5	1.82	31.0	-0.97
1.2	21.2	1.86	30.5	1.54	33.0	0.34
CD (0.05)	Irrigation level-2.45		Water table-1.51			

7.2 Sources and their extent of contribution to rise in ground water table

To assess the situation of water table in the Hirakud Command and to determine the contribution of different sources towards the rise in groundwater table, a field study was initiated in the year 1985. The depths of water table were recorded fortnightly at three situations i.e., near canal, uncultivated irrigated and rain fed areas.

Studies on the fluctuation of ground water table revealed that the percentage of rise in water table was maximum (33.28%) in case of irrigated site followed by near canal

(14.75%) and in rain fed areas (10.53%). This is attributed to inefficient use of canal irrigation water, seepage from the canal system and inadequate provision of surface and sub-surface drainage. Different sources of ground water recharge leading to rise in water table were

I. Recharge from rain fall in the command area.
II. Seepage losses from main canals, branch canals and distributaries
III. Deep percolation from canal irrigated areas
IV. Deep percolation from well irrigated areas
V. Lateral inflow/outflow of water from adjoining areas

7.2.1 Recharge from rainfall

The average annual rainfall of the Hirakud Command area is 1500 mm. Therefore the average annual recharge from rainfall is 1500×0.18 ×316000×104/10 = 853 MCM (Million Cubic Metres)

7.2.2 Seepage from canals

Length of canal =25 km.

Average wetted perimeter =18.2 m

Seepage factor = 18.2×1.3= 23.66 ha-m/km

Total seepage = 592ha-m

Average seepage losses taking 40% of the total

=592×0.4 ha-m

=236 ha-m

=2.36 MCM

7.2.3 Deep percolation from canal irrigated areas

Water released in RRTTS, Chiplima branch canal per year is 8 MCM out of which 2.36 MCM is estimated to be lost on seepage from canal and 7% of the rest 5.64 MCM i.e., 0.39 MCM is estimated as seepage from the distributaries.The quantity of water recharging the water table through deep percolation from the field is thus (5.64-0.39) ×0.3=1.57 MCM. The average annual ground water drift is assumed to be 82 MCM. Accordingly, the deep percolation from the areas irrigated by wells is 15% of MCM i.e., 12 MCM.Lateral inflow and outflow is taken to be the same. Thus, recharge from various sources resulting in the rise in water table are as follows.

Table 7.2 Average annual recharge of groundwater in RRTTS Chiplima

Sources	Recharge (MCM)
Rainfall contribution	853
Seepage from main	3
Seepage from canal distributaries	1
Seepage through deep percolation	2
Recharge from areas irrigated by wells	12
Total	**871 MCM**

Thus, the average annual recharge of ground water in the RRTTS Chiplima experimental site was 871 MCM.

7.3 Fluctuation and quality of ground water in Hirakud Command area

Hirakud command has vast utilizable groundwater resources (139852.57 ha-m).Survey conducted during 1994 revealed that only 1.9% of the ground water has been exploited and rest 98.1% can be utilized safely and economically for irrigation purposes. To explore the cause of fluctuation of ground water in Hirakud command area data were collected on water table from different observation wells fortnightly at four sites namely near the canal, irrigated, uncultivated and dry farming areas. The contributing factors for fluctuation at different locations were determined. The ground water level remained below the zone of drawal of water by the field crops in areas covering near canal, cultivated and dry farming areas. However, the irrigated tract was observed to get benefit by the ground water . The analysis of ground water samples showed that ground water can safely be used for irrigation purpose.

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CHAPTER - 8

WATER LOGGING AND DRAINAGE STUDIES

Although the total rainfall received by the eastern region of India is sufficient to meet the evaporative demand of the crops, spatial heterogeneity and temporal variability of rainfall often cause surface flooding on one hand and water scarcity at critical crop growth stages on the other hand . Development of micro-level water resources by utilizing surface and sub-surface flow of rain water at various plausible storage sites will provide stability to agricultural production. Therefore, various aspects of development of micro level water resources, efficient utilization of the stored water to enhance agricultural production and impact of such water resources created on downstream hydrology need to be thoroughly studied.

8.1 Reuse of drainage water

The storage reservoir in the RRTTS, Chiplima gets recharged by seepage from canal, rain water and run off water coming from plots which can be reused during the lean period. In order to determine the capacity of the reservoir water spread area at different depths of heads of water and contour lines were drawn at 0.5 m interval. Trapozoidal formula was used to determind the volume of water stored at different depths of heads.

The water level readings were recorded at weekly intervals with the help of wooden batten graduated to half centimeter intervals installed at up stream side of the reservoir. The inflow and outflow for the reservoir were recorded daily by installing parshal flume (throat width 7.5 cm).During the lean period (December-June) crops required life saving irrigation from the reservoir. Therefore, the observations on water depth, rainfall and evaporation were taken into account for consideration of the volume of water available in the reservoir and other losses during every standard week.

The maximum evaporation of 0.172 ha-m was recorded in the 1st week of April, 1989 with water spread area of 5.75 ha and the minimum evaporation of 0.062 ha-m was recorded in the 3rd week of December, 1988 with water spread area of 5.38 ha. The seepage loss trend was at par with that of head water. With in a span of 5 months of dry season (1st week of December 1988 to 1st Week of April, 1989) the volume of water in the reservoir was reduced from 12.80 ha-m to 5.53 ha-m. It was further reduced to 2.91 ha-m at the 2nd week of May, 1989. During this lean period life saving irrigation could be recycled by installing the diesel or electric pump set covering an area of 15 ha (up and medium land) excluding the seepage and evaporation losses. Further, in the low land areas of the reservoir high yielding varieties of paddy could be grown successfully by utilizing the seepage water from the reservoir.

8.2 Effect of furrow length and furrow slope on the surface drainage of excess water

In order to control excess water from high intensity rainfall and improve crop yield an experiment was conducted on a clay loam soil during *Kharif* 1981with furrows of three slope levels (0.1, 0.3, and 0.5%) and three lengths of 30 m, 45 m, and 60 m in maize.

The result revealed no significant difference in cob or stalk weights in different furrow slopes, but there was significant difference due to different furrow lengths. Among the three furrow lengths, 30 m furrow produced the highest yield of both cobs (2000kg/ha)and stalk(5883kg/ha) in kharif maize (Table 8.1).

Table 8.1 The cob and stalk yield of maize as influenced by slope and furrow length

Furrow slope (%)	Furrow length(m)					
	60		45		30	
	Cob	Stalk	Cob	Stalk	Cob	Stalk
0.5	907	2241	1420	3086	1611	5852
0.3	759	1750	1506	3050	2185	5722
0.1	926	2093	1395	3407	2204	6074
Mean	864	2028	1440	3181	2000	5888
CD(0.05)	Cob			Stalk		
Slope	NS			NS		
Furrow length	216			314		
SxL	NS			NS		

8.2 Studies on depth and spacing of sub-surface drainage

In order to find out the optimum depth and spacing of tile drain and its effect on water table and crop response a field experiment was conducted during 1976 to 1980 in a ill drained sandy clay loam soil of Chiplima with tile drains placed at depths of 1.2m and 1.5m and spacing of 18, 16, 14.25, 13.5, 12, 10, 8, 6.5, 5.75, and 4 meter.

The results indicated that sub-surface drainage by installing tiles at 1.2m depth and spacing of 12m has been very effective in controlling the rise of water and reclaiming the water logged area. Closer spacing of tiles resulted in excessive drainage and reduced

the yield, whereas, higher spacing was less ffective in draining the excess water and thus reduced the yield. It was substantiated by measurement of drainage co-efficient which was higher for tile drain placed at 1.2m depth than at 1.5m .In *kharif* the average drainage coefficient was found to be 0.113 and 0.183 ha-m/day for 1.5m and 1.2m tile depths, respectively. However, during *rabi* the corresponding coefficients were 0.110 and 0.174 ha-m/day. Maximum yield was obtained at 12 m spacing and the yield declined when the spacing was higher or lower than this.

At higher spacing water logging and lack of aeration and at lower spacing excessive drainage and rise in cost were observed. Tiles placed at a depth of 1.2m with 12m spacing was the most effective in providing adequate drainage and aeration for increasing the yield of crop to an optimum level.

Table 8.2 Effect of depth and spacing of tiles on the yield of crops

Depth of tiles(m)	Spacing of tiles(m)	Crop Yield(q/ha) (Mean of 4years)	
		Kharif (ragi)	Rabi (wheat)
1.20	18.00	8.50	19.85
	16.00	8.45	22.11
	14.25	10.34	23.56
	13.50	13.10	23.90
	12.00	16.11	28.25
	10.00	12.60	22.23
	8.00	11.90	17.87
	6.50	10.60	21.80
	5.75	12.00	20.90
	4.00	12.40	----
Drainage Coefficient		0.183	0.174
1.50	18.00	6.48	17.00
	16.00	7.50	18.48
	14.25	10.58	16.91
	13.50	10.41	19.65
	12.00	13.10	24.80
	10.00	10.23	18.05
	8.00	9.90	17.53
	6.50	10.29	17.38
	5.75	10.28	20.75
	4.00	10.45	----
Drainage Coefficient		0.133	0.110

8.3 Effect of shape of check basin and water management practice on under bund percolation in rice field

Seepage and percolation constitute major loss in rice field. Almost 52 to 68 % of total losses of water in rice field occur due to these factors. This loss generally comprises of varietal percolation down the plough pan and the horizontals seepage loss. The horizontal seepage loss especially through rice field bund is a major loss. When the bund is not compacted well or is made of light textured soil, the loss becomes more. Another factor responsible for this loss is due to un-ploughed/ under ploughed land near the bund. The horizontal seepage through rice bund is here-in called as under bund percolation. Under bund percolation in rice field depends on the perimeter area ratio of field as well as water management practices followed. More is the perimeter area ratio for a given field size, more will be the loss. Similarly under ponding, the percolation loss is more than saturation and/or unsaturated case. Keeping this in view, the present study was undertaken with three different shape of rice check basin with length breadth ratio of 1:1, 2:1 and 3:1 and with two water management practices of shallow submergence (5 $\pm$ 2 cm) and 3 ADP (irrigation at 3 days of disappearance of ponded water). These two water management practices are designated as submergence and intermittent irrigation.

To evaluate the performance of shape of check basin on under bund percolation in rice field under different water management practices and study their effect on yield, water requirement and water-use-efficiency a field experiment was conducted during *kharif* 2006 in a loam soil(pH6.4, ASM 10.7%) with rice-rice system.

The experiment consisted of three field check basins of Length: Breadth (L:B) ratio of 1:1, 2:1and 3:1 and two water management practices shallow submergence of (5 $\pm$ 2 cm) and intermittent irrigation at 3 ADP. For shallow submergence when ponded depth reduced to 3 cm or less, irrigation was applied till ponded depth of 7 cm and incase of 3 ADP, 7 cm irrigation was applied.

A daily water balance model of rice in ponding and unsaturated phase was run to compute the different water balance model parameters. The inflow and outflow components of the water balance model were measured on daily basis. Two types of drums were set up in each plot. Bottomed drum was used to measure crop evapotranspiration and bottomless drum was used to measure percolation. Besides, a half cut drum like English alphabet "C" with both top and bottom open was set up near bund and was used to measure horizontal seepage called under bund percolation.

The various model parameters were measured on daily basis and then summed up to get seasonal value.

Table 8.3 Water balance model parameters of rice as affected by different water management practices

Water management practice		Irrigation (mm)	Effective rainfall (mm)	Evapotranspiration (mm)	Seepage and percolation (mm)
Check basin	Irrigation interval				
CB_1	Submergence	420	480	402	498
	Intermittent	330	488	377	441
CB_2	Submergence	435	485	405	515
	Intermittent	340	494	381	453
CB_3	Submergence	455	492	401	546
	Intermittent	360	500	380	480

N.B.: CB_1 = Check basin with L:B ratio 1:1

CB_2 = Check basin with L:B ratio 2:1

CB_3 = Check Basin with L:B ratio 3:1

Table 8.4 Yield, water requirement (WR) and water use efficiency (WUE) of rice as affected by different water management practices.

Water management practice		Yield (q/ha)	WR (cm)	WUE (kg/ha/cm)
Check basin	Irrigation interval			
CB_1	Submergence	50.1	90.0	55.66
	Intermittent	48.5	81.8	59.29
CB_2	Submergence	48.0	92.0	52.17
	Intermittent	48.8	83.4	58.51
CB_3	Submergence	49.5	94.7	52.27
	Intermittent	49.2	86.0	57.21

Table 8.5 Seasonal values of under bund percolation as affected by different water management practices

Water management practice		Total seepage and percolation including under bund percolation (mm)	Seepage and percolation (mm)	Under bund percolation (mm)
Check basin	Irrigation interval			
CB_1	Submergence	498	202	296
	Intermittent	441	211	230
CB_2	Submergence	515	203	312
	Intermittent	453	205	248
CB_3	Submergence	546	220	326
	Intermittent	480	213	267

Result indicated that water requirement of rice was found to vary from 81.8 cm to 94.7 cm (Table 8.4). The submerged crop required on an average 10 % more water than the intermittent irrigation. The check basin system with more perimeter-area ratio needed more water than the lower perimeter-area ratio. The irrigation requirement, actual crop evapo-transpiration and seepage and percolation losses were observed to be higher for submerged condition than the intermittent one. The values of seepage and percolation in check basin system with higher perimeter area ratio were found to be more than the one with lower values of perimeter area ratio. The reason may be due to higher under-bund percolation caused by more length of bunds in rice field in the former case (Table 8.5).

The values of under bund percolation were found to be more than vertical percolation. The average daily values of under bund percolation ranged from 2.4 to 3.7 mm whereas the vertical percolation down the plough pan ranged from 2.1 to 2.2 mm. Thus total seepage and percolation loss ranged from 4.5 to 5.9 mm. The ET crop ranged from 4.1 to 4.3 mm. The water requirement varied from 8.6 to 10.2 mm/day.

8.4 Effect of land fragmentation on water application efficiency and yield of rice in terraced ecosystem

In an on farm study it was observed that mean land slope varied from 0.70 - 0.88%. Plot size of 800-1000 m^2 showed minimum slope of 0.7% besides sowing overall leveling on contour mapping. Water application efficiency was maximum (61.8%) with 800-1000 m^2 plot size with corresponding grain yield of rice (46.3 q/ha). Lowest yield of rice (40.2 q/ha) was observed with larger plot size of 1000-1800 m^2 having land slope of 0.86%.

8.5 Increasing land productivity of chronically waterlogged areas though land configuration

Low lands at quite a few locations in the Hirakud command have become permanently waterlogged and uncultivable. The area under this type of land is increasing day by day. Waterlogging has already emerged as a major threat to the water productivity in these areas. With an objective to assess the feasibility and performance of different crop combinations and fish in chronically water logged eco-system an experiment was started in 2001 at RRTTS, Chiplima in a part of a chronically waterlogged location.

The waterlogged site selected for carrying out the experiment was not suitable for raising any crop because of unfavorable land, water and soil conditions.

8.5.1 Land configuration

The entire area (2800 m^2) was put under land configuration through digging a small pond, trenches and development of field plots, with drainage channels at one side, to grow lowland rice and bunds to grow vegetables (Table 8.6).

Table 8.6 Land configuration of the chronically waterlogged area

Land Pattern	Dimension	% of the total area
Trenches	2m x 0.75m	8.60
Pond	$112m^2$ x 1.5m (depth)	4.01
Elevated plots	-	42.72
Bunds	1.0 & 1.5m width	41.25
Drainage channels	1.2m width	3.42
Total		**100.00**

8.5.2 Selection of suitable rice varieties

After few years of experimentation it was established that cultivation of rice in the developed plots, aquatic crops like water chestnut in trenches and fish in pond was feasible. Through the process, long duration rice cultivars were identified as better performers. The varieties suitable for the elevated plots in order of their productivity were: Mahanadi, Kanchan, Sabitri, Ramachandi, Sarala, CR 661236, CR 780-1937, CR 662-2210 and Swarna.

8.5.3 Use of rice mill waste

The yield of rice declined gradually with time. Assuming this might be due to deterioration of soil health, a soil fertility management intervention was undertaken. Locally available rice mill waste (RMW) which is rich in potassium and calcium was applied to the elevated plots and were used for rice cultivation. It was observed that application of rice mill wastes @2 t/ha resulted in increased grain yield of paddy by 6.5%.

8.5.4 Cropping system

The study established that it is possible to raise different crops in the configured land, which not only make the land productive but also facilitates multiple use of water by different components of the system. The cropping system adopted in the experiment is presented in Table 8.7.

Table 8.7. Change in the cropping system

Site	Crops in different seasons
Plots	Rice – rice – fallow
Trench	Water chestnut – fallow – fallow
Trench Bund	Okra+ridge gourd – Okra + ridge gourd – fallow
Pond	Fish
Pond bund	Banana

8.5.5 Intercultural practices

Fertilizers and manures applied to different crops, fish feed and other intercultural operations carried out were as follows:

Rice	60:30:30 kg of N, P_2O_5 and K_2O/ha. N was applied in 3 splits (50 % basal + 25 % at tillering + 25 % at panicle initiation), full dose of P_2O_5 and K_2O were applied at final puddling.
Water chestnut	20:40:20 kg N, P_2O_5 and K_2O/ha was applied basally during planting.
Fish	Oil cakes @ 1 t/ha + Lime @ 2 t/ha
Intercultural operations	Normal weeding and plant protection measures were undertaken

8.5.6 Income from the land

It is observed that all the components of the configured system performed well individually. After incorporation of RMW the soil condition of the elevated plots were highly improved resulting in very good grain yield. The soil of the trench bunds was found to be fertile and availability of water in the trenches facilitated good yield of vegetables on the bunds. There was ample scope of rearing fish in the: pond and trenches. The detailed component-wise return and their rice equivalent yield for the last two years are presented in Table 8.8.

Table 8.8 Rice equivalent yield and gross return per hectare

Crop component	Yield			Unit sale price (Rs)	Gross return (Rs)	Rice equivalent yield
	Rabi	Kharif	Total			
Rice (q)	20.92	18.44	39.36	800	31488	39.36
Fish (kg)	-	71.5	71.5	60	4290	5.36
Water chestnut (kg)	36	-	36	15	540	0.68
Okra (kg)	143	136	279	10	2790	3.49
Ridge gourd (kg)	186	157	343	10	3430	4.29
Banana (bunch)		20	20	200	4000	5.00
Total					**46538**	**58.18**

Thus, uncultivated chronically water logged areas located in the bottom reach of terraced topographic situation of irrigated command can be utilized properly with suitable land configuration. Opening of trenches and a pond of appropriate dimension in proportion of the total land area provides ample scope for growing two crops of rice in *kharif* and *rabi* in progressively developed field plots, vegetables on bunds, water chestnut in trenches, fish in trenches and ponds. The technology is suitable for all chronically water logged ecosystems. This can raise the farm income and provide scope for nutritional security as different items can be harvested from a single unit with profit.

Figure 8.1 Multiple use of water in chronically waterlogged area through land configuration

8.6 Raised and sunken bed system of cultivation – A viable option for crop diversification in medium and lowland

Medium and low lands with inadequate drainage facilities in the command area are mostly used for cultivation of rice alone throughout the year. There is little scope for crop diversification in these areas as the field remains submerged during most part of the cropping season. The water productivity as well as the water use efficiency of these lands are very less due to wastage of water. Moreover, the soil quality deteriorates because of poor aeration and drainage. There is ample scope to utilise these lands for raising different crops with suitable land modification and water management practices.

With an objective to assess the feasibility of raising rice along with other crops in the medium and low lands, and evaluate the performance of different crop combinations an experiment was conducted at Chiplima in a medium land. The site selected for carrying out the experiment was not suitable for raising any crop other than rice because of presence of surface water thought the cropping season. The soil condition was also not favourable for growing vegetables.

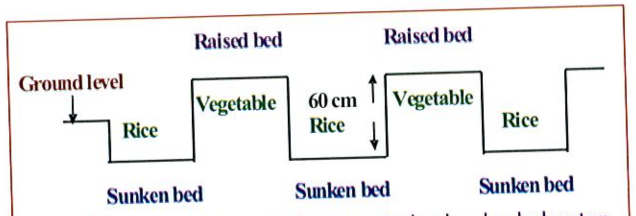
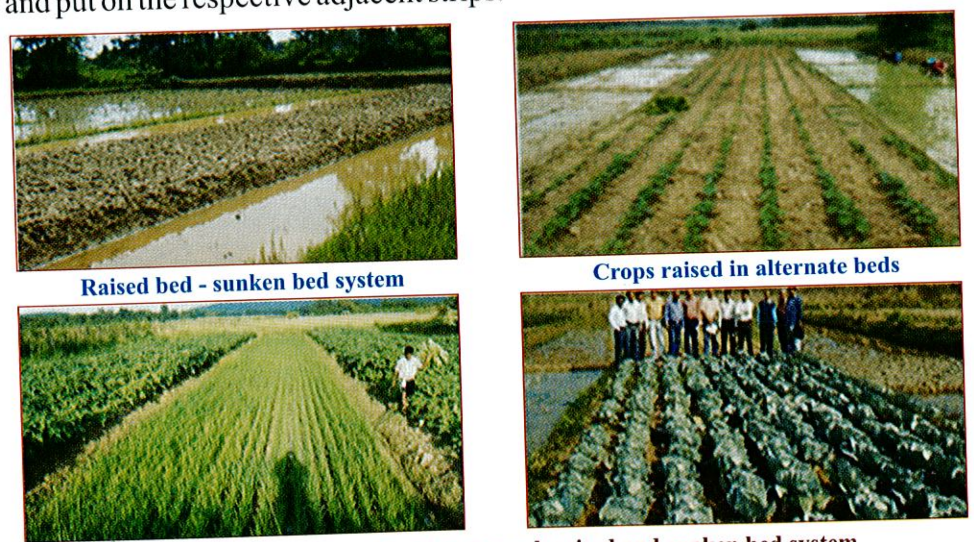


Figure 8.2 Schematic diagram of alternate raised and sunken bed system

8.6.1 Land management

The top soil from 1500 m^2 (50 m x 30 m) area was removed and kept aside. The land was then divided into six strips of 5 m width along the slope so that each strip was having dimension of 5 m × 50 m. Afterwards soil of 30 cm depth was cut from alternate strips and put on the respective adjacent strips.


Raised bed - sunken bed system

Crops raised in alternate beds

Figure 8.3 Crop diversification through raised and sunken bed system

Subsequently all the strips were filled with 15 cm top soil that was kept aside earlier and levelled. In this process, the entire land was divided into two types of cropping areas, *viz.* the elevated or raised beds and the lowered or sunken beds, with 60 cm elevation difference between two adjacent beds.

8.6.2 Water management

The sunken beds were used for cultivation of rice with normal water management practices (5 ± 2 cm of standing water). Vegetables were planted in the raised beds. No irrigation was applied to the vegetable crop except for survival of the seedlings during planting.

8.6.3 Benefits of the system

Due to permanent availability standing water in the rice fields, water was drawn to the root zone of the vegetable crops planted in the raised bed because of capillary action. The soil in the raised bed remained well drained throughout the year and was suitable for growing non-paddy crops, enhancing the scopes for crop diversification and increasing the water productivity. Furthermore, the surface soil (raised beds) remained dry during the entire cropping period, which minimized the growth of shallow rooted weeds. The benefits of the cropping system can be summarized as follows:

Higher watèr and crop productivity

- Higher crop diversity
- Higher cropping intensity
- Better soil management
- Nutritional security

8.6.4 Cropping System

Rice was cultivated in the sunken bed in *kharif* and *rabi* seasons, and left as fallow during summer. Three different combinations of crops *viz.* Okra – radish – cowpea, Okra – cabbage – cowpea, Okra – beans – cowpea were grown in the raised beds.

8.6.5 Income from the system

The land was used for two crops of rice during *kharif* and *rabi* seasons and used to give normal yields. However, there was no scope for cultivation of other crops. After adopting the raised bed – sunken bed system the yield from the land could be increased by two times.

Table 8.9 Comparison of cropping intensity and gross annual income per hectare by conventional practice and the new system

Season→	*Kharif*	*Rabi*	Summer	Cropping Intensity (%)	Annual Gross Income (Rs)
Conventional System					
	Entire Land (1.0ha)			200	60,000
Crop	Rice	Rice	-		
Yield (t)	4.0	4.5			
Raised –Sunken Bed System					
	Sunken bed (0.5ha)			250	24,000
Crop	Rice	Rice	-		
Yield (t)	1.5	1.5			
	Raised Bed (0.5ha)				
Crop	Okra	Radish	Cowpea		81,500 (1,05,000)*
Yield (t)	7.5	1.2	3.0		
Crop	Okra	Cabbage	Cowpea		97,500 (1,21,500)
Yield (t)	7.5	10.0	3.0		
Crop	Okra	Beans	Cowpea		97,500 (1,21,500)
Yield (t)	7.5	5.0	3.0		

* values in parenthesis represents total income from the land

Raised and sunken bed technique for improving water productivity in lowlands proved very effective than conventional system of rice cultivation. For modification of land into raised and sunken bed system Rs. 35000 - 40000/ha was required, which may be recovered within 1 to 2 years in most of the cases. This system not only increases farm production and income but also generates more rural employment, livelihood options and provides food and nutritional security for poor rural masses.

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CHAPTER-9

CROP WATER PRODUCTION FUNCTIONS

An agriculturist very often comes across a number of constraints as the major resources like land, water and funds are limited and there are limitations beyond his control such as climatic uncertainties, quality of land and water and social limitations etc. If the cost, return, profit and constraints in agriculture can be quantified and expressed in forms of equations for optimization then different problems can be solved. At Chiplima centre some works related to yield optimization with use of crop water production functions have been developed.

9. 1 Development of crop water production functions of cowpea, sesame and moong in Hirakud Command

A field experiment was conducted during summer 2005 to investigate the effect of stress caused by varying moisture status on yield, evapo-transpiration and water use efficiency of crops and to develop crop water production function of crops on a medium land with available soil moisture(ASM) of 10.7% with irrigation at 20,30,40 and 50% depletion of ASM.

Table 9.1 Number and total depth of irrigation including pre-sowing irrigation for cowpea, sesame and moong

Irrigation schedule (% depletion ASM)	Irrigation (mm)		
	Cowpea	Sesame	Mung
20	283(13)*	255(12)	266(12)
30	296(9)	281(9)	282(11)
50	297(7)	290(6)	281(6)
60	303(6)	269(4)	263(5)

*Values in parentheses represent number of irrigations

9.1.1 Depth of water applied at each irrigation

Depth of water applied at each irrigation varied depending on the available soil moisture content in the root zone of the crop at the time of irrigation. At each irrigation, amount of water applied was such that the available soil moisture contents in the effective root zone of crops (effective root zone of all three crops assumed to be 60 cm) attained field capacity.

Table 9.2 Yield, water requirement (WR) and water use-efficiency (WUE) of crops

Irrigation schedules (% depletion of ASM)	Crop	Yield (q/ha)	WR (cm)	WUE (kg/ha-cm)	Calculated ETc
I_1 - 20	Cowpea	54.01	30.50	177.08	26.06
I_2 - 30		57.55	28.60	201.22	26.90
I_3 - 50		51.85	24.85	173.12	25.48
I_4 - 60		46.18	32.05	144.09	24.35
I_1 - 20	Sesame	7.05	28.05	25.13	22.65
I_2 - 30		8.11	26.55	30.55	23.38
I_3 - 50		6.45	27.90	23.12	22.09
I_4 - 60		5.60	28.85	19.41	21.21
I_1 - 20	Mung	8.95	28.55	31.35	23.51
I_2 - 30		9.98	26.65	37.45	2414
I_3 - 50		8.05	27.25	29.54	22.89
I_4 - 60		6.51	28.5	23.04	21.87
CD(0.05) for crop yields	Cowpea-4.65; Sesame-0.64 and Mung-0.98				

Table 9.3 Stage wise crop evaporation (ETc) of crops

Irrigation schedule (% depletion of ASM)	Crop	ETc (mm)				
		Stage-I	Stage-II	Stage-III	Stage IV	Total
20	Cowpea	22.45	65.12	118.25	54.80	260.62
30		34.46	67.80	120.90	55.85	269.01
50		21.75	64.15	16.15	52.77	254.82
60		18.88	63.25	111.85	49.50	243.48
20	Sesamum	16.55	69.46	108.80	32.65	226.46
30		18.88	70.55	110.21	35.05	233.69
50		16.05	67.56	106.25	31.11	220.97
60		13.01	65.65	105.40	28.50	212.06
20	Mung	17.85	70.62	105.65	40.89	235.01
30		18.85	72.56	107.50	42.08	241.39
50		16.05	69.21	104.55	39.05	228.86
60		14.01	106.38	102.26	36.02	218.67

N.B. Stage I : Initial, Stage II : Crop development, Stage III : Mid Season and Stage IV : Maturity

9.1.2 Crop yield

The experimental results indicated that irrigation at 30 % depletion of available soil moisture (I_2) produced maximum crop yield of 57.55, 8.11 and 9.98 q/ha in cowpea, sesamum and mung, respectively. The next best irrigation schedule was at 20 % depletion of ASM (I_1). The irrigation schedule of 60% depletion of ASM (I_4) gave lowest yield for all the crops. The per cent depletion of yield at I_1, I_3, I_4 irrigation schedules were 6.2, 9.9, 19.8 compared to I_2 for cowpea. Similarly, the per cent decrease of yield at I_1, I_3 and I_4 irrigation schedules were 13.1, 20.5 and 30.9 than I_2 for sesamum and 10.3, 19.3 and 34.8 than I_2 for mung, respectively (Table 9.2).

9.1.3 Effects of stress on crop yield

Variations of irrigation schedules resulted in different amount of stress on crop yield. The stress was measured in terms of actual crop evapotranspiration. The gravimetric method was used to measure the soil moisture content at 0-15, 15-30, 30-45 and 45-60 cm soil depth. Using soil moisture balance study and utilizing the measured data of the soil moisture content, irrigation, rainfall etc., the values of ETc was measured. The values of ETc for different growth stages and seasonal values were measured. It is seen that seasonal ETc of all the crops were maximum at 30% depletion level (Table 9.3). The values at 30 % depletion level were on an average 10.1% more than that at 60% depletion level. The reason for having highest ETc for 30 % depletion level might be due to frequent irrigation applications that caused a favourable soil moisture regime around the crop root zone.

Creation of a favourable soil moisture regime in the root zone might be the reason to produce more crop yield at 30 % depletion elvel. The actual crop evapotranspiration and actual yield data of all the treatments and replications of each crop (20 data for each crop) were used to develop crop production function in terms of a model relating to relative yield decrease (1-Ya/Ym) with relative evapotranspiration deficit (1-ETa/ETm). The crop production function of the crops of cowpea, sesamum and mung developed are given below in Equation (1), (2) and (3), respectively.

$$\left(1-\frac{Ya}{Ym}\right)=1.312\left(1-\frac{ETa}{ETm}\right),\ r^2 = 0.84 \qquad (1)$$

$$\left(1-\frac{Ya}{Ym}\right)=0.901\left(1-\frac{ETa}{ETm}\right),\ r^2 = 0.82 \qquad (2)$$

$$\left(1-\frac{Ya}{Ym}\right)=1.32\left(1-\frac{ETa}{ETm}\right),\ r^2 = 0.80 \qquad (3)$$

The values of coefficient of determination(r^2) for all the three equations were found to be high ranging from 0.80 to 0.84 indicating the relationship satisfactory. The coefficient 1.312, 0.901 and 1.32 were the crop stress function(Ks) for cowpea, sesamum and mung, respectively.

In the above mentioned equation (1) to (3), Ya and Ym were the actual and potential (maximum) yields, and ETa and ETm were the actual and potential (maximum) crop evapotranspiration, respectively.The crop production functions or models so developed (Equation (1) to (3)) were applicable only for the total growing period instead of individual growth stages. The models will help in estimating the actual yield of the crops knowing other parameters of the model. Further, it will help in designing and planning of the irrigation systems of a command.

9.1.4 Yield, water requirement (WR) and water use efficiency (WUE)

Water requirement of cowpea, sesamum and mung are found to vary from 28.6 to 32.05 cm , 26.55 to 28.85cm and 26.65 to 28.55 cm, respectively. The values of WR at 60 % depletion level of ASM were maximum and that at 30 % level were minimum for all the crops. The higher yield and lower WR resulted in obtaining higher values of WUE for all crops at 30% depletion level. The values of WUE at 30% depletion level were 25.3, 51.2 and 60.4 % more than that at 60 % depletion level for cowpea, sesamum and mung, respectively.

9.2 Field test of soil water balance simulation model of mung crop

In order to develop and test a soil water balance simulation model for mung crop and to simulate the soil moisture content in the root zone the experiment conducted for development of crop water production functions was used.In addition to the data generated for development of crop water production function,other data like daily soil moisture content in different profile zones (0-15, 15-30, 30-45 and 45-60 cm) were measured. The effective root zone of the crop was observed to be 60 cm at 70 days after germination. The duration of the crop was 83 days.

9.2.1 Soil water balance simulation model formulation

The maximum rooting depth of mung was considered as the soil reservoir which was divided into two layers (i) an active soil layer in which the roots were present and from which both moisture extraction and drainage occured and (ii) a passive soil layer from which only drainage occured. During the initial period of crop growth, these two zones exist separately with their relative dimensions being determined by the rate of root growth. When the roots attain maximum depth, the entire root zone was occupied by the active layer.

The daily soil water balance in the active root zone, ignoring upward flux due to capillary rise was as follows

$$SMC_i\ ,RD_i = SMC_{i-1}\ RD_{i-1} + P + SI + DRD_1\ SMCO_{i-1} - DP_i - AET_i - SR_i \quad (1)$$

Where, SMC = soil moisture content in the active root zone (mm cm^{-1}); SMCO = soil moisture content in the passive root zone (mm cm^{-1}); RD is the root depth (cm); D RD = incremental root depth (cm); P = rainfall (mm); SR = surface runoff (mm); SI = supplemental irrigation given to crop (mm), DP = production out of active root zone (mm); AET = actual evapotranspiration (mm) and i= time index taken as 1 and in the study.

The term (D RD_i $SMCO_{i+1}$) represented the addition of soil moisture content of a soil layer (equivalent to root growth during the period). when the analysis proceeded from (I = 1) th to i-th day. However, before this interval was reached, value of soil moisture content in the incremental layer was not known. It was assumed that the soil moisture content of the additional soil layer was same as that of the passive root zone. Values of SMC in both active and passive root layer at the beginning of the simulation period i.e., germination day of mung, which took three days after sowing of seeds were measured from fields. The soil moisture content on the day of germination of mung seed as measured were converted to per cm depth of soil layer to find out the soil moisture content (SMC_{i-1} and $SMCO_{i-1}$) at the active and passive zone, respectively.

9.2.2 Model parameters

Different model parameters like percolation, surface runoff, actual evapotranspiration etc. were evaluated by following some standard procedure. A computer programme was written in C language to compute the soil moisture content on daily basis in the active and passive root zone layer of mung by using the soil water balance model.

Results indicated that daily variations of observed and simulated soil moisture content in the root zone of the crops for treatments with irrigation at 20, 30, 50 and 60 % depletion of available soil moisture (ASM) were very close to each other. The mean absolute relative error (MARE) between the observed and simulated soil moisture content was found to vary between 6.1 and 8.3 % which showed that the developed model could work well in simulation of daily soil moisture in the crop root zone.

The study further revealed that at 20 % and 30 % depletion of ASM, the soil moisture content in the root zone remained close varying between 16.1 (1.61 mm/cm) and 21.8 % (2.18 mm/cm) .This was because of application of frequent irrigation as per the need. However, at 50 and 60 % depletion of ASM, frequencies of irrigation was less, but the application amount was more and hence the variations of the soil moisture content readings were large.

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CHAPTER-10

ON FARM WATER MANAGEMENT

Orissa is bestowed with ample of rainfall resources with average annual amount of 1500mm, 80% of which is available during the rainy season. During this period, about 50% of the annual rainfall comes from a few intense storms. Water received from such intense storms is subjected to high run off that causes a lot of soil and nutrient loss in arable lands. The fate of millions of rice growers in the region can be greatly improved by the use of effective rain water conservation and management. Use of on farm reservoir (OFR) is one such alternative to over come drought and to increase land productivity. Construction of OFR helps the farmers to harness surplus rainfall produced in the catchment and to store it for subsequent uses to crops at the their convenience. OFRs in the canal command areas near the irrigation channels have an added advantage of harvesting canal water through diversions, which can be used for agriculture, pisciculture and thus form an important component in farming system.

10.1 Hydrological characteristics of on farm reservoir (OFR) in rice growing areas

In the present study, three OFRs in Barahguda village of Bargarh distributory were taken. The hydrology of these OFRs are briefly mentioned in Table 10.1.

Table 10.1 General features of OFRs in study area

Particulars	On-Farm Reservoir		
	1	2	3
Catchment area (ha)	1.10	1.80	2.05
Service area (ha)	0.70	1.30	1.89
Dimensions of OFR Top (m) Bottom (m)	 31x23.5 23.5x16.0	 43.1x26.6 34.0x17.5	 37.9x29.2 30.0x21.3
Depth of OFR (m)	2.5	3.5	3.3
Side slope of OFR (H:V)	1.5:1.0	1.3:1.0	1.2:1.0
Open water area (m^2)	728.5	1146.5	1106.7
Capacity of OFR (m^3)	2714.0	5998.0	5695.0
Date of construction	25.6.1998	10.6.2000	10.12.2000
Soil characteristics (%) (a) Sand (b) Silt (c) Clay	 78.4 13.6 8.0	 76.8 11.4 11.8	 75.6 13.2 11.2
Textural Class	Sandy loam	Sandy loam	Sandy loam

The components of different water balance are estimated by an OFR water balance model. The OFR water balance model was studied by inflow-outflow analysis. The model is :

$$S_I = S_I - S_{I-1} = Q_I - Q_0$$

Where S = OFR strorage (m^3)

Q_I = OFR inflow component (m^3)

Q_0 = OFR outflow component (m^3)

i = index referring to present day

Inflow to OFR consists of contribution due to in-situ rainwater, runoff from catchments and canal water entering to the OFR. Outflow from OFR consists of evaporoation, seepage and percolation loss, supplemental irrigation to crops in service area and volume of overflow of OFR water.

The study area received total rainfall of 1107mm during the study period of June, 2003 to May, 2004. Out of this, monsoon months received 940 mm rainfall. Irrigation requirement of paddy was found to be highest for catchment area of OFR II than those of OFR I and OFR III with values of 385 mm in *kharif* and 398 mm in *rabi*. The irrigation requirements of paddy in catchment area of OFR II were maximum due to the reason that continuous submergence was maintained in field. However, the irrigation requirements of paddy in OFR I catchment area were found to be minimum (169mm in *kharif* and 190 mm in *rabi*). The reason may be due to the intermittent water management practice followed as described earlier. The irrigation requirement to paddy in catchment area of all OFRs were met fully from canal.

Table 10.2 Water balance components of OFRs during study period

Components	On-Farm Reservoir			
	I	II	III	Mean
Direct rainfall (m^3)	806 (4.1)	1269 (4.8)	1225 (4.6)	1100 (4.5)
Rainfall (m^3)	0	4356 (16.4)	5330 (20.0)	3229 (13.3)
Canal flow (m^3)	18985 (95.9)	20942 (78.8)	20145 (75.4)	20024 (82.2)
Total Inflow (m^3)	19791	26567	26700	24353
Outflow				
Evaporation (m^3)	3021 (16.0)	3910 (15.8)	3917 (15.1)	3616 (15.6)
Seepage & Percolation (m^3)	12108 (64.3)	15755 (63.5)	15797 (60.9)	14553 (62.8)
Irrigation (m^3)	1475 (7.8)	2690 (10.9)	5587 (21.5)	3251 (14.9)
Overflow (m^3)	2234 (11.9)	2405 (9.7)	637 (2.5)	1759 (7.6)
Total outflow (m^3)	18838	24760	25938	23179
Change in storage (m^3)	953	1807	762	1174

N.B.: Value in parenthesis represent per cent

The loss of water through actual crop evapotranspiration in the paddy field of OFR I, OFR II, and OFR III were 416,424,427mm in *kharif* and 420,428 and 430mm in *rabi*, respectively. The losses due to seepage and percolation in paddy fields of OFR I, OFR II and OFR III were observed to be 865, 1050 and 1062mm in *kharif* and 860, 1042, and 1050mm in *rabi*, respectively. Similarly, the runoff was estimated as 230,242 and 260mm for OFR I, OFR II and OFR III in kharif, respectively.

Water balance parameters in OFR

(a) **Inflow components :** Direct rainfall contribution to OFR I, II and III were observed to be 806,1269 and 1225 m^3 with a mean value of 1100 m^3, respectively. The contribution of direct rainfall in OFRs ranged from 4.1 to 4.8 % of total inflow with a mean value of 4.5% (Table 10.2). The run off contribution from catchment areas of OFRs II and III were 4356 m^3 and 5330 m^3 which was 16.4 and 20.8% of total inflow. It was found out that canal inflow to OFR constituted the highest percentage of total inflow ranging from 75.4% to 95.9% with a mean value of 82.2% (Table 10.2)

(b) **Outflow components :** Maximum loss of water from the OFRs were due to seepage and percolation (average being 62.8% of total outflow) because of unlined OFRs and soil being light textured. The mean evaporation loss was 15.6% and irrigation share was 14.0% (Table 10.2)

(c) **Balance stored in OFRs :** There was, on an average 24353 $m^3$and 23179 $m^3$of inflow and outflow in OFRs leaving a final storage of 1176 m^3. OFR II had maximum storage (1807 m^3) and OFR III had the minimum (762 m^3)

10.2 On farm irrigation water management in the command of godbhanga minor

In order to demonstrate the improved water management technology developed at the centre and study its impact on agricultural production, on Farm Irrigation water management studies were taken up in the Village Kujapali under Attabira Block in Sambalpur District during 1985-88.Topography of the area was undulating with land slope as high as 10%. Land has been classified as Att, Mal, Berna, and Bahal. Soil of the study area varied from sandy loam to sandy clay with pH ranging from 5.5 to 6.5, low available nitrogen and medium levels of phosphorus and potassium.

The study area received irrigation from Godbhanga minor with a design discharge capacity of 4.2 cusecs. The total rainfall of the study area varied from 935 mm to 1396 mm, about 85% of which is concentrated in June – September. The annual evaporation of the study area varied from 1566 mm to 1733 mm. Maximum (45°C) and minimum (12 °C) atmospheric temperature occurs during the month of May and December, respectively.

Eight cropping sequences : rice-mustard-rice; rice-wheat-til , rice-wheat-mung, rice-potato-till, rice-potato-mug, rice-groundnut-rice, rice-potato-rice and rice-rice were tried in the year 1983-84 and six crop sequences: rice-mustard-rice, rice-wheat-mung, rice-potato-til, rice-potato-rice, rice-groundnut-rice and rice-rice during 1984-85 in a total area of 16 ha out of which 8 ha was covered under demonstration trial and rest 8 ha under conventional rice-rice sequence.

Highest net profit of Rs.11661/ha was obtained from the sequence of rice-potato-rice with a water requirement of 286 cm followed by rice-potato-til (Rs.10390/-) with a water requirement of 177 cm . The rice-rice sequence not only gave less net return but also consumed higher amount of water (Table 10.3 and Table 10.4).

Table 10.3 Grain yield and net profit of different cropping sequence

Crop sequence	Grain yield (q/ha)			Value of produce (Rs./ha)				Cost of cultivation				Net profit (Rs./ha)
	1st crop	2nd crop	3rd crop	1st crop	2nd crop	3rd crop	Total	1st crop	2nd crop	3rd crop	Total	
Rice-mustard-rice	40.00	7.75	46.00	60000	3100	6900	16000	3000	1413	3200	7613	283.5
Rice-wheat-mug	39.10	23.00	9.55	5865	4600	2865	13330	3000	2650	1163	6813	6517
Rice-potato-till	38.10	122.50	11.80	5711	1025	3838	20578	3000	5900	1288	10188	10390
Rice-potato-rice	34.65	124.25	45.80	5708	11183	6870	23761	3000	5900	3200	12100	11661
Rice-groundnut-rice	38.85	19.25	46.15	5828	5325	6923	18076	3000	2613	3200	8813	9263
Rice-rice	31.50	-	41.80	4725	-	6270	10995	2900	-	3100	6000	4995

Table 10.4 Yield water requirement (WR) and water use efficiency (WUE) (kg/ha-cm) under different sequences

Crop sequences	1st crop			2nd crop			3rd crop			Total WR (cm)
	Yield (kg/ha)	WR (cm)	WUE (kg/ha.cm)	Yield (kg/ha)	WR (cm)	WUE (kg/ha.cm)	Yield (kg/ha)	WR (cm)	WUE (kg/ha.cm)	
Rice-mustard-rice	40.00	122	32.79	7.75	25.5	30.39	46.0	136	33.82	283.5
Rice-wheat-mung	39.10	122	32.05	23.00	33.5	68.66	9.55	25.5	37.45	181.0
Rice-potato-til	38.10	122	31.23	122.50	28.5	435.97	45.80	26.5	33.68	177.0
Rice-potato-rice	38.05	122	31.19	124.25	28.5	435.97	45.80	136	33.68	286.5
Rice-groundnut-rice	38.85	122	31.84	19.25	52.5	36.67	46.15	136	33.93	310.5
Rice-rice	31.50	162	19.44	-	-	-	41.80	167	25.03	329.0

10.3 Demonstration on improved water management practices

For the demonstration of improved water management practices 40 ha area was selected and divided into the blocks : one for demonstration on improved technology and the other for farmers practice. The crop sequences rice-mustard-rice and rice-rice were taken for the study.

An improved water management practice of 7 cm irrigation one day after the disappearance of ponded water (1ADP)was adopted for demonstration in case or rice against the farmer's practice of continuous flooding with 10-15 cm water that moved from field to field and 6 cm depth of irrigation at 0.9 IW/CPE ratio (20-23 days interval) in case of mustard against farmer's practice of one irrigation at flowering stage were adopted.

An increase of 13, 29 and 15% in yield of *Kharif* rice, mustard and summer rice. respectively was recorded due to the adoption of improved water management practices than farmers' practice. The field water use efficiency in rice was also increased by 36%. A saving of about 45 cm irrigation water could be achieved in rice-rice and rice-mustard-rice sequences due to the improved water management practices.

Table 10.5 Yield, water requirement (WR) and water use efficiency (WUE) of crops and sequence at Kujapali

Crop	Year	Duration (days)	Treated Plots			Un treated plots			
			Yield (q/ha)	WR (cm)	WUE (kg/ha-cm)	Duration (days)	Yield (q/ha)	WR (cm)	WUE (kg/ha-cm)
Rice (*Kharif*)									
	1985	132	26.80	142.3	18.83	136	22.50	177.3	12.69
	1986	132	26.80	142.3	18.83	136	22.50	177.3	12.69
	1987	128	39.80	127.3	31.26	133	35.20	141.0	24.97
	1988	123	38.13	119.0	32.04	125	35.40	132.8	26.66
	Mean	130	33.91	136.0	24.93	133	29.90	163.0	18.34
Mustard									
	1985	74	7.00	22.6	30.97	72	5.80	16.6	34.18
	1986	64	7.10	16.4	43.29	65	6.90	10.4	66.35
	1987	69	6.60	19.8	33.33	70	4.20	13.8	30.43
	1988	66	8.23	18.0	45.72	69	5.52	14.0	39.43
	Mean	68	7.23	19.0	38.05	69	5.61	14.0	40.07
Rice (Summer)									
	1985	141	42.60	159.6	26.69	144	38.00	183.6	20.70
	1986	140	41.90	131.4	31.89	142	38.80	162.4	23.89
	1987	134	39.70	134.7	29.47	138	34.60	156.7	22.08
	1988	132	42.77	127.2	33.62	137	35.25	140.7	25.05
	Mean	137	41.74	138.0	30.25	140	36.66	161.0	22.77

Table 10.6 Water requirement (cm) of crop sequences

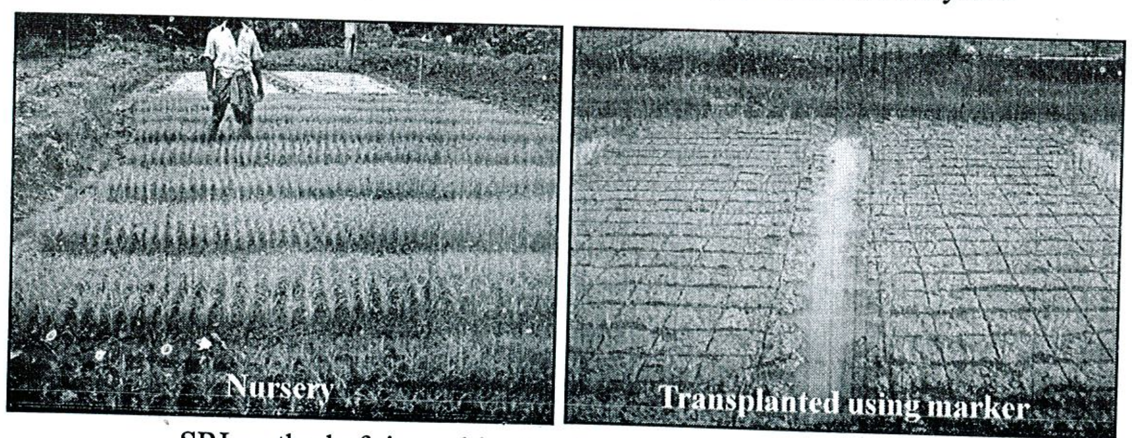
Year	Rice-Mustard-Rice		Rice-Rice	
	Treated	Untreated	Treated	Untreated
1985	324.5	377.5	301.9	360.9
1986	301.8	374.5	285.4	364.1
1987	281.8	311.5	262.0	273.5
1988	264.2	287.5	246.2	283.4
Mean	293.0	338.0	274.0	320.0

10.4 Demonstration on water saving through systems of rice intensification (SRI) method of rice cultivation

In order to demonstrate the benefits of higher yield and water saving with SRI method of rice cultivation vis-a-vis conventional method of rice planting with respect to their crop production, three numbers of demonstration trials, two in farmers fields of Garmunda village and one at research farm of RRTTS, Chiplma were conducted during *rabi* 2008-09 on medium lands with irrigation from canal.

On an average, the total number of effective tillers per hill (16.5) under SRI method was 174% higher than the conventional method (6.0). Number of spikelets per panicle (115.8) was 14.4 % higher than the conventional method (101.2). Percentage filled grains was 7.2% higher and the test weight was 4.26% more in SRI method than the conventional one.The rice production from SRI out yielded the production by conventional method in all the locations with a mean yield advantage of 11.64%.

The per hectare cost of cultivation under SRI method was more than that of conventional method by Rs700/- which might be due to lack of experience in handling SRI method of planting. Moreover, the yield advantage obtained in SRI method could compensate the extra cost which was 8.6% more than the conventional method. However, the water requirement in SRI method was 22.1% less and the water use efficiency was 43.27% more than that in conventional method. Thus, SRI method of cultivation with yield advantage of 11.6 % and saving of water of 22.1% is a better method than the conventional way of rice cultivation in Hirakud command. The additional expenditure in SRI could be minimized with experience in cultivation practices over the years.



SRI method of rice cultivation for higher water productivity

Table 10.7 Relative performance of conventional and SRI method of rice cultivation both in research station and farmer's field of Hirakud command

	SRI				Conventional	Advantage over conventional (%)
	On-Station	Gautam	Tarakanta	Mean		
Crop variety	Khandagiri	Khandagiri	Khandagiri		Khandagiri	
Date of planting						
Spcaing	25 × 25 cm	25 × 25 cm	25 × 25 cm		20 × 10 cm	
Nutrient Management	100% RD (80:40:40)	100% RD (80:40:40)	100% RD (80:40:40)		100% RD (80:40:40)	
Water Management	Maintenance of water in channels	Maintenance of water in channels	Maintenance of water in channels		Shallow submergence	
Weed Management	Mechanical weeding thrice	Mechanical weeding thrice	Mechanical weeding thrice		Hand Weeding twice	
No of hills/ m^2	16.0	16.0	16.0	16.0	50.0	
No.of effective tillers/ hill	17.0	17.0	15.4	16.5	6.0	174.44
No.of spikelets/panicle	115.3	114.6	117.5	115.8	101.2	14.40
% of filled grain	87.0	89.4	84.0	86.8	81.0	7.18
Test weight (g)	24.5	25.0	24.0	24.5	23.5	4.26
Estimated grain yield (q/ha)	66.8	69.7	58.4	65.0	57.8	12.40
Actual grain yield (q/ha)	46.3	47.1	49.3	47.6	42.6	11.64
Cost of cultivation (Rs/ha)	9200.0	8950.0	8700.0	8950.0	8250.0	-8.48
Irrigation water requirement (cm)	60	60	60	60.0	77	22.08
Water use efficiency (kg/ha.cm)	77.13	78.50	82.15	79.3	55.32	43.27

10.5 Farm pond in canal command for higher productivity : A Success Story

Mr. Rakshya Pal Seth, a farmer from Barahaguda village of Bargarh district in Orissa, has four and half acres of land. His family was solely dependant on farming. With the available resources and conventional practices he was unable to sustain his livelihood and was managing his family hand to mouth. For farming he was depending on the canal water of the Hirakud Canal system. The transplanting of rice was delayed due to late raising of seedlings because of canal closure during pre-*kharif* and pre-*rabi* seasons. Further, the wet situation in *berna* (medium) land did not allow any crop between two rice crops. In *mal* land (bunded uplands) unavailability of water at appropriate time was the major constraint for crop intensification. Due to scarcity of water, he was able to cultivate only two acres of land under rice-rice system and two and half acres with either one vegetable/ pulse / oilseed crop in a year. The yield from the rice and other crops was very low due to scarcity of water during the critical stages of crop growth and conventional practices.


On farm reservoir of Mr. R. Seth of Barahaguda

The scientists of All India Co-ordinated Research Project on Water Management, Chiplima Centre realized these problems of the canal command and came out with a solution. They persuaded the farmer to go for a farm pond for storage of water which could be used during canal closure periods for crop production and where pisciculture, duckery etc. could be undertaken profitably. Frequent visit of the scientists, their persuation and demonstration motivated Mr. Seth to go for a farm pond.

He dug a farm pond of size 50m × 30m and 2.5m deep very close to the canal and stored water for utilization throughout the year. With the available water, he could grow three crops of rice-mustard-rice in two acres of *berna* land in place of only rice-rice and three to four vegetable crops such as brinjal, potato, okra, cauli flower, cabbage, bitter gourd and cowpea in his two acres of *att*

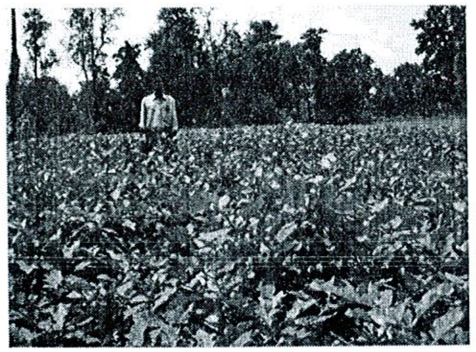

A successful brinjal crop using farm reservoir water

Table 10.8 Economic analysis of the pond based farming system adopted by Mr. Rakshya Pal Seth of Barahaguda village

Name of the enterprise	Area/ number	Expenditure incurred (Rs)	Net return (Rs)	Return per Re invested (Rs)
Rice-mustard-rice	2.0 acre	36,000	44,000	2.22
Brinjal-cauli flower-chilli	0.6 acre	41,000	85,000	3.07
Cowpea-cabbage-bitter gourd	0.7 acre	27,000	60,000	3.22
Okra-potato-cucumber	0.7 acre	20,000	38,000	2.90
Cross bred cow	3 nos.	36,000	54,000	2.50
Duckery	20 birds	1,250	4,000	4.20
Poultry (layer)	25 birds	1,150	4,800	5.17
Pisciculture	0.4 acre	3,500	10,000	3.86
Total		**165,900**	**2,99,800**	**2.81**

and *mal* land where he was growing only one vegetable in a year. Now he is also getting more production from both the rice crops due to proper water management and adoption of better package of practices. Besides, he is also able to grow fish and ducks in the pond which adds to his total income. On an average, he is getting a net profit of about rupees three lakhs per annum with an investment of Rs. 1.66 lakhs (Table 10.8). Mr. Seth is now a very happy person. He says that farm pond is the best technology to conserve water and use it for higher crop production and profit throughout the year. He is planning to purchase some farm implements to reduce the requirement of manual labour and to avoid labour scarcity during the peak periods of need. The other farmers of the area have also been inspired by the success of Mr. Seth.

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CHAPTER-11

SUMMARY OF TECHNOLOGICAL INNOVATIONS

Based upon the experiments conducted on different aspects of water management the following recommendations/technologies were developed by AICRP on water management, Chiplima Centre over years :

- Total water availability and crop water demand analysis in Hirakud command indicated a net surplus of 24.01 M ha-cm on annual basis confined to months from May to August.
- Water balance studies indicated a surplus of 600 mm water to rice crop during monsoon months when p > PET. November and December months however, are the deficit months.
- Hybrid rice, PA 6201 recorded the highest grain yield of 41.6q/ha in summer and 51.2q/ha in *kharif* under a water management practice of continuous shallow submergence of 5±2 cm with water requirement of 110 and 93cm, respectively. However, the highest water use efficiency was observed at 7 cm irrigation at 1 day after the disappearance of ponded water with 42 and 57kg/ha-cm during summer and *kharif,* respectively.
- On Farm studies revealed that inclusion of cauliflower as catch crop between the two rice crops increased the net return by 77% (Rs. 1619/ha) over that with mustard. However, rice-potato-okra was adjudged as the most remunerative sequence with a net profit of Rs.20014/ha, per day net return of Rs.68.6/ha and benefit cost ratio of 1.26 where as the sequence rice-mustard-rice recorded the highest land use efficiency (92.3%).
- Non availability of canal water in November-December causes moisture stress leading to poor establishment and restricted initial growth of *rabi* crops. Conjunctive use of surface and ground water could overcome the situation and helped to increase cropping intensity from 159% in farmer's field to 224% in study block.
- Parallel field drains at 10 m spacing were efficient in removing the excess water (drainage coefficient 10.76x10-5 cm/s) providing maximum profit of Rs7352/ha with maximum B:C ratio (1.31). Drains helped in lowering the ground water table form initial of 1.0 cm to 17.5 cm to 3.8cm to 30.0cm at the end of 6th years. This helped to record more yield of rice and facilitated the growing of succeeding dry crops.

- Sugarcane cv Co87037 planted at a row to row spacing of 80 cm and irrigated at 1.2 IW/CPE ratio (23 irrigation) produced the highest cane yield of 73.24t/ha.
- Rajmash cv. Chitra produced highest grain yield (10.44q/ha) under 1.2 IW: CPE ratio (six irrigations). There was no difference in yield due to sowing rajmash from 1st November to 20th November (98-103 days) which were significantly superior to 20th October sowing.
- In a preliminary study, the crops like water chestnut, lotus and rice did not perform well under ill drained water logged situation showing high motality (38 to 95%).
- Newly opened ponds with light textured soil showed maximum loss of water through seepage and percolation (67.6%).
- Encouraging channel to field irrigation and using pond water as alternate source of irrigation during channel closure period, it was possible to successfully grow three crops in sequence in a year.
- The crop sequence, rice-cauliflower-cauliflower with a net return of Rs.79190/ha was the most remunerative and was superior to the sequence rice-cauliflower-rice and rice-potato-rice and rice-potato-okra by 9.02, 19.43 and 20.89%, respectively.
- With increase in plot size from 200-400 m^2 to 800-1000 m^2 the water application efficiency increased by 56.6% to 61.8%. Plot size of 800-1000 m^2 is attributed to least land slope and uniform leveling. Due to minimum land slope, uniformity in land slope and higher water application efficiency the field of size, 800-1000 m^2 produced higher grain yield of rice (46.3 q/ha) which was 12.1, 8.9, 3.3 and 15.2% more than the yields of 200-400 m^2, 401-600 m^2, 601-800 m^2 and 1001-2000 m^2, respectively.
- In banana + ginger intercropping system, planting methods did not have any significant effect on banana yield, however, irrigating the crop at 1.2 IW/CPE ratio produced maximum banana yield of 17.3 t/ha with water use efficiency (WUE) of 74.41 kg/ha-cm.
- Ginger planted on raised bed with mulching (T0 t/ha) and irrigating the crop at IW/CPE ratio of 1.0 registered maximum rhizome yield of 14.1 q/ha with WUE of 14.4 kg/ha-cm.

- Sunflower crop grown after puddle rice with the tillage practice of two ploughings in country plough followed by tractor drawn rotavator twice and iirrigation at 0.8 IW/CPE ratio produced maximum seed yield of 7.93 q/ha which was almost 38% higher than that of farmer's practice (ploughing once with country plough, irrigation as per availability.)
- Crop coefficient (Kc) values of paddy in the study area found to be maximum (1.11-1.16) at crop development stage. The average Kc value during the entire crop growth stage of paddy was almost 1.02.
- Irrigation at 30% depletion of available soil moisture (ASM) in crops like cowpea, sesamum and mung produced more yield of 57.55,8.11 and 9.98 q/ha, respectively than at 20,50, and 60% depletion of ASM with higher WUE. The values of WUE at 30% depletion of ASM were 25.3, 51.2 and 60.4% higher than that at 60% depletion of ASM in cowpea, sesamum and cowpea, respectively.
- The daily soil water balance in the active root zone, ignoring upward flux due to capacity rise is as follows.(model of mung crop).

  SMCi,RDi=SMCi-1 RDi-1+P1+SI1+j RD1 SMCoi-1-Dpi-AETi-SR1 (1)

  Where, SMC=soil moisture content in the active root zone, (mm) SMCo= soil moisture content in the passive root zone, (mm); RD is the root depth (cm); j RD= incremental root depth (cm); P= rainfall (mm); SR=surface runoff (mm);

  SI= supplemental irrigation given to crop (mm), DP=production out of active root zone (mm) AET=actual evapotranspiration (mm) and i= time index taken as 1 in the study.
- The under bund percolation in rice field ranged between 2.4-37 mm/day where as the vertical percolation was 2.1-2.2 mm/day where as the vertical percolation was 2.1-2.2 mm/day. To reduce the under bund percolation in rice field, the perimeter-area ratio of rice field check basin should be 1:2.
- Chronically water logged soils can be very productive with appropriate land configuration and farming with suitable technology. Digging trenches with 2m width and 0.75m depth in 8.60% area and a farm pond (1.5m depth) in 41.25% area and allowing drainage (3.4% area) in one side it was possible to raise multiple crops along with rearing of fishes with multiple use of water. Raising water chestnut in trenches, okra in ridge were also tested to be highly successful in raising the probability of the system with enhanced water productivity. The per hectare yearly gross income can be around Rs50,000/- from various crops and allied farmings followed in the converted water logged eco system.

- Irrigation at 60% depletion of available soil moisture of a rajmash crop (cv.Chitra) grown on a slightly acidic loamy textured soil produced maximum seed yield of 6.61q/ha which was at par with that of 50% depletion of ASM but superior to that of 30% depletion of ASM by 5.8%. Among the mulching materials tried, paddy straw was found to be superior to sugarcane trash and plastic mulching with around 21% higher yield than no mulching with maintenance of better soil health.
- Irrigation at 30% depletion of soil moisture in a moderately well drained soil produced maximum yields in cowpea (38.63q/ha) where as maximum yield in sesamum (5.13q/ha) was obtained when irrigation was provided at 60% depletion. The next best irrigation schedule was 20% depletion of ASM for first two crops and 30% depletion of ASM for sesamum.
- Organic vis-a-vis INM practices of manuring in a rice-tomato cropping sequence on a slightly acidic well drained soil showed maximum grain yield of 42.70 q/ha in rice (cv:Surendra) grown during *kharif* when it was fertilized with 100% recommended dose of fertilizers under shallow submergence.Which was at par with the yield recorded from the crop applied with 75% as inorganic and rest 25% as organic sources of nutrient. Lowest crop yield was obtained with 100% organic treatment that received FYM @10t/ha along with green manure.
- In Hirakud Canal Command rice- potato –til cropping sequence with total water requirement of 148cm was the most remunerative cropping sequence which generated 70% more income with saving of about 73% more water than rice-mustard –rice cropping sequence.
- Under water deficit situation application of 7cm irrigation at 1day after depletion of ponded water to kharif rice followed by irrigation at 0.9IW/CPE ratio to the rabi crops of maize. potato, mustard and groundnut generated good net return. Rice groundnut sequence was the most profitable one net profit of Rs. 10,157/ha per year.

Water saving techniques for rice

- Proper land leveling and puddling. Tractor with cage wheel or power tiller with rotavator is most economical for puddling and saves 10% of water.
- Growing rice in a compact rather than in isolated patches in summer season. Seepage losses from 1 ha isolated patch of rice in summer season is 5 times higher than from 1 ha rice field in a compact patch of 25 ha.
- Continuous shallow submergence (5±2 cm) gives as much or higher yields than deep submergence but saves 10-50% irrigation water.
- Saturation throughout is optimum particularly under shallow water table (20-30 cm in *rabi* and 20-45 cm in *kharif* under Hirakud command), high relative humidity and low evaporative demand.
- Rotational irrigation at 1 to 3 days after disappearance of ponded water (DADPW) through field channels instead of field to field irrigation saves 9 and 27% irrigation water in *kharif* and summer seasons, respectively. Improvement in yield and WUE was, respectively, by 9 and 20% in summer season and by 12.2 and 54% in *kharif*.
- Under Orissa condition the recommended practice is irrigating rice with 7 cm water 3 DADPW during *kharif* (5-7 irrigations) and 1 DADPW during *rabi* season (13-15 irrigations) which produced at par yield with 3-7 cm shallow submergence throughout.
- The recent developments like System of Rice Intensification (SRI) and aerobic rice aimed at water saving in rice cultivation. Bed planting saves 26-42% water as compared to conventional planting.
- Drainage particularly at maximum tillering stage or even at panicle initiation stage in iron toxicity area is beneficial to the crop.
- Drainage at dough stage along with that at maximum tillering increased head rice recovery by 10%. Draining the field gradually 15-20 days after flowering facilitates mechanical harvesting and timely sowing of succeeding crops and saves 16-22 cm water.

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CHAPTER - 12

TRANSFER OF TECHNOLOGY AND ITS IMPACT

The AICRP on Water Management Chiplima centre has evolved many field solutions on various crop-water related aspects and some of them have provided important input for further research. The data so generated also have helped in planning the irrigation projects mainly on the aspects of irrigation scheduling in various crops and cropping systems. However, some important technologies developed on various water management aspects have been considered as deliverables and most of which have been field tasted under the Agriculture Intensification Programme (AIP) of the government.

12.1 Deliverable Technology

- **Method of irrigation**
  - a) Application of water to crops through channel to field instead of field to field
  - b) Application of irrigation water (7cm) to rice field through field channel 3days after disappearance of ponded water in kharif and 1day after in rabi which results in saving of about 15% irrigation water with increase in water use efficiency of 20%.
  - c) Opening up of farm pond with canal water as main recharge source.The stored water is used for supplemental irrigation during the period of canal closure in November-December.
  - d) Drip method of irrigation in tomato to save water and earn more profit
- **Method of drainage**
  - a) Providing parallel field drains with need based dimension at 10-15m interval for quick and efficient disposal of excess water and lowering the ground water
  - b) Subsurface drainage with tiles placed at a depth of 1.2m at 12m drain spacing can reduce excess water in the soil profile and enhance soil productivity and cropping Intensity in water logged area.
- **Method and time of planting**
  - a) Autumn (October-November) planting of sugarcane instead of February-March planting for higher cane yield and efficient use of water

b) Paired row planting of potato for higher water and nutrient use efficiency and crop productivity than conventional system

- **Method of tillage**

a) Puddling of rice fields with tractor drawn cage wheel as cost effective method and for better land preparation than conventional bullock drawn cage wheel and desi plough

- **Preventing loss of water**

a) Rice fields should have optimum perimeter: area ratio of 1:2 for reducing under-bund percolation loss of applied water

b) Optimum plot size for uniform use of applied water for rice should be 800-1000m^2 with slope of 0.70%.

- **Reclamation of water logged ecosystem**

a) Chronically waterlogged ecosystem could be put into cultivation through land configuration. Crops of water chestnut in trenches, vegetables on trench bunds and rice on flat fields were cultivated besides rearing of fishes in trenches and sump.

- **Enhancing nutrient use efficiency**

a) Works on interaction effect of nutrients and irrigation water on crop yield have generated number of management interventions. Both irrigation and nutrient requirements of various crops for yield optimization have been determined.

12.2 Extent of adoption of technology and its impact

Some of the technologies delivered to the farmers have been accepted in the area and the adoption has shown some impact in various forms.

i. Technology

Channel to field irrigation is being adopted by many farmers particularly in tail end areas in Hirakud Command. The practice has widely been tested under Agriculture Intensification Programme in different irrigation commands of the state and found acceptance with the farmers.

Impact

This practice has facilitated conservation of water for tail end users and created conditions for undertaking crop diversification from conventional to more remunerative

non paddy crops. As a result there is reduction in acreage under Rabi rice and increase in acreage under oilseed (groundnut, mustard, and sesame), pulses and vegetables in the Hirakud Command Area.

ii. Technology

Farmers of Barahguda in Bargarh district have adopted the farm pond concept and already experienced the benefit accrued due to the Integrated farming system approach with components of rice- oilseed/ vegetables- rice/vegetables on adjacent fields, fruits(papaya, coconut, guava, banana) and vegetables (Spine gourd/Ridge gourd) on pond embankments and fish in water. The concept acted as conduit in diversification efforts.

Impact

The technology has been accepted in the area and already 30 new ponds have been opened after the 1st pond in 1998. It has increased the cropping Intensity and profitability.

iii. Technology

Puddling by Tractor drawn cage wheel has become a common practice in both Sambalpur and Bargargh district. It has increased water use efficiency in rice over desi puddler and desi plough.

Impact

In time planting and higher productivity from rice and reduction in water loss

iv. Technology

Autumn planting of sugarcane has been adopted by the farmers of Bhatli, Bheden, Bargarh and Attabira blocks of Bargarh district.This practice also provides scope for successful intercropping with mustard(toria)

Impact

About 12% of sugarcane area has switched over to autumn (Oct.-Nov.) planting that produced higher cane yield with more remuneration than Feb-Mar planting.

v. Technology

Paired row planting of potato has been accepted by the potato growers of Barahguda village as a water saving method of potato planting for higher benefit.

Impact

It is still continued by the farmers who first adopted the technology. Though with little spread, there is a wide scope for its large scale use.

vi. Technology

Rajmash as a rabi pulse crop introduced under crop diversification programme with supplemental irrigation has found acceptance by the farmers in Barahguda village.

Impact

It has now become a successful new pulse crop that can be cultivated in Bargarh district and hasa tremendous scope as the area is in want of a suitable winter crop.

vii. Technology

Optimum doses of N and P for different crops at recommended irrigation levels have been worked out for the canal commands.

Impact

Farmers have gained the experience of using fertilizers and reaped the benefit. There is now increased demand for fertilizers in the area.

General impacts

1. Crop diversification has increased the net income of farmers, ensured nutritional security and created job opportunity for the rural poor thus discouraged migration.
2. On farm consultancy and training has made the farmers aware of the bad impact of injudicious use of water.

For successful adoption of all deliverables there should be more on farm trials and farmers' trainings and all line departments should work hand in hand.The future research needs to be oriented towards exploitation of underground water.

12.3 Scaling up of water productivity in agriculture for livelihoods through teaching and demonstration

The project on "Scaling up of water productivity in agriculture for livelihoods through Teaching and Demonstration" sponsored by ICAR, New Delhi commenced during the year 2007-08 was a timely intervention through which trainers and farmers were trained by experts for 14 and 7 days, respectively, with latest technologies developed in agriculture to suit the water management needs of a particular location. Analysis of different

water management related problems and on the spot demonstration of water management practices, visits to different water management units have added to the knowledge and confidence of the farmers. Through this training programme, linkages are established between the officers of Government Departments, Financial Institutions, Agricultural University and other Research Institutes of the State and Central Government with the farmers.

12.3.1 Training

Trainings on different aspects of water management for farmers, scientists and Govt. officers are regularly conducted by the centre.Two numbers of two week trainers' training for 50 participants consisting of officers from Line Departments, subject matter specialists from KVKs, faculty of OUAT were conducted from 2007 to 2009 at RRTTS, Chiplima. Besides, 21 numbers of one week farmers trainings were conducted at 21 different locations of the state for 1050 farmers on various aspects of scaling up of water productivity in agriculture for livelihood.

12.3.2 Demonstration

On demonstration front, four numbers of demonstration trials were conducted on:

a. Raised and sunken bed system for increasing crop productivity and cropping intensity
b. Tissue culture banana cultivation with drip irrigation
c. Water management in sugarcane
d. SRI method of rice cultivation

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CHAPTER- 13

FUTURE THRUST AREAS OF WATER MANAGEMENT

Water is one of the most important factors to boost agricultural productivity. It is, therefore, high time that we start thinking about water as the most scarce natural resource and plan for its strengthening and most efficient use. Emphasis should be given on the following aspects of water management.

a. Multiple use of water

It has been realized that the overall efficiency of the medium and large irrigation projects are very low owing to huge losses in the distribution system and poor application efficiency. This results in uneven distribution of water in the command area and lowering of water use efficiency. Multiple use of water is required to combat the situation. In this method the water entering into the system would be utilized by different non-competing components of the farming system. If required the water would be treated by natural or artificial means.

b. Popularisation of micro irrigation

In the flood irrigation method the water applied to a crop field is not uniform which results in poor application efficiency. While, in micro irrigation methods such as drip and sprinklers, the uniformity can be maintained as well as the losses of water is minimized. Further, application of fertilizers and control of weeds can also be done by applying water to the rootzone using drip irrigation. However, micro irrigation is not popular in this region due to high initial investments and requirement of power which becomes a major component of the operational cost. The micro irrigation methods need to be popularized with suitable demonstrations and economic analysis.

c. Deficit irrigation management

The crop yield reduces drastically if irrigation is not provided at the critical periods of crop growth. However, in situations when water is very scarce, the available water can be utilized to provide irrigation at the right time and at the right quantity to save the crop as well as get optimum yield. The deficit irrigation management deals in identifying the critical stages of crop growth and the optimum quantity of water needed at each stage.

d. Conjunctive use of water and crop diversification

In the canal commands the irrigation is mainly applied through flow irrigation of surface water which results in waterlogging of the low lands. If the ground water available in the water table can be utilized then both the purposes of irrigation and drainage can be

served. This requires more studies on feasibility of conjuctive use of surface and ground water.

e. Water optimisation in all canal commands of the state

The water availability at all the reaches of a command area is not the same. Hence the cropping pattern can also not be the same. Studies are needed to find the right cropping pattern in different reaches of the command area considering all constraints including water availability through application of modern optimization techniques.

f. Drainage in canal commands

Due to poor drainage conditions the low lands of the command areas suffer from water logging. Thorough drainage studies are required to design the drainage system as per the prevailing land conditions as well as to identify the areas which can be reclaimed and put into cultivation.

g. Standardisation of water management in SRI method

The systematic rice intensification (SRI) method of raising rice crop has been recommended for optimizing the yield. Although the SRI method is practiced in different parts of the state, local conditions may influence the yield. It is therefore necessary to standardize the method for different land, labour, machinery, manure and water availability conditions. It is also necessary to develop standard water management practices for the method.

h. Standardisation of package of practices for aerobic rice

Similar to SRI method, cultivation of aerobic rice in areas of water scarcity is being promoted now a days in order to increase the water use efficiency in rice. The standard practices, especially the water management practices, are not yet developed for the farmer's field conditions. Hence extensive studies are needed to standardize the practices for cultivation of aerobic rice in uplands of the command areas.

i. Water management in organic farming system

Due to misuse of agrochemicals a large area of cultivable land is being degraded. The concept of organic farming in which application of chemicals has raised the hopes of preventing land degradation. However, the water management for organic farming may be different from the prevailing water management practices. More studies are needed to standardize it under different conditions and for different crops.

j. Exploiting use of industrial waste water

Nowadays the industries have started competing with agriculture in using surface and ground water. Many studies have been conducted at national and international levels to utilize the industrial wastes in agriculture. In this region also, for coexistence of industries with agriculture, extensive studies are needed for use of industrial waste water.

k. More emphasis on farm water management

A major portion of water is being wasted at the farm level due to adherence of inappropriate practices such as field to field irrigation, improper land leveling etc. The water application efficiency can be improved significantly if more emphasis is given at the farm level.

j. Rain water management

A major portion of the rain wateris lost through runoff and some times be the cause of water logging of some areas. Proper Management of rainwater will help in conservation of water for its multiple use and minimize the problem of water logging.

k. Canal automation

A new concept which may be tried in Hirakud Command in a microscale to test its feasibility in the beginning in order to enhance the canal water use efficiency. This can prevent both water logging and deficit water supply and enhance both irrigation and field water use efficiency with efficient water distribution among the end users.

l. Water management for mitigating the effect of climate change on crops

Global warming has its effect on climate, hydrologic cycle and crop production systems. Studies are needed to establish empirical relationship between water management and changed growth pattern of crops under high or low temperature conditions and develop appropriate water management practice for mitigating the problem.

m. Management of soil fertility in canal command

In canal commands very little attention is given towards maintenance or improvement of soil health. Most of the areas under canal command are now degraded and have become physically very poor with reduced nutrient supplying capacity. Studies are needed on nutrient dynamics and nutrient balance in order to improve the soil health.

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CHAPTER-14

PUBLICATIONS

Research publications

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Bulletin/Leaflet

a. Water management in vegetables – Part I
b. Water management in vegetables – Part II
c. Raised and sunken bed system of cultivation – a viable option for crop diversification in medium and low land
d. Increasing land productivity of chronically waterlogged area through land configuration
e. Farm pond in canal command for higher productivity – a success story
f. SRI paddhatire dhana chasha
g. Bibhinna fasalare jalara sadupojoga
h. Unnata Pranalire kadali chasha

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