

# WTCER

Research Bulletin

Publication No. 13

## Crop Diversification Technology in Rainfed Upland Rice Area of Eastern India for Increased Productivity and Rainwater Use Efficiency

**GOURANGA KAR, RAVENDER SINGH, HARSH NATH VERMA**



**WATER TECHNOLOGY CENTRE FOR EASTERN REGION**

*(Indian Council of Agricultural Research)*

Chandrasekharpur, Bhubaneswar - 751 023, India

**2003**



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Gouranga Kar, Ravender Singh and Harsh Nath Verma (2003) Crop diversification technology in rainfed upland rice area of eastern India for increased productivity and rain water use efficiency. Research Bulletin 13/2003. Water Technology Centre for Eastern Region, Bhubaneswar - 751 023, Orissa, India.

*Published by:*

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*Printed By :*

**Capital Business Service & Consultancy**  
Bhubaneswar, Telephone : 0674 - 2545484

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## FOREWORD

With the unprecedented increase in human population of India during the last few decades, clearly mankind faces formidable problem to ensure food and environmental security for all, considering reduced per capita availability land and water. Most part of the country is bestowed with good quality of natural resources basic to agriculture with plenty of rainfall ; but poor management of these resources give very low productivity, particularly from rainfed rice ecosystem.

Among different rainfed rice ecosystems, productivity of rainfed upland rice area is still low ( $< 1 \text{ t ha}^{-1}$ ). In spite getting low and unstable yields, farmers grow rice traditionally in upland due to lack of improved alternate cropping systems. Under this situation the on-farm research work on "Crop diversification technology in rainfed upland rice area of eastern India for increased productivity and rain water use efficiency" contributed by the Water Technology Centre for Eastern Region, Bhubaneswar is having immense value to increase production, productivity, profitability and sustainability of rainfed upland rice ecosystem. I had an opportunity to visit the project implementation site during both rainy and winter seasons along with NATP World Bank team, NATP review team, Directors and Scientists of different ICAR Institutes and found rice substituted, low water requiring crops like black gram, maize, groundnut, pigeonpea, horsegram, sesamum (through sole cropping or intercropping) performed very well in light textured rainfed upland rice soils even in deficit rainfall years (rainy season of 2000 and 2002). The outcome of research has created a great impact in Dhenkanal district, Orissa and farmers are in the process of automatic adoption of improved cropping system. Scientific dissemination and extension bulletins in local language highlighting this cost effective and farmers' friendly technology for wide scale adoption to other rainfed areas are the real needs. Extensive mini but many demonstrations must be laid down on resource poor farmers under varying rainfed farming situations. These will have dramatic impact in augmenting productivity and profitability of the small and marginal upland rice farmers and ensures food and nutritional security for the farming community living in inhospitable environment. In this context, organization of 'farmers' fair', 'field day', 'training cum crop diversification programme' and circulation of extension bulletins on improved rainfed farming in local language by WTCER, Bhubaneswar helped to disseminate the improved crop diversification technology of upland rice area to the farming community of other rainfed areas. Authors deserve much appreciation for writing this valuable research bulletin based on their on-farm research findings for increased productivity of rainfed upland rice area.

(I.C.MAHAPATRA)

## PREFACE

Increase demand of food to cater to the needs of ever increasing population, shrinking natural resources, in-appropriate, exploitive and unscientific land use planning in rainfed farming represent a massive challenge to the agricultural sector which not only provides food, nutrition and environmental security of the country but also engages large rural population to make a living. Under such a situation site-specific, alternate sustainable crop diversification plan, based on potential and prospects of existing natural resources may serve as an effective tool in the hands of farmer for improving productivity and profitability of rainfed ecosystem which covers 63 % of the total cultivated area but contributes only 40 % to the national food basket. Crop diversification that involves crop rotation and cropping system of cereals, legumes, oilseeds and vegetables results in availability of wide variety of food grains and improved productivity by enhancing soil fertility and reducing build up of pest and diseases.

It is hardly disputed that the productivity and cropping intensity of upland rice ecosystem can not be raised to a desired level to alleviate poverty unless the existing rice production systems are diversified through inclusion of low duty high value crops or introduction of other farm enterprises as a compliment to crop production. Keeping the importance of crop diversification in rainfed upland rice area for its increased productivity and rain water use efficiency, sustainable crops/cropping system were recommended and implemented in representative rainfed upland rice area of Dhenkanal district, Orissa through National Agricultural Technology Project (RRPS-3).

We take this opportunity to extend our deep sense of gratitude and indebtedness to the Director General, Deputy Director General (Natural Resources Management) and Assistant Director General (IWM), ICAR for their encouragement and guidance to carry out the study. The authors are extremely helpful to World Bank authority for providing fund to execute on-farm research work through National Agricultural Technology Project. Adequate thanks need to be given to the Scientific Advisory Panel of Rainfed Agro-Ecosystem of NATP Chairman Dr. J.S.Kanwar and its Director Dr. H.P.Singh and members who designed the technical programme and their monitoring. We sincerely thank PPSS Dr. B. Venkateswarlu and Dr. K.P.R. Vittal who undertook the responsibility of implementation of the programme through financial and technical support facilitating the process of execution of World Bank funded NATP project. We also take this opportunity to extend our deep sense of gratitude and indebtedness to Dr. I.C.Mahapatra for reviewing the manuscript critically. Authors sincere thanks are due to Dr. R.S. Tripathy, lead PI, IGKV, Raipur for his proficient guidance and constant encouragement during study period. We are grateful to different programme leaders of WTCER, Bhubaneswar for providing laboratory facilities for soil and plant analysis. We are also thankful to Director, NRSA, Hyderabad, NATMO, Calcutta, NBSS & LUP, Nagpur, CGWB, Bhubaneswar and SOI, Bhubaneswar, for providing hard copy thematic maps of the study area. We take this opportunity to extend our gratitude to Collector and DDA, Dhenkanal,, B.D.O., Kamakhyanagar, KVK, Dhenkanal, Central Rubber Board, Dhenkanal for their support to undertake the programme in Dhenkanal district and for providing necessary information to carry out the study. Author's sincere thanks are due to villagers of Arnapurapur for their active participation during study. Thanks are due to project associates, scientists, senior research fellows and staff members of WTCER, for their moral support and help rendered during study. We hope the generated technology will be useful for line departments, NGOs and farmers for augmenting productivity of upland rainfed rice area.

(AUTHORS)

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## 1. EXECUTIVE SUMMARY

Out of 42.3 million hectares of total rice area in India, rainfed upland rice occupies 6.1 million hectares of which 4.3 million hectares are located in eastern India (Assam, West Bengal, Orissa, Jharkhand, eastern Uttar Pradesh and Chhattisgarh). In eastern India, upland is mainly rainfed monocropped, dominated by rice with low ( $<1$  ton  $ha^{-1}$ ) and unstable yield. In spite of getting low and unstable yield due to erratic south west monsoon, moisture stress during crop growth period, light textured soils with low water retention capacity and fertility status, existence of biological constraints like weeds (*Cyperus rotundus*, *Echinochloa colona*), diseases (blast, brown spot) and pests (gundhi bug, termite, worms), traditional farmers of eastern region, especially in Orissa grow rice in rainfed upland rice ecosystem. Keeping the urgent need of augmenting productivity of the vast rainfed upland rice ecosystem (4.3 mha) of eastern India in view, technology was generated through problem solving, demand driven, participatory, on-farm research trials at representative rainfed upland rice area of eastern India (Arnapurnapur village, Kamakhyanagar Block, Dhenkanal district, Orissa) after analyzing agroclimatic, adaphic and socio-economic constraints and prospects. To determine alternate diversified crops/cropping systems with their approximate sowing periods, weekly probability of receiving particular amount of rainfall, wet-dry spell analysis (Markov chain model), onset and withdrawal of effective monsoon (Ashok Raj, 1979), climatic water balance (Thornthwaite and Mather, 1957) and probability distribution of monthly rainfall (Extreme Value Distribution Type-1) were carried out. As per the rainfall analysis, sowing of direct seeded, low water requiring upland crops namely maize, groundnut, pigeonpea, greengram, blackgram, cowpea etc. (sole or intercropping) was done in representative upland rice field in 24<sup>th</sup> meteorological week (11<sup>th</sup> to 17<sup>th</sup> June) in three study years (2000, 2001, 2002) with 2-3 summer ploughings during pre-monsoon shower.

The study revealed that in deficit rainfall years (2000 and 2002) in Orissa when rainfed upland rice yield was affected adversely and net economic return from upland rice area was nil to negative, higher net economic return per annum was obtained through crop diversification from maize cob (Rs. 19,500 to 26,000  $ha^{-1}$ ) followed by groundnut + pigeonpea intercropping (Rs. 20,124 to 20,704  $ha^{-1}$ ), sole groundnut (Rs. 15,420 to 16,060  $ha^{-1}$ ), sole pigeonpea (Rs. 15,072 to 16,200  $ha^{-1}$ ) and rice + pigeonpea intercropping (Rs. 8,472 to 9,564  $ha^{-1}$ ) on the same land. Study also revealed that productivity of rice substituted crops in upland rice field did not differ significantly in rainfall excess (2001) and rainfall deficit years (2002 & 2000). Double cropping in rainfed upland rice field was explored through maize-horsegram / sesamum rotation. The experience of crop diversification in upland rice area showed that the technology was very much useful for drought mitigation with increased productivity and rainwater use efficiency of rainfed upland rice area of eastern India. The outcome of the participatory research on upland crop diversification has created a great impact in the state of Orissa where crop diversification is the need of hour for drought mitigation, increasing rainwater use efficiency and productivity of rainfed upland rice area. The technology was widely disseminated by organizing 'farmers' fair', 'field day', 'training', 'crop diversification awareness programme' and circulating extension bulletins in local language. As a future approach of research, upland light textured soils were mapped on watershed basis using Remote Sensing and GIS tools for identifying the location of possible upland rice substitution through crop diversification. For sowing time characterization and water balance analysis of upland rice substituted rainfed crops, a computer programme was also developed.

## 2. INTRODUCTION

It is matter of concern that out of 329 mha geographical area in India, about 145 mha is cultivated with practically no scope to bring more area under plough. The agricultural progress made so far has largely been confined to irrigated areas but country's vast rainfed arable land is still neglected. Current projection of population growth, increase demand of food, shrinking natural resources, in-appropriate, exploitive and unscientific land use planning in rainfed farming represent a massive challenge to the agricultural sector which not only provides food, nutrition and environmental security of the country but also engages large rural population to make a living.

The eastern India which comprises of Orissa, West Bengal, Chhatisgarh, Assam, Jharkhand and eastern Uttar Pradesh is the rice dominated area of the country, accounts for about 63.3% of the India's rice area (26.8 mha out 42.3 mha total rice area). About 78.7 % (21.1 mha) of rice farming in the region is rainfed and only 21.3 % (5.7 mha) is irrigated. Out of total rice area in the region about 16% of the rice area (4.3 mha) is rainfed upland, 48% (12.9 mha) is rainfed lowland (0-50 cm water depth) and the remaining 14.7% (3.9 mha) is deepwater or very deep water (Singh & Hossain, 2000).

Most part of the eastern India is bestowed with plenty of rainfall and good quality of natural resources basic to agriculture, but poor management of these resources and unscientific land use planning has lead to a situation where people of this 'resource rich region are resource poor'. Major part of this region receives higher average annual rainfall which varies from 1000 to 2000 mm but due to lack of appropriate water and soil management practices, the region has one of the lowest agricultural productivity, particularly from vast rainfed upland rice area. The defining feature of rainfed upland rice ecosystem is the lack of ponded water at any time during the life cycle, so soils remain aerobic throughout where establishment of rice is risky (Wade 2003). The 70.4 % (4.3 mha) of total rainfed upland rice area of India (6.1 mha) are located in eastern region (Orissa, West Bengal, Assam, Jharkhand, Chhattisgarh and eastern Uttar Pradesh) where productivity of rice is very low ( $< 1 \text{ t ha}^{-1}$ ) and unstable. The productivity from such land fluctuates drastically from year to year due to vagaries of southwest monsoon, occurrence of dry spells and moisture deficit during growing season. The soils of upland rice area are also light textured with low water holding capacity and severe nutrient deficiencies, acidic and high P-fixation, which results low ( $< 1 \text{ t ha}^{-1}$ ) and unstable rice yield. Traditionally farmers of the region grow rice in rainfed light textured upland simply to cover the fallow during rainy season, neither they get net positive return nor they expect any yield certainty from such land. For obtaining food, yield certainty and net positive economic return rather, they heavily depend on medium and lowland rainfed rice ecosystem which covers about 48% of total rice area of the region. Under this situation in this study emphasis was given to develop crop diversification technology (through partial and complete substitution of rice) in rainfed upland rice field for growing low duty high value crops (maize, blackgram, cowpea, greengram, groundnut, pigeonpea etc.) which may be best option at the hands of farmers for drought mitigation and increased productivity of such land. Idea of crop diversification in rainfed upland rice area is to emphasize that these crops can provide assured and higher return even with low rainfall and in soils with low water holding capacity because water requirements of these crops are less than that of rice. Further, absense of flooding does broaden the scope of growing diversified crops in that system (Wade 2003). For very traditional rice farmers those who can not afford to leave rice even in upland, partial substitution of rice though rice based intercropping may give some yield containty for them. If rice fails to grow with

full potential, other low water requiring or deep rooted intercrops will mitigate effects of drought and thus productivity of rainfed upland rice area may be stabilized. Though some research works were conducted at research farm for improving productivity of rainfed upland rice area of eastern India but hitherto the rate of adoption of the new production technology by farmers was relatively poor. The possible reasons were many. Farmers were either unaware of the new technology or farmers were averse to change because they could not afford the high input required by new technology. The new technology was developed for 'maximum productivity' rather than for 'maximum profit'. Therefore, in the present study technology was generated to increase productivity, cropping intensity and rain water use efficiency of rainfed upland rice ecosystem of eastern India based on participatory, on-farm, adoptive research trials in one of the representative rainfed districts of Orissa (Arnapurnapur village of Kamakhyanagar Block, Dhenkanal District). The region belongs to Subhumid Subtropical agro-ecological zone where modern production technologies have yet to make an impressive impact and strategic research is needed to improve the overall productivity of the rainfed area. The spatial location of study area are given in Fig. 1.

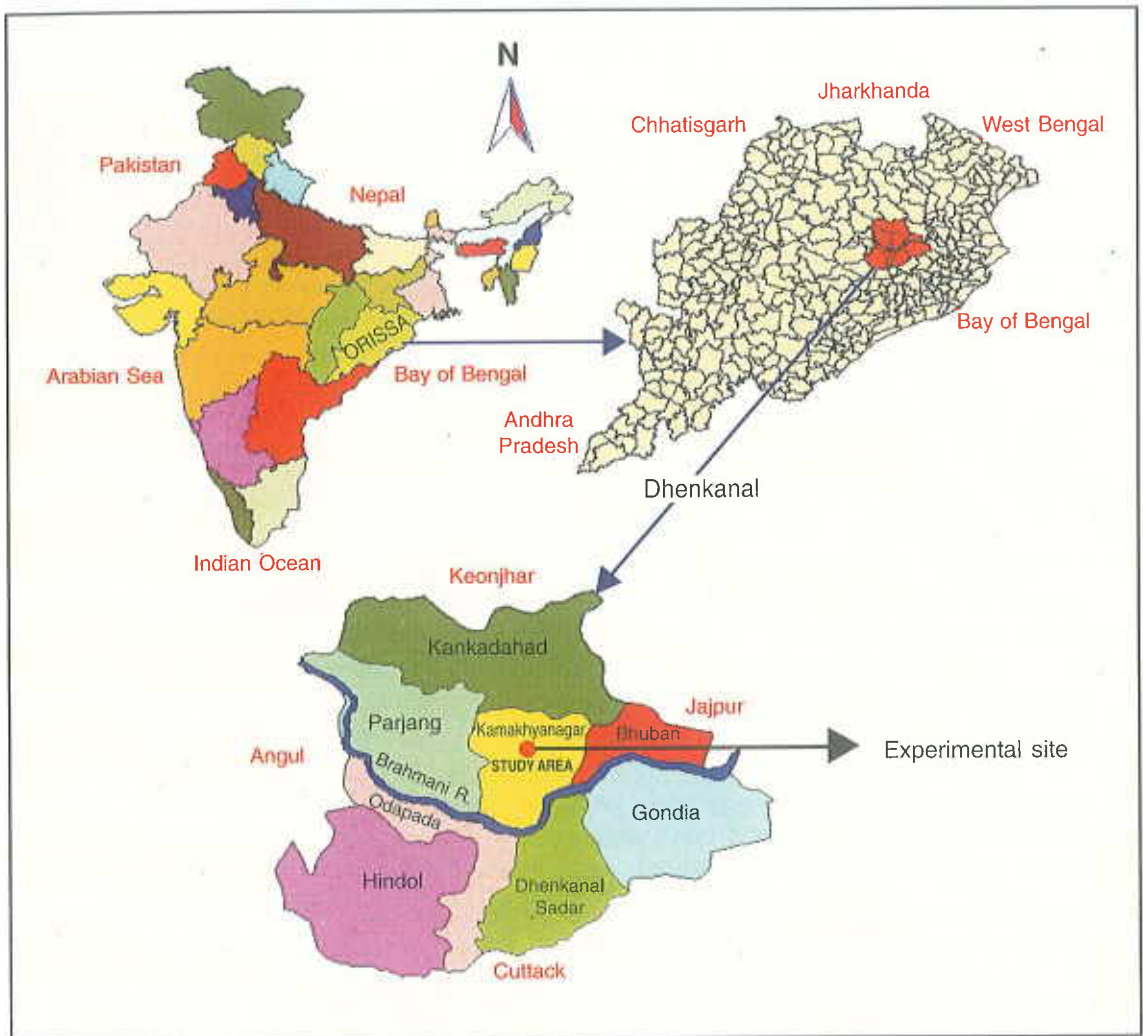


Fig. 1 : Location of experimental site of rainfed upland rice substitution and crop diversification

Any pragmatic rainfed crop planning needs a thorough understanding of rainfall (variability, probability of occurrence, onset of effective monsoon, water balance etc.) and soil physico-chemical, water retention-transmission properties. Since in India, agriculture is mainly dependant upon the performance of southwest monsoon rainfall, so rainfed crop planning is also decided by the onset and withdrawal of effective monsoon and availability of soil moisture. Therefore, rainfall and soil properties of the study area were also analysed to characterize earliest probable sowing time, length of growing period and types of suitable crops to be grown on upland rice area.

Site-specific crop diversification package must take into account existing topography, land use/land cover, soil resources, climate, hydro-geomorphology etc. Survey techniques and manual methods for apprising spatial natural resources over large agricultural area are time consuming and tedious. With the advent of Remote Sensing and Geographic Information System (GIS), the natural resources appraisal becomes faster, easier and accurate. Therefore, an attempt was also made to identify similar adaphic and topographic conditions on watershed basis using Remote Sensing and GIS tools for effective dissemination and application of upland rice substitution and crop diversification technology over large agricultural area.

### 3. REVIEW OF LITERATURE

Crop diversification and rice substitution in rainfed upland rice area through low water requiring or deep-rooted crops like maize, blackgram, greengram, pigeonpea, groundnut, cowpea, horsegram, sesamum etc. was effective means for ensuring higher and stable productivity of rainfed upland rice ecosystem (Verma and Singh, 1990; Kar and Verma, 2002). Pulses had inherent quality to trap the moisture from the lower strata of the soil; therefore, they were considerably moisture stress tolerant and fit well in rainfed condition (Chaturvedi and Masood Ali, 2002). For traditional rice farmers and in rice dominant area, partial substitution of rice with legumes through rice based intercropping in upland rice area provided more yield advantage and monetary return than that of sole crops (Misra 1983). Beneficial effects of intercropping of rice with pigeonpea were reported by Mahapatra and Srivastava (1983). Jha and Chandra (1980) at CRRI, Cuttack tried intercropping of rice with ragi, til, cowpea, mesta etc. and found rice + cowpea was the best combination for fetching higher return and giving highest land equivalent ratio (LER).

Inter-cropping of two different crops gave higher yield advantage than that of sole cropping through better use of land, light, rainfall and nutrient. The complementarities, in combination, was due to better temporal and/or spatial use of these resources (Rao *et al.*, 1982). When plants were grown in association (as inter-cropping or mixed cropping), interaction between components species occurred, which were essentially the response of one species to the environment as modified by the presence of another species (Mandal *et al.*, 2000). Increasing production of legumes without sacrifice of rice in rice area was possible through inter-cropping of these crops with rice (Ramamoorthy *et al.*, 1997; Sengupta *et al.*, 1985; Mahapatra 1987). Inter-cropping of rice with legumes under rainfed upland condition also improved rainwater use efficiency and productivity due to better combined leaf and root distribution system (Patra *et al.*, 1997).

Characterization of onset of effective monsoon (OEM) and weekly wet-dry spell analysis were of paramount importance in rainfed agriculture in eastern India because agricultural operations here largely depended upon the onset of south west monsoon and slight delay in sowing of rainfed upland crops may lead to drastic reduction of yield. (Bhatnagar and Kundu, 1992; Panigrahi and Panda, 2002; Kar and Singh, 2002). The rainfall probability and OEM analysis for crop planning

were thus essential basic tools for cropping system characterization in rainfed area (Victor and Sastry, 1979 ; Pandarinath, 1991 ; Das and Senapati, 1992). Better utilization of rainfall, effective control of soil erosion and runoff depended largely on the water retention and transmission properties. (Kumar *et al.*, 2002 ; Gupta *et al.*, 1986 ; Oswal, 1993 and Singh and Bhargava, 1994 & Singh and Nayak, 1999) for light textured upland.

Hitherto the rate of adoption of production technology for improving productivity and cropping intensity of rainfed upland rice area developed at research farm was relatively poor due to lack of proper extension activities. To overcome these problems, demand driven, problem solving, participatory on-farm research trials on crop diversification and rice substitution were conducted with the aim to improve productivity of rainfed upland rice area after analysing agroclimatic (rainfall) and adaphic (soil physical, physico-chemical and water retention) properties.

#### **4. EXISTING PRODUCTION CONSTRAINTS OF RAINFED UPLAND RICE AREA**

The existing production constraints of rainfed upland rice area of eastern India necessitates better crop production technology through introduction of diversified crops to improve productivity and cropping intensity of such area. The different constraints are categorized as follows.

##### **4.1 Biophysical constraints**

- The defining feature of rainfed upland rice ecosystem is the lack of ponded water at any time during the life cycle of crop, as a result soils remain aerobic throughout and may encounter water deficit when rain fails.
- The net economic return from rainfed upland rice ecosystem of eastern India fluctuates drastically from year to year due to vagaries of south west monsoon, occurrence of dry spells and moisture deficit during growing season inspite of receiving high total annual rainfall (1000-2000 mm) in the region.
- The upland rice soils are also light textured, often kaolinite and have low water holding capacity because of coarse texture and have severe nutrient deficiencies. The soil reaction is acidic to moderately acidic (pH varies from 4 to 6) with low fertility status, low cation exchange capacity and high phosphorus fixation, Al and Mn toxicity.
- In rainfed upland, rice roots may encounter both chemical (Soil pH) and physical barrier (hardpan).
- Weeds (*Cyperus rotundus*, *Echinochloa colona*) are also important biological constraints for rainfed upland rice cultivation followed by diseases (brown spot, blast and sheath rot) and pests (termites, gundhi bug or stick bug ) of rice.
- Unfavourable rainfed rice uplands are having shallow soil depth, unbunded with undulating and sloping topography.

##### **4.2 Technological constraints**

- Lack of proactive advice on meteorological information (medium and long range weather forecasting), marketing information (potential demand in domestic and external markets) and management information (soil characteristics, irrigation water availability and agro-ecological conditions).



- No soil and water conservation measures, improved agronomic practices like integrated nutrient management, pest management, soil management, weed management and crop management were followed for maintaining sustainable productivity in rainfed upland rice area.
- No corrective measure for micro-nutrient deficiency, Al and Mn toxicity of upland light textured rice soils.
- Lack of farm yard manures/compost which results low organic matter or organic carbon content in upland rice soils.
- Unscientific land use planning, near absence of green manuring or green leaf manuring and absence of use of soil amendments.
- Lack of improved farm implements like efficient bullock drawn field equipments for upland preparation, mechanically operated electrical or diesel pump, sprayers, dusters etc.

#### 4.3 Socio-economic constraints

- Farmers of eastern India are traditional rice growers and inspite of getting low (<1 ton ha<sup>-1</sup>) and unstable yield, traditional farmers of the region grow rice in upland.
- Lack of knowledge about improved cropping system, proper production and protection technology and non availability of inputs and varieties of non-rice crops at proper time.
- Dominance of marginal and small farmers, lack of resources and low literacy levels for adopting improved cultivation or technology.
- High cost of cultivation compared to value of produce and distress sale of rice at non-remunerative prices.
- Lack of modern agricultural implements like tractor/power tiller, seed drill, seed-cum-fertilizer drill on co-operative basis/custom hiring for ensuring timely agricultural operation reducing drudgery of farmers.

#### 4.4 Administrative/Institutional constraints

- Non-synchronous delivery of credit, input and technology, as a result farmers get very little time for precision farming.
- Lesser minimum support price than market price or wholesale market price indicating that the farmers are not getting the real price for their produce, which they should otherwise get.
- Poor linkages between Research-Extension-Farmers-Market. Lack of field demonstration or frontline demonstration of improved production and protection technology.
- Inadequate extension literature, non-functional village extension agents, near absence of mini but many small demonstrations.
- Improper implementation of crop insurance scheme.

#### 4.5 Budgetary support

- Poor budgetary support for human resource development in rainfed farming as compared to irrigated agriculture.
- Lack of incentives for development of small scale processing mills and their establishment at village *Panchayet* level for producing value added products.
- Non-existence of budgetary support for diagnostic survey by the team of competent scientists to improve productivity of rainfed upland rice area.

### 5. PRIORITIES IDENTIFIED THROUGH DIAGNOSTIC SURVEY TO IMPROVE PRODUCTIVITY OF UPLAND RICE AREA OF EASTERN INDIA

#### 5.1 Research option

- Absence of flooding in rainfed upland rice area does broaden the scope of growing diversified crops in the system, even with intercropping or mixed cropping. Rice substitution (complete or partial) and crop diversification technology with short duration, low water requiring or deep rooted crops namely maize, blackgram, greengram, pigeonpea, cowpea, sesamum etc. through sole/intercropping may stabilize and enhance productivity of upland rice area.
- Priorities should also be given for better seeding and tilling practices to improve the existing sowing methods of farmers. Use of suitable seed-drills and simple intercropping equipment has to be encouraged to facilitate row seeding, mechanical weeding and fertilizer placement. Introduction of modern agricultural implements like tractor/power tiller, seed drill, seed – cum-fertilizer drill on co-operative basis/custom hiring are needed, to ensure timely agricultural operation because performance of the rainfed crops in upland depends on the timely sowing.
- Efforts should also be made to improve the physical conditions of the soil and soil fertility through integrated nutrient management like legumes in cropping sequence/crop rotation or intercropping, green manuring, use of farmyard manures, biofertilizer etc.
- Since weed in upland is a very serious problem, integrated weed management through summer tillage, use of combination of biological, manual and chemical weed control practices should be adopted.
- Improved water management and in-situ water conservation methods namely off-season tillage or summer tillage, conservation tillage, contour farming, deep ploughing, surface mulching, use of soil amendments and conditioners, intra-plot runoff collection measures, inter-plot runoff conservation measures should be followed to improve water retention capacity of upland rice soils.
- Strategic research is needed for the region, not only for maintaining the natural resource base but also for genetic improvements of germplasm of diversified crops so that constraints of upland rice ecosystem to increase production imposed by abiotic and biotic stresses can be minimized.
- Priority to pest-disease management by genetic resistant should be given because by excessive dependence on expensive pesticides has not only raised the cost of production but also creates high pesticide residues.

- Identification of light textured upland rice area for crop diversification using advance tools like Remote Sensing, GIS and to concentrate research in those areas to make them more productive and remunerative.
- Development of integrated dynamic simulation model for forecasting and predicting rainfall distribution (wet-dry spells), rainfall amount (at different probability levels) and onset of effective monsoon for sowing time characterization, contingency crop planning and water balance study of upland rice area.

## 5.2 Policy option

- Synchronization of delivery of credit, input and technology of crop diversification under one umbrella at Panchayet level which will ensure precision farming by saving farmers' valuable time and energy.
- Proper linkage should be developed among research, extension, farmers and markets for successful adoption of technology and fetching good return. Close linkages and interactions among research institutes, seed producing organizations/companies and development agencies may ensure better seed replacement rate of pulses and oilseeds in rainfed upland rice area.
- Incentives to be provided for development and establishment of small scale processing mills at village Panchayet level for producing value added products from diversified cropping system in rainfed upland rice area, like processed 'dal' from pulses, 'oil' from oilseeds and 'pop corn', 'corn flakes', 'flour from maize etc.
- All pulses, oilseeds or low water requiring cereals-millets should be covered under minimum support price. The Government should announce the procurement price and fare price for all crops as strategy for required interventions.
- Assured procurement of processed products from upland crops like processed 'dal', 'oil' etc. from local mills/processing units and their distribution through fair price shop will ensure better price to farmers.
- Implementation of crop insurance scheme by the Government for all pulses, oilseeds, low water requiring cereals and millets and trifurcation of existing Technology Mission, each on oilseeds, pulses and maize.
- In tune with National Agricultural Policy, there is need to strengthen activities on the development of low cost production technologies, cropping systems, crop modeling, precision farming etc.

Keeping the above constraints and priorities for improving productivity of rainfed upland rice area of eastern India in view, some of the options were prioritized and technology was generated based on demand driven, problem solving, participatory, adaptive research in upland rice ecosystem of one of the representative rainfed districts of Orissa i.e. Dhenkanal, Orissa. (Fig.I). According to NARP classification (1979), the study area belonged to Mid Central Table Land Zone of Orissa. The total cultivated area of the district was 20,56,07 ha, out of which 50 % was rainfed upland (10,36,96 ha). The cropping intensity of the district was only 145%. In regard to crop husbandry practices during rainy season, 96 % of the cultivated area was dominated by rice and rest 4 % was under different crops like groundnut, maize, greengram, sesamum etc. During

rainy season upland was dominated by rainfed rice with very low and unstable productivity. Therefore, as a case study, the on-farm adaptive research trials on crop diversification were conducted in upland rainfed rice ecosystem of Arnapur village, Kamakhyanager Block, Dhenkanal district, Orissa (Fig. 1) after analysing agroclimatic (rainfall), adaphic (soil water retention) and socio-economic problems and prospects.

## 6. RESULTS OF SOILS & CLIMATE ANALYSIS AND EXPERIMENTAL FINDINGS

### 6.1 Soil properties of representative rainfed upland rice fields

To characterize rainfed upland rice soils of experimental sites, 12 soil profiles, comprising of 10 farmer's field were dug randomly and soil samples at 0-0.15 m, 0.15-0.30 m, 0.30-0.60 m, 0.60-0.90 m and 0.90-1.20 m depths were collected. The soil water retention along with their physical and physico-chemical properties were analyzed and average results of which are presented in Table 1. Water retention at different suction values was estimated by using pressure plate apparatus (Richards, 1965). Bulk density was estimated on undisturbed samples collected with metal cores of 4.2 cm diameter and 5.2 cm height (Klute, 1986). The other physical and physico-chemical properties were estimated by following standard procedures (Jackson, 1976).

**Table 1 : Soil physical, physico-chemical and water retention properties of experimental site.**

#### (a) Important soil physical properties

Soil Depth (m)	Particle size analysis (%)				Bulk density (Mg m <sup>-3</sup> )	Ks (cm hr <sup>-1</sup> )
	Coarse sand	Fine Sand	Silt	Clay		
0 - 0.15	31.8	28.3	18.4	21.5	1.53	1.19
15 - 0.30	30.3	23.2	20.8	25.7	1.55	1.05
0.30 - 0.60	31.2	17.6	22.7	28.5	1.55	0.95
0.60 - 0.90	30.6	20.4	20.3	28.7	1.57	0.76
0.90 - 1.20	27.4	14.6	31.2	26.8	1.58	0.68

#### (b) Important soil physico-chemical properties

Soil Depth (m)	pH <sub>2</sub>	EC <sub>2</sub> (dS m <sup>-1</sup> )	Organic carbon (%)	Olsen P (mg P kg <sup>-1</sup> soil)	NH <sub>4</sub> OA <sub>C</sub> -K (mg K kg <sup>-1</sup> of soil)
0 - 0.15	5.1	0.05	0.52	4.3	55
0.15 - 0.30	5.1	0.06	0.48	6.4	65
0.30 - 0.60	5.6	0.04	0.26	5.8	62
0.60 - 0.90	6.1	0.03	0.25	6.3	68
0.90 - 1.20	6.2	0.05	0.23	8.3	67

(c) Water retention properties

Soil Depth (m)	$\theta_s$ ( $m^3m^{-3}$ )	$\theta(m^3m^{-3})$ at 0.01 MPa	$\theta(m^3m^{-3})$ at 0.03 MPa	$\theta(m^3m^{-3})$ at 1.5 MPa	Available water content ( $m^3m^{-3}$ )
0-0.15	0.355	0.231	0.171	0.061	0.110
0.15-0.30	0.373	0.245	0.173	0.063	0.110
0.30-0.60	0.403	0.291	0.212	0.077	0.135
0.60-0.90	0.405	0.300	0.227	0.078	0.145
0.90-1.20	0.371	0.281	0.199	0.071	0.127

(d) Functional relationship between  $\Psi$  &  $\theta$ , K &  $\theta$  and D &  $\theta$

Soil Depth (m)	$\Psi_e$ (cm)	b	Relationship between $\Psi$ and $\theta$	Relationship between K and $\theta$	Relationship between D and $\theta$
0-0.15	21.21	3.61	$21.21(\theta/0.355)^{-3.61}$	$1.19(\theta/0.355)^{9.22}$	$91.1(\theta^{5.61}/0.355^{6.61})$
0.15-0.30	23.2	3.59	$23.2(\theta/0.373)^{-3.59}$	$1.05(\theta/0.373)^{9.18}$	$86.2(\theta^{5.59}/0.373^{6.59})$
0.30-0.60	28.37	3.87	$28.37(\theta/0.403)^{-3.87}$	$0.95(\theta/0.403)^{9.74}$	$104.3(\theta^{5.87}/0.403^{6.87})$
0.60-0.90	29.13	3.97	$29.13(\theta/0.405)^{-3.97}$	$0.76(\theta/0.405)^{9.94}$	$87.8(\theta^{5.92}/0.405^{6.97})$
0.90-1.20	27.85	3.81	$27.85(\theta/0.371)^{-3.81}$	$0.68(\theta/0.371)^{9.62}$	$72.15(\theta^{5.81}/0.371^{6.81})$

$\Psi_e$  = air entry suction values (cm),  $\Psi$  = soil water suction (cm), K = hydraulic conductivity ( $cm\ hr^{-1}$ ), D = soil water diffusivity ( $cm^2\ hr^{-1}$ ), b = a soil parameter,  $\theta$  = water content ( $cm^3\ cm^{-3}$ )

**6.1.1 Physical and physico-chemical properties**

Study reveals (Table 1,a) that texture of the soil was sandy loam in nature with high sand and silt. The clay content of the soil varied from 21.5 to 28.7 %. Bulk density of soil ranged between 1.53 to 1.58  $Mg\ m^{-3}$  and it increased with soil depth. The pH of the soil varied from 5.1 to 6.2 and electrical conductivity (EC) values ranged between 0.03 to 0.06  $dS\ m^{-1}$ . No salt problem was detected in the soil profile.

Organic carbon (%) content of the soil varied from 0.52 % in upper layer (0-0.15 m) to 0.23 % in lower layer (0.90-1.20 m depth). Available phosphorus (Olsen P) in the soil was less and varied from 4.3 to 8.3  $mg\ P\ kg^{-1}$  of soils and potassium (K) content varied from 55 to 68  $mg\ K\ kg^{-1}$  of soils. In general, soil was sandy loam, strong to moderately acidic with low organic carbon, phosphorus and available potassium.

**6.1.2 Water retention characteristics**

Water content at saturation ( $\theta_s$ ) varied from 0.355 to 0.405  $m^3\ m^{-3}$  in different depths of the soil profile (Table 1,c). At maximum water retention capacity (0.01 MPa), highest water was retained by soils at 0.60-0.90 m depth i.e. 0.300  $m^3\ m^{-3}$  and the lowest was at 0-0.15 m depth (0.231  $m^3\ m^{-3}$ ). At field capacity (0.033 MPa), the highest amount of water was retained by soils at 0.60-0.90 m depth (0.227  $m^3\ m^{-3}$ ) and the lowest was at 0.00-0.15 m depth (0.171  $m^3\ m^{-3}$ ). The values of water content

at 1.5 MPa (permanent wilting point) varied from 0.061 to 0.0781 m<sup>3</sup> m<sup>-3</sup> and highest water was retained by soils at 0.60-0.90 m depth (0.078 m<sup>3</sup> m<sup>-3</sup>). Available water capacity of the soils varied from 0.110 to 0.145 m<sup>3</sup> m<sup>-3</sup> at different depths. Saturated hydraulic conductivity (Ks) of soil ranged between 0.68 to 1.19 cm hr<sup>-1</sup>. The values of air entry suction varied from 21.21 to 29.13 cm and highest value of it was observed at 0.60-0.90 m depth. The highest value of 'b', a soil parameter was observed at 0.60-0.90 m depth with the values being 3.97. The values of saturated moisture content ( $\theta_s$ ), saturated hydraulic conductivity (Ks), air entry suction values ( $\Psi_e$ ) and 'b', a soil parameter were used to develop functional relationship between soil water suction ( $\Psi$ ) and water content ( $\theta$ ), hydraulic conductivity (K) and water content ( $\theta$ ) and between soil water diffusivity (D) and water content ( $\theta$ ) (Table 1, d). These functional relationships can be utilized in a algorithms of dynamic simulation model for estimation of unsaturated hydraulic conductivity or soil water diffusivity. The graphical relationships between matric suction values,  $\Psi$  and soil moisture content,  $\theta$  (soil moisture characteristics curve) was also established and are presented in Fig. 2.

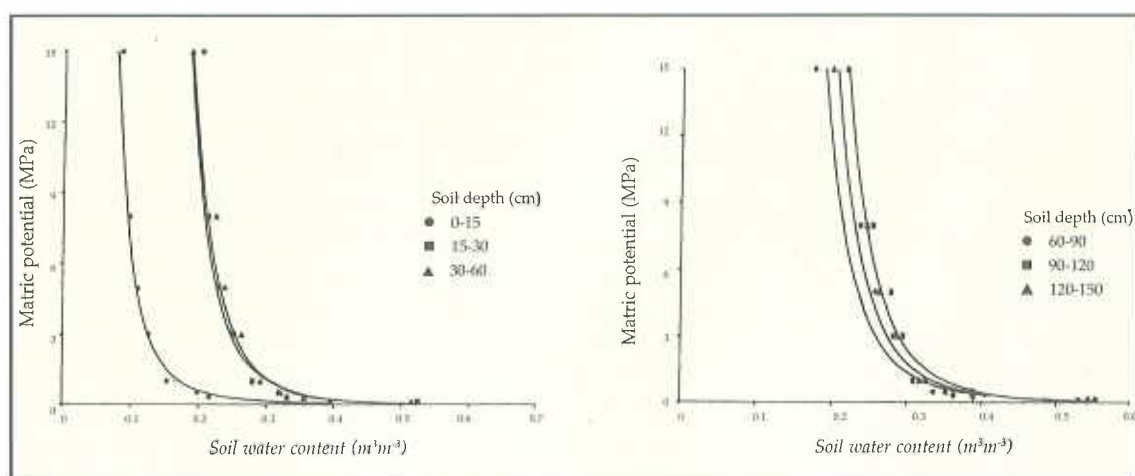


Fig. 2 : Soil moisture characteristics curve of upland experimental rice fields  
(Average results of 12 soil profiles)

In general, upland experimental rainfed rice soils were light textured with low water retention and available water capacities. The fertility status of the soils was also very low. Therefore, addition of organic matter with integrated nutrient management and inclusion of legumes in the cropping system on such soils were advocated to improve soil fertility and water retention capacity. Idea of rice substitution in upland rice soils was to emphasize that these crops could provide much higher and assured return in soils with low water retention capacity and less available water. Whereas, productivity of rainfed rice on such soils was very less and unstable with nil to very low net economic return. Rice substituted crops, especially pulses have inherent capacity to trap the moisture from the lower strata of soil, therefore, they are considerably moisture stress tolerant and fit well in light textured upland rice soils. Besides, the heavy leaf fall of legumes adds sufficient organic matter to the soils.

## 6.2. Rainfall analysis and crop diversification planning in rainfed upland rice area of eastern India

### 6.2.1 Analysis of long-term rainfall data

Any pragmatic rainfed crop planning needs a detailed understanding of rainfall pattern and in particular, the variability in the amount, distribution, probability of occurrence, onset of effective monsoon (OEM) etc. Since in eastern India agriculture is mainly dependant upon the performance of southwest monsoon rainfall, so rainfed crop planning is also decided by the onset and withdrawal of effective monsoon. Slight delay in sowing of rainfed upland crops in the region may lead to drastic reduction of yield. Rainfall studies are thus helpful to characterize earliest probable sowing time, defining risk levels in arable agriculture, characterizing length of growing period and cropping system particularly in rainfed upland rice area where water retention and available water capacity are low. Therefore, rainfall data (1970-2002) of the study area were analyzed before initiating the sustainable crop diversification experiments to characterize length of growing period and cropping system on such area. To determine alternate diversified crops/cropping systems with their approximate sowing period, seasonal distribution of rainfall, probability of receiving particular amount of rainfall in a week, wet-dry spell analysis (Markov Chain Model), onset and withdrawal of effective monsoon (Ashok Raj, 1979), climatic water balance (Thorntwaite and Mather, 1957), monthly probabilistic rainfall (Extreme Value Distribution Type-1) were carried out.

### 6.2.2 Seasonal distribution of rainfall

On an average, in the study area premonsoon (April to May) and southwest monsoon (June to September) showers contributes 19% and 63 % of the total annual rainfall of the region. In this region, premonsoon showers are of special significance for performing summer tillage (off-season tillage operation) and land preparation for upland crops. Based on seasonal distribution of rainfall, farmers are advised to perform summer tillage and prepare upland rice soils with pre-monsoon shower, so that they can sow the direct seeded rice substituted crops in rainfed upland just with the onset of southwest monsoon. Besides, summer tillage in light textured upland rice soils improves water retention capacity and reduces weed, pest and disease infestation. During post or retreating monsoon period (October-November), 15% of total annual rainfall occurs, which can play a very crucial role for sowing and establishment of second short duration, low water requiring pre-winter crops like horsegram, sesamum and niger etc. in rainfed upland rice field after harvesting of first rainfed *kharif* crops.

### 6.2.3 Onset of effective monsoon

The onset of effective monsoon(OEM) was determined by using criteria of Ashok Raj (1979) as per below,

- i) The first days rain in the seven-day rainy spell should not be less than 'e' mm, where 'e' is the average daily evaporation of June and July months.
- ii) The total rain during the seven-day rainy spell should not be less than 'x' mm, where 'x' is the amount of rainfall which brings the top 30 cm soil layer to the field capacity. Here 'x' is equal to the total soil moisture content ( in terms of depth) at field capacity in the top 30 cm soil layer.

iii) At least three out of these seven days must be rainy days with not less than 2.5 mm of rain on each day.

As per the criteria, the mean date of onset of effective monsoon (OEM) was found to be 15<sup>th</sup> June and southwest monsoon generally ended on 27<sup>th</sup> September. The earliest and latest probable dates of OEM were found to be 1<sup>st</sup> and 20<sup>th</sup> June respectively. Whereas, earliest and latest probable dates of monsoon withdrawal were worked out to be 15<sup>th</sup> September and 05<sup>th</sup> October, respectively. Based on OEM analysis, farmers are advised to be ready for upland sowing of short duration, low water requiring, direct sown rainy season crops from first week of June and sowing should be completed within 20<sup>th</sup> June. The early sowing ensures double cropping in rainfed upland rice area and reduces infestation of weeds, pests and diseases.

#### 6.2.4 Weekly rainfall probability analysis

The week in which initial probability of receiving 20 mm or more rainfall exceeded most dependable limit (70% probability) is considered as wet week. The first wet week after the onset of southwest monsoon in the region can be considered as sowing week of direct seeded upland crops. Result reveals (Fig. 3) that initial probability,  $P(W)$  of receiving 20 mm or more rainfall exceeded most dependable limit (70% probability) in the 24<sup>th</sup> to 33<sup>rd</sup> and 36<sup>th</sup> to 43<sup>rd</sup> standard meteorological weeks' after onset of monsoon so the 24<sup>th</sup> standard week (11 to 17<sup>th</sup> June) can be considered for final land preparation and sowing of upland crops in the region. The conditional probability [wet week followed by wet week,  $P(W/W)$ ] of occurring 20 mm or more rainfall followed almost same trend, exceeded 70 % probability level after onset of full fledge southwest monsoon and occurred from 23<sup>rd</sup> to 28<sup>th</sup> and 36<sup>th</sup> to 42<sup>nd</sup> standard weeks. At 16<sup>th</sup> to 19<sup>th</sup> weeks (during premonsoon period) initial probability,  $P(W)$  of receiving 10 mm or more rainfall exceeded 70% probability level (dependable limit), so in those weeks light showers can be expected which can be utilized for off-season tillage in rainfed upland rice area.

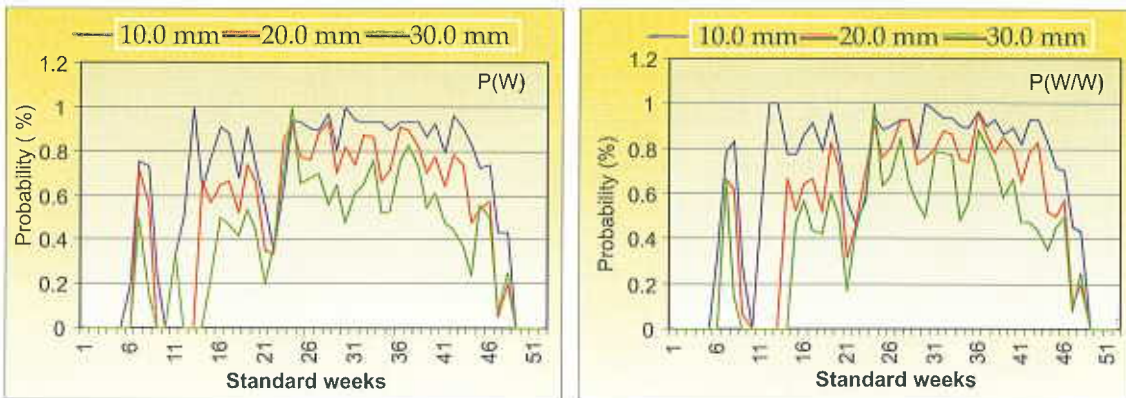


Fig.3 : Initial  $P(W)$  and conditional probabilities  $P(W/W)$  of weekly rainfall

In general, from weekly rainfall probability analysis it can be said that (i) pre-monsoon shower may occur between 16<sup>th</sup> to 19<sup>th</sup> weeks making off-season tillage and preparation of seed beds for rainy season upland crops feasible then. (ii) rainfed, low water requiring, direct seeded upland crops can successfully be grown in upland rice soils during rainy season (24<sup>th</sup> to 38<sup>th</sup> weeks) and



earliest sowing can be completed in 24<sup>th</sup> standard meteorological week (11<sup>th</sup> to 17<sup>th</sup> June) at 70 % (dependable) probability level.

### 6.2.5 Monthly rainfall probability analysis

At 90% probability level, 119 mm of rainfall occurred during June while at 75%, it was 181 mm. (Table 2). Therefore, at highly assured level also sufficient amount rainfall may be expected for sowing of low water requiring rainy season crops like maize, cowpea, pigeonpea, groundnut, blackgram, greengram etc. in 24<sup>th</sup> standard meteorological week ( 11 to 17<sup>th</sup> June) with the commencement of south west monsoon in the region. Maximum amount of rainfall occurred during July i.e. 163 mm and 237 mm at 90% and 75% probability level, respectively. The higher amount of rainfall at 75 % probability level could be utilized for rice transplanting starting from first fortnight of July in medium and lowland rice area after completion of sowing in rainfed upland rice area of the region.

**Table 2 : Monthly rainfall at different probabilities in the study area  
(Kamakhyanager Block, Dhenkanal)**

Month	Precipitation (mm) at probability leves of					Normal rainfall (mm)
	90%	75%	50%	25%	10%	
January	1	1	1	1	2	17.3
February	4	14	28	63	105	27.2
March	0	1	5	16	34	17.5
April	50	76	116	166	223	35.8
May	71	95	129	171	214	79.3
June	119	181	196	288	324	201.2
July	163	237	265	370	419	359.7
August	166	200	236	275	308	331
September	124	154	173	188	232	234.2
October	98	113	146	170	201	100.6
November	16	35	70	123	189	23.9
December	0	1	3	8	15	3.8
Annual	812	1108	1368	1839	2266	1431.5

Data Source : Rainfall (1970-2002) - DDA Office, Dhenkanal

Normal rainfall - IMD report (vol. XXXI, Part III)

### 6.2.6 Climatic water balance for assessing water harvesting potential

The moisture availability analysis with respect to rainfall (P) and potential evaporation (PET) of the study area was performed for successful crop planning and assessing water harvesting potential. After moisture availability analysis, climatic water balance on weekly basis was computed using Thornthwaite and Mather's book keeping procedure (1957), considering the average available water capacity was 130 mm. Based on rainfall and PET analysis, the moisture availability period of the study area can be divided into three subclasses like most of the places of eastern India.

- i) Moist I: This stage starts at the beginning of June when  $P < PET$  and most of the rainy season crops are at early vegetative stage or sowing operations are still going on in upland rice area.
- ii) Humid: Humid stage appears after onset of full fledged southwest monsoon in the region when  $P > PET$ , starts from second fortnight of June. Rice transplanting and majority of intercultural operations are performed at this stage.
- iii) Moist II: The moist II stage approaches immediately after withdrawal of southwest monsoon (last of week of September) when crops are at full canopy stage. Generally crop harvesting and processing operations are done at this stage.

The weekly water balance of the study region (Kamakhyanagar, Dhenkanal District, Orissa) reveals that total annual potential evapotranspiration (PET) and actual evapotranspiration (AET) were 1536.4 mm and 800.4 mm, respectively. The moisture availability index (AET/PET) exceeded 0.5 for 25 weeks in the region, which can be considered as length of the growing periods (LGP). The climatic water balance analysis also provides periods and quantities of water surplus or deficit, moisture availability and recharge patterns. Study reveals that there was a surplus of 529 mm rainfall in normal rainfall year during southwest monsoon period (June to September), started from 23<sup>rd</sup> standard meteorological week (second week of June). Therefore, there is a potential to harvest excess water in the study area which can be stored in tank and utilized as supplemental irrigation for growing of second crops (during dry season).

#### **6.2.7 Rainwater management during crop growth period**

Excess water is equally or even more harmful than moisture stress for non-rice crops as these cannot tolerate stagnant water and very sensitive to water logging. Making of ridges and furrows during first earthing up (20 days after sowing) in maize and groundnut was found effective to avoid water logging during heavy downpour. For other other crops field was properly drained immediately after heavy rain. The same furrows were utilized for in-situ rainwater harvesting during low rainfall periods. The crops were sown across the slope and excess water was disposed off through grass water ways to avoid breaching of ridges. The excess runoff water was collected in the existing pond below the field for providing supplementary irrigation during dry season crops.

### **6.3. On-farm, participatory rice substitution and crop diversification research trials**

As per the rainfall analysis, sowing of rice-substituted crops in each study years (2000, 2001, 2002) in rainfed upland rice field was done in 24<sup>th</sup> meteorological week (11<sup>th</sup> to 17<sup>th</sup> June) with 2-3 summer ploughings during premonsoon shower. In the rainfed upland rice area, emphasis was given to develop technology of crop diversification by complete rice substitution. But for very traditional farmers those who cannot afford to leave rice even in rainfed upland, rice based intercropping technology was developed for them through on-farm participatory research. To develop most viable, profitable and sustainable technology, following trials were conducted during rainy season of 2000, 2001 and 2002 to improve productivity of rainfed upland rice area of eastern India.

#### **6.3.1 Complete substitution of rice through sole cropping in rainfed upland rice field**

Under this experiment productivity and rainwater use efficiency of five crops *viz.*, maize, (cv. Navjyot), pigeonpea (cv. UPAS-120), groundnut (cv. Smriti), blackgram (cv. T9) and cowpea (cv. Pusa Kamal) were compared with that of sole rice (cv. Vandana) to explore possibility of crop diversification in rainfed upland rice area. The crops were grown following recommended agronomic practices (Table 3) and the treatments of this on-farm trials were executed in six farmers' field of 2 ha area of Arnapurapur village, Dhenkanal district, Orissa considering one farmer as one replication.

### 6.3.2 Partial substitution of rice through rice based intercropping

In this experiment productivity and rainwater use efficiency of three rice based intercropping combinations *viz.*, rice+pigeonpea (4:1), rice + groundnut (4:1), rice + blackgram (4:1) were compared with that of sole rice (farmers' practice). Since weed is the main biological constraint in rainfed upland, weed control treatments were also imposed with crops in mainplots and weed control treatments in subplots. Weed control treatment consisted of (a) W1-Farmers' practice (manual weeding at 35 days after sowing (b) W2- Manual weeding at 20 and 45 days after sowing (DAS), (c) W3- Combination of chemical and mechanical weeding (Butachlor @ 1.5 kg a.i. ha<sup>-1</sup> for sole rice and early post application of Pendimethaline @ 1.0 kg ha<sup>-1</sup> for intercropping of rice with legumes + mechanical weeding at 30 DAS). This on-farm experiment was conducted in 4 farmers' field of about 1 ha of area, considering one farmer as one replication.

### 6.3.3 Complete substitution of rice through legume based intercropping

Under this experiment four legume based intercropping combinations (groundnut based intercropping) *viz.*, groundnut+pigeonpea (4:1), groundnut+greengram (4:1), groundnut + blackgram (4:1), groundnut + cowpea (4:1) were grown with recommended practices and productivity of which were compared with sole rice yield (Farmers' practice). This on-farm experiment was conducted in 6 farmers' field of approximate 2 ha of area, considering one farmer as one replication.

### 6.3.4 Complete substitution of rice through double cropping (maize-horsegram/sesamum)

Under this experiment the first crop maize (cv. Navjyot) was taken as test crop by replacing upland rice due to its low water requirement and better market prospects of maize cob with assured return. To explore the possibility of double cropping in rainfed upland rice field, two short duration pre-winter crops *viz.*, horsegram(cv. Madhu) and sesamum (cv. Gujrat-1) were grown on the same land utilizing residual soil moisture after early harvest of rainy season maize (cv. Navjyot). The second crops were sown following both broadcasting and line methods of sowing. These on-farm experiments were conducted in 6 farmers' field of about 1 ha of area, considering one farmer as one replication.

**Table 3 : Package of practices adopted for crop diversification in rainfed upland rice area.**

Crop	Varieties	Spacing (cm × cm)	Seed rate (kg ha <sup>-1</sup> )	Fertilizer dose (N:P:K)
Maize	Navjyot	60 × 30	15	80:40:40
Groundnut	Smruti	30 × 10	80 (Kernel	20:40:40+250 kg zypsum ha <sup>-1</sup>
Pigeonpea	UPAS-120	60-75 × 20 -25	15-20	20:40:0
Blackgram	T-9	30 × 15	20	20:40:0
Greengram	K-851	30 × 10	25	20:40:0
Horsegram	Madhu	25 × 10	20	20:40:0
Sesamum	Gujrat-1	20 × 10	5	30:15:15
Rice	Vandana	20 × 5	80	40:20:20 + 2 t ha <sup>-1</sup> FYM

#### 6.4 Principal findings of crop diversification on-farm trials in rainfed upland rice area

Among three study years (2000, 2001 and 2002), first years' rainfall (1149 mm) was below long term annual average (1442 mm) and that year 38.4% and 29.8% deficit rainfall were observed in two critical months of growing rice i.e. in June and July, respectively (Fig. 4). The second years' rainfall (1617 mm) was above the long term average (1442 mm) and well distributed. Again in the third crop year (2002), deficit rainfall (1002 mm) was received with 20 % and 58.4 % less rainfall in June and July, respectively. Thus, three contrasting rainfall distribution patterns were found during three study years, which made different impact on different upland crops.

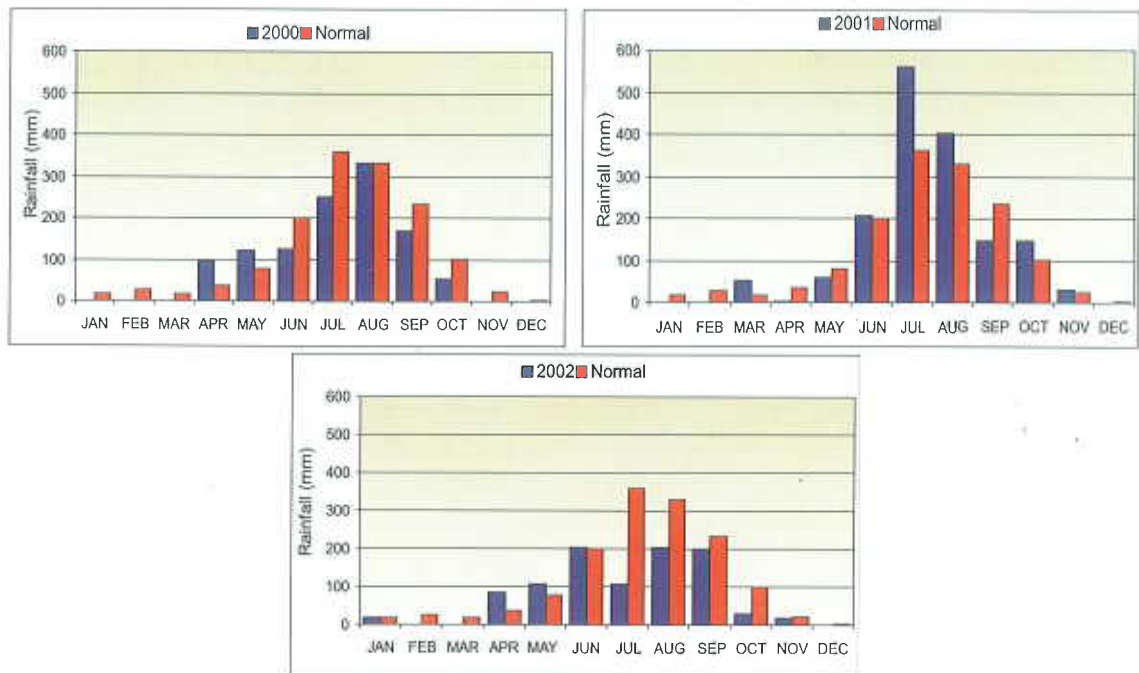


Fig. 4: Actual monthly rainfall in three study years with normal monthly rainfall

The study revealed that at 26<sup>th</sup> to 28<sup>th</sup> (25<sup>th</sup> June to 15<sup>th</sup> July) standard weeks of first year (2000) and 27<sup>th</sup> to 30<sup>th</sup> standard weeks (2<sup>nd</sup> July to 28<sup>th</sup> July) of third year (2002), dry spells existed which coincided with tillering stage of upland rice and vegetative stage of all other upland crops like maize, blackgram, pigeonpea, cowpea and groundnut. Whereas, in second crop year (2001), no dry spell was found and rainfall was in excess than that of normal and also well distributed. Since at initial stage, water requirements of maize, groundnut, pigeonpea, cowpea and blackgram were less as compared to that of rice, these crops suffered less due to occurrence of dry spells in the year 2000 and 2002. But high water requiring rice crop suffered adversely in those rainfall deficit years (2000 and 2002) because it was under active tillering stage during that period which required irrigation (Fig. 5) during that stage to meet the crop water requirement. Due to reduction of tiller number, rice yield was reduced significantly in those years. Whereas in second crop season (2001), rice was grown with assured rainfall, resulted some net economic return but rice substituted crops produced much higher return in that rainfall excess year (2001) also. Therefore, through crop diversification productivity and profitability from rainfed light textured upland rice ecosystem

were stabilized and rainwater use efficiency was enhanced in rainfall deficit or rainfall excess year, which may be visualized from the results discussed below.

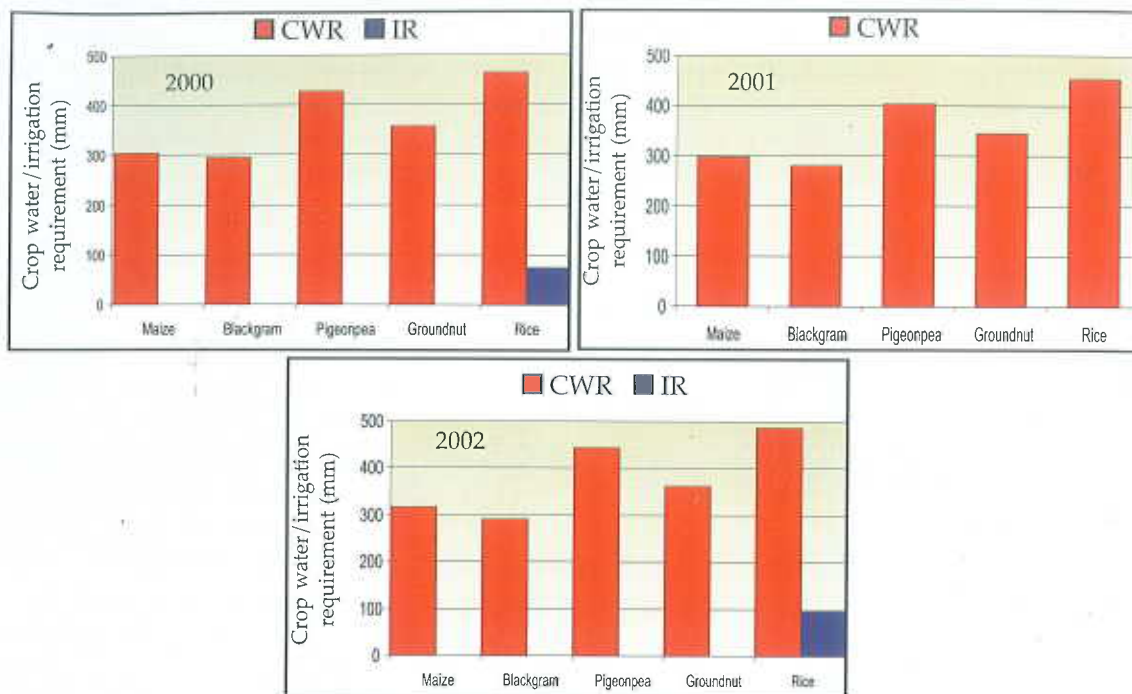


Fig. 5 : Crop water and irrigation requirements of upland rice and non-rice crops in three study years

## 6.4.1 Enhancement of production and profitability from rainfed upland rice area

### 6.4.1.1 From rice substituted sole crops

The study revealed that in first rainfall deficit year (2000), when rice yield was affected adversely (Table 4 and Fig. 6) in rainfed upland rice ecosystem and net economic return from rice was nil or negative, highest net economic return (Rs.26, 000 ha<sup>-1</sup>) was obtained from maize cob (Table 4 and Fig. 7), followed by pigeonpea (Rs.16, 200 ha<sup>-1</sup>) and groundnut (Rs.16, 060 ha<sup>-1</sup>) with rice equivalent yield of 8125, 5550 and 5640 kg ha<sup>-1</sup> from maize cob, pigeonpea and groundnut respectively. In the second study year (2001, excess rainfall year), the situation was different. The rainfall was 56.5% and 22% excess in July and August, respectively and throughout the crop growth period, rainfall was uniformly distributed. As a result upland rice gave good yield (2850 kg ha<sup>-1</sup>) than that of first year (1010 kg ha<sup>-1</sup>) but in the second year also, highest net economic return was obtained from maize cob (Rs.22, 748 ha<sup>-1</sup>) followed by groundnut (Rs.18, 960 ha<sup>-1</sup>) and pigeonpea (Rs.13, 325 ha<sup>-1</sup>) with the rice equivalent yield of 7312, 6240 and 5081 kg ha<sup>-1</sup> from maize cob, groundnut and pigeonpea, respectively (Fig. 6). In the third crop season (2002, rainfall deficit year), net economic return was again nil from rice in rainfed upland but diversified crops resulted higher net economic return even under deficit rainfall situation (Table 4). Maize cob gave highest return (Rs. 19500 ha<sup>-1</sup>) followed by groundnut (Rs. 15420 ha<sup>-1</sup>) and pigeonpea (Rs. 15072 ha<sup>-1</sup>) (Fig. 7). In that year, sole

rice yield was only 1215 kg ha<sup>-1</sup> whereas, rice equivalent yield of non-rice crops were 6500, 5480 and 5268 kg ha<sup>-1</sup> from maize cob, groundnut and pigeonpea, respectively (Fig. 6). Based on this study farmers are advised to adopt rice substitution and crop diversification technology for enhancing productivity of rainfed upland rice area of eastern India.

#### 6.4.1.2 Productivity from partial substitution of upland rice through rice based intercropping

For rice dominant area and traditional rice growers, partial substitution of rice through rice based intercropping was recommended/suggested. Partial substitution of rice with intercrops (especially legumes) may give some yield certainty, as an insurance against total rice failure during drought. If sole rice fails to grow with full potential, other low water requiring or deep rooted intercrops will mitigate effects of drought and thus productivity of upland rice field will be stabilized. Since weed in rainfed upland is hindrance for successful rice cultivation, weed management treatment was also imposed under this experiment. The study of rice based intercropping revealed that rice yield was adversely affected in light textured upland soils and its sole crop cultivation was found uneconomical in first (2000) and third (2002) crop years due to occurrence of dry spells. But intercropping of rice with pigeonpea, blackgram and groundnut gave rice equivalent yield of 3618, 2890 and 2970 kg ha<sup>-1</sup> (Table 5 & Fig. 8) with net economic return of Rs. 8,472, Rs. 5,560 and Rs. 5,580 ha<sup>-1</sup>, respectively in first rain deficit year (2000) under integrated weed management (W3) treatment (Table 9 & Fig. 9). In the second year (2001) rice produced good yield because of well distributed rainfall but its association with intercrops gave higher net return than that of sole rice for all the weed management practices. Among intercropping combinations, in that year (2001) also rice+ pigeonpea produced more rice equivalent yield with the values being 4625 kg ha<sup>-1</sup>. While yield from sole rice was only 2750 kg ha<sup>-1</sup> in that year (Table 5) under the integrated weed management (combination of chemical and mechanical weeding). The net economic return from rice + pigeonpea was Rs. 12,500 ha<sup>-1</sup> while, net economic return from sole rice was only Rs 5,500 ha<sup>-1</sup> under that treatment. In the third crop year (2002) also deficit rainfall occurred, which affected yield of sole rice adversely but rice based intercropping system produced much higher rice equivalent yield and net economic return than that of sole rice. In that year (2000) intercropping of rice with pigeonpea, blackgram and groundnut gave rice equivalent yield of 3891, 2850, 3125 kg ha<sup>-1</sup> (Table 5 & Fig. 8) with net economic return of Rs. 9564, Rs. 5400 and Rs. 6,500 ha<sup>-1</sup>, respectively, in rainfed upland rice field (Table 9 & Fig. 9), while net economic return from sole rice was nil on such land.

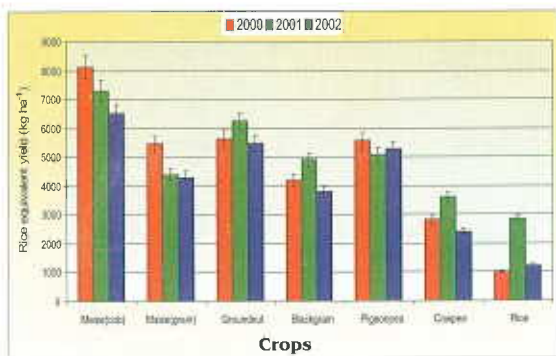


Fig.6 : Rice equivalent yield of diversified sole crops

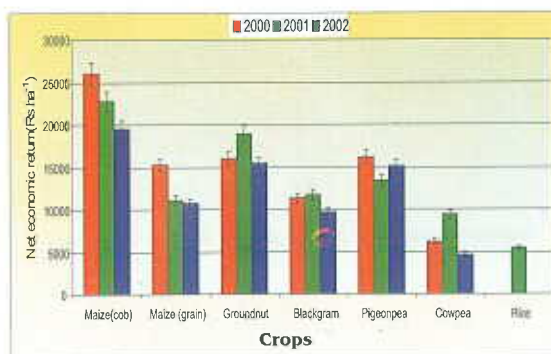


Fig.7 : Net economic return from diversified sole crops

**Table 4 :Rice equivalent yield and net return from rice substituted sole crops**

Treatments (Crops)	Yield (kg ha <sup>-1</sup> ) of individual crops			Rice equivalent yield (kg ha <sup>-1</sup> )			S.E.m (±)	Net return (Rs ha <sup>-1</sup> )			
	2000	2001	2002	2000	2001	2002		2000	2001	2002	S.E.m (±)
Maize (grain)	5450	4400	4300	5450	4400	4300	368.7	15300	11100	10700	1471.2
Maize (cob), No. of cobs ha <sup>-1</sup>	50,000	45,000	40,000	8125	7312	6500	469.0	26000	22748	19500	1876.3
Pigeonpea	1480	1355	1405	5550	5081	5268	136.3	16200	13325	15072	836.3
Groundnut	1410	1560	1370	5640	6240	5480	231.3	16060	18960	15420	1089.1
Blackgram	1050	1225	1010	4200	4900	3787	324.8	11300	11650	9648	617.3
Cowpea	1400	1800	1200	2800	3600	2400	352.7	6200	9400	4600	1411.0
Rice	1010	2850	1215	1010	2850	1215	582.1	—	5400	—	—
			S.E.m (±)	864.2	572.9	696.4	S.E.m (±)	2674.5	2217.0	2144.1	—



Photo -1(a)



Photo 1(a & b) : Crop diversification trials in rainfed upland rice field.

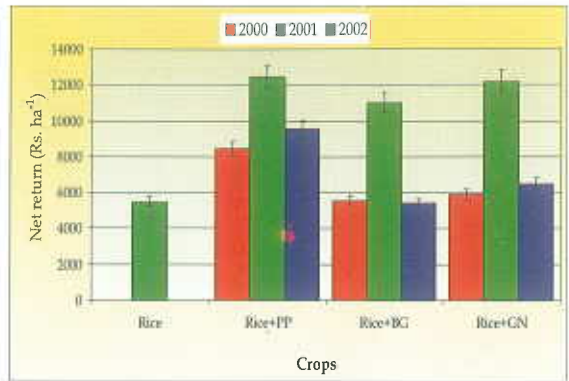
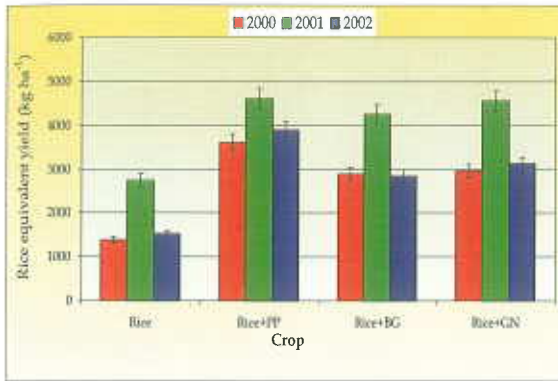
Photo 1(b)



Photo 1(c) : Farmers' satisfaction with crop diversification technology in upland rice field



Photo 1(d) : Director, WTCER, Dr. H.N. Verma assessing yield potential of rice substituted crops in upland rice field.



Rice + PP = Rice + Pigeonpea, Rice + BG = Rice + Blackgram, Rice + GN = Rice + Groundnut

Fig. 8: Rice equivalent yield from rice based intercropping under integrated weed management. Fig.9: Net economic return from rice based intercropping under integrated weed management.

Table 5 : Grain yield and rice equivalent yield in rice based intercropping system.

Treatments	Yield of (kg ha <sup>-1</sup> ) main crop (Rice)			Yield (kg ha <sup>-1</sup> ) of Inter-crop			Rice equivalent yield (kg ha <sup>-1</sup> )			S.E.m (±)
	2000	2001	2002	2000	2001	2002	2000	2001	2002	
Sole rice										
W1	1083	2350	1120	-	-	-	1083	2350	1120	416.3
W2	1215	2575	1400	-	-	-	1215	2575	1400	425.8
W3	1395	2750	1525	-	-	-	1395	2750	1525	431.6
S.E.m (±)	90.4	115.7	119.7	-	-	-	90.42	115.77	119.73	
Rice + Pigeonpea(4:1)										
W1	833	1945	933	545	510	521	2876	3857	2886	325.3
W2	1075	2250	1058	550	540	610	3137	4275	3345	349.8
W3	1113	2365	1285	668	608	695	3618	4625	3891	300.6
S.E.m (±)	87.6	125.3	103.0				217.3	221.9	290.4	
Rice+ Blackgram(4:1)										
W1	812	2060	900	310	360	315	2052	3500	2160	465.7
W2	950	2210	975	360	400	375	2390	3810	2475	459.8
W3	1170	2380	1150	430	470	425	2890	4260	2850	463.4
S.E.m (±)	104.2	92.4	74.0				243.4	220.6	199.4	
Rice + Groundnut(4:1)										
W1	850	2093	900	380	475	395	2370	3939	2480	505.6
W2	1071	2364	1170	425	498	455	2771	4356	2990	495.8
W3	1150	2495	1185	455	515	485	2970	4555	3125	504.4
S.E.m (±)	89.7	118.3	92.6				176.4	181.4	196.4	

W<sub>1</sub>= Farmers' practice (manual weeding at 35 DAS), W<sub>2</sub>= Manual weeding at 20 & 45 DAS.

W<sub>3</sub>=Integrated weed management (Butachlor @ 1.5 kg a.i. ha<sup>-1</sup> + mechanical weeding at 30 DAS for sole rice, in case of intercropping of rice with legumes, early post application of Pendimethalin @ 1.0 kg ha<sup>-1</sup> followed by one hand weeding at 30 DAS).





Photo- 2 : Rice + pigeonpea inter-cropping, alternate option for upland rice farmers.



Photo-3 : Comparison of performance of groundnut, maize, pigeonpea and rice in upland rice field

The study also revealed that combination of mechanical and chemical weeding ( $W_3$ ) was found effective for enhancing yield or net economic return. In different study years 14.5 to 36.1 % sole rice yield was enhanced under that treatment than that of farmers' practices ( $W_1$ ). In rice + pigeonpea intercropping combination, 25.7%, 16.6% and 25.8% rice equivalent yield was enhanced in the year 2000, 2001 and 2002, respectively when combination of mechanical and chemical weed management was followed. The enhancement of rice equivalent yield of 21.7 to 28.9 % and 13.5 to 20.2 % was observed in rice + blackgram and rice + groundnut, respectively in different years of study. Since, weed is a severe problem in rainfed upland rice cultivation, integrated weed management (combination of chemical + manual weeding) on such land are advocated for enhancing rice or rice equivalent yield.

#### 6.4.1.3 Productivity from complete upland rice substitution through legume based inter-cropping

Under this approach, the productivity of four groundnut based intercropping *viz.*, groundnut+pigeonpea, groundnut+blackgram, groundnut+greengram, groundnut+cowpea was compared with that of sole rice (farmers' practice) and are presented in Table 6. The study revealed that groundnut based intercropping produced much higher return than that of sole rice or rice based intercropping in rainfed upland rice area. The yield of groundnut was higher in association with pigeonpea, than with other combinations. It might be due to less competition between these two crops for light, nutrient and space because of their different growth habits. This combination recorded rice equivalent yield of 6656, 7023 and 6801 kg ha<sup>-1</sup> in first (2000, rain deficit), second (2001, rain excess) and third ((2002, rain deficit) years, respectively (Table 6 & Fig. 10), whereas sole rice produced only 1350, 2810 and 1400 kg ha<sup>-1</sup> yield in three respective years. Net economic return from groundnut + pigeonpea was Rs. 20124 ha<sup>-1</sup>, Rs. 21592 ha<sup>-1</sup> and Rs. 20704 ha<sup>-1</sup> in first, second and third years, respectively (Table 10 & Fig. 11.), which revealed that net return was not much varied between rainfall deficit or rainfall excess years. Among inter-cropping combinations, lowest net return was obtained from groundnut + cowpea with the values being Rs. 10,220 ha<sup>-1</sup>, Rs. 12076 ha<sup>-1</sup> and Rs. 11500 ha<sup>-1</sup> in first (2000), second (2001) and third (2002) years, respectively. On the other hand, sole rice produced net return of only Rs. 5240 ha<sup>-1</sup> in rainfall excess year (2001) and in other years (2000 & 2002) net economic return from rice was nil to negative due to occurrence of dry spells during tillering stage of rice. Based on this study, farmers are advised to adopt groundnut + pigeonpea intercropping system in rainfed upland rice area for increased

**Table 6 : Grain yield and rice equivalent yield from legume based intercropping.**

Treatments	Yield of (kg ha <sup>-1</sup> ) of main crop Groundnut)			Yield of (kg ha <sup>-1</sup> ) inter-crop			Rice equivalent yield(kg ha <sup>-1</sup> ) of groundnut+intercrops			S.E.m (±)
	2000	2001	2002	2000	2001	2002	2000	2001	2002	
Groundnut + Pigeonpea(4:-1)	1105	1295	1120	670	578	695	6656	7023	6801	106.7
Groundnut +Blackgram (4:1)	920	965	930	370	420	395	4930	5298	5067	107.3
Groundnut + Greengram (4:1)	1015	1090	1005	360	498	375	5410	6227	5426	269.7
Groundnut + Cowpea (4:1)	875	920	890	340	482	470	4180	4644	4500	137.1
Sole rice(Farmers' practice)	1350	2810	1400	-	-	-	1350	2810	1400	478.5
S.E.m (±)	84.1	354.5	91.5	78.5	32.5	73.3	885.6	721.4	894.0	



*Photo- 4 : Groundnut+ pigeonpea inter-cropping, best option for upland rice farmers.*



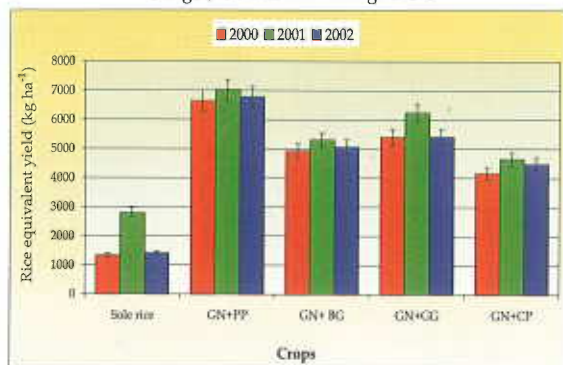
*Photo-5 : Visit of review team on groundnut+pigeonpea adoption site on 16.10.2002 at Arnapurapur village, Dhenkanal.*

productivity, cropping intensity and sustainability. From our study it is revealed that productivity of rice fluctuated significantly between rainfall deficit or rainfall excess years but rice substituted legume based intercrops performed well both in rainfall deficit and rainfall excess years and productivity did not differ much among different study years. It may be due to the fact that water requirement of these crops are low and pulses have inherent capacity to draw soil moisture from lower strata, therefore fit well under rainfed system. Besides, pulses fix atmospheric nitrogen to sustain the soil fertility of light textured upland rice soils.



Photo-6 (a) : Adoption of groundnut in large upland rice area at Kingol, Dhenkanal during 2002.

Photo-6 (b) : Adoption of groundnut in rainfed upland rice field at Arnapurapur village during 2002.



GN+PP = Groundnut +Pigeonpea, GN+BG = Groundnut + Blackgram, GN + GG = Groundnut +Greengram, GN+CP = Groundnut + Cowpea

Fig. 10 : Rice equivalent yield from groundnut based intercropping.

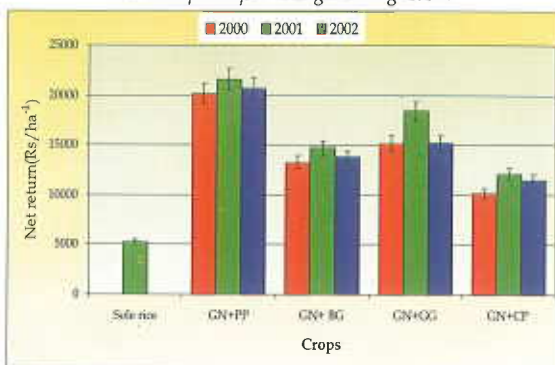


Fig. 11: Net economic return from groundnut based intercropping

#### 6.4.1.4 Productivity from complete substitution of upland rice through double cropping

Possibility of double cropping in rainfed upland rice area utilizing residual moisture was also explored through maize-horsegram/sesamum rotation. During rainy season upland rice was substituted by maize as a test crop considering its low water demand and better market prospects in the region. Owing to low water requirement of maize, the crop produced much higher yield even in rainfall deficit years (2000 & 2002) as compared to sole rice (farmers' practice) in rainfed upland. The grain yield of 5350, 4380 and 4508 kg ha<sup>-1</sup> was produced in first (2000, rainfall deficit), second (2001, rainfall excess) and third (2002, rainfall deficit) years, respectively. After harvesting of rainy season maize (as first crop), two pre-winter crops *viz.*, horsegram and sesamum were sown as second crop following line as well as broadcasting methods of sowing on that land. The study revealed that line sown horsegram produced 6.1, 7.2 and 5.9 q ha<sup>-1</sup> grain yield (Fig. 12) with net return of Rs. 3,820 ha<sup>-1</sup>, Rs. 5,140 ha<sup>-1</sup> and Rs. 3,580 ha<sup>-1</sup> in first, second and third years, respectively (Fig. 13). Where as line sown sesamum crop produced 3.2, 5.9 and 3.3 q ha<sup>-1</sup> grain yield in first, second and third years, respectively (Fig. 12). For both the crops, the second years' (2001) yield was higher, due to occurrence of reasonable amount of rainfall during crop growth period. Line sown sesamum gave net return of Rs.980 ha<sup>-1</sup>, Rs.4,760 ha<sup>-1</sup> and Rs. 1,120 ha<sup>-1</sup> in first, second and third years, respectively (Fig. 12). For better comparison, the yield of first and second

crops (maize-horsegram/sesamum) was converted into rice equivalent yield and was compared with yield of sole rice (farmers' practice). The study revealed that even in rain deficit year (2000), maize-horsegram/sesamum produced much higher rice equivalent yield than that of sole rice with the values being 6875, 6310, 6650 and 8160 kg ha<sup>-1</sup> from maize-horsegram (line sown), maize-sesamum (line sown), maize-horsegram (broadcasting) and maize-sesamum (broadcasting), respectively (Table 7) with net economic return of Rs. 17,500, Rs. 15,240, Rs. 16,600 and Rs. 14,640 ha<sup>-1</sup> in four respective treatments (Table 11). In the other rain deficit year (2002) also rice substituted double crops produced much higher yield and net economic return than that of sole rice (Table 7 & 11).

To increase the cropping intensity of rainfed upland rice area and to obtain economic return from two sequential crops, farmers are advised to sow the first crop immediately after onset of south west monsoon i.e. in 24<sup>th</sup> standard meteorological week (11<sup>th</sup>-17<sup>th</sup> June). Early sowing of first crop also reduces weed infestation, ensures early harvest and early sowing of second crops (during pre-winter season) utilizing residual moisture and subsequent rainfall.



Photo-7: Maize as first crop by replacing upland rice



Photo -8: Visit of District collector (Mr. N.Mohanty), Director of CRIDA & AED (Dr. H.P.Singh) and Director of WTCER (Dr. H.N.Verma) to crop diversification site on 25.8.2001 at Arnapurnapur village, Dhenkanal.

Since second crops were grown almost after cessations of south west monsoon in the region, soil remained unsaturated for most part of their growing period. For better understanding of crop growth in relation to soil moisture availability, the moisture depletion pattern during dry spells of second crop (horsegram) were analyzed and are depicted in Fig. 14. The study reveals that in first and third crop years (2000 & 2002), soil moisture started depletion below field capacity after two weeks of sowing of second crop because of early occurrence of dry spells. Whereas in the year 2001, the soil moisture depleted below field capacity from 60 days after sowing on second crop because of late occurrence of dry spells in that year. In the year 2000 & 2002 crop approached wilting point about 25 days before harvesting while in 2001, crop reached wilting point almost at harvesting time. As a result crops produced much higher yield in that year in rainfed upland rice soils.

From the above mentioned on-farm trials it can be concluded that crop diversification (sole cropping/intercropping) with low water requiring crops like maize, groundnut, blackgram, greengram, cowpea, pigeonpea etc. ensured higher net economic return in rainfed upland rice field even in rainfall deficit years (2000 & 2002) when net return from sole rice was nil or negative.



Photo - 9: Lead PI, Dr. R.S. Tripathy and Director, WTCER, Dr. H.N. Verma assessing yield potential from second crop, horsegram in rainfed rice field.



Photo-10 : Comparison of productivity of maize with rainfed rice in upland rice field during 2001.

Among different crops/crop combinations studied complete rice substitution with groundnut+pigeonpea was found the best from productivity, profitability and sustainability point of view in rainfed upland rice field. For very traditional rice growers those who can not afford to leave rice even in rainfed upland, for them rice+pigeonpea was recommended to improve and stabilize productivity of such land. Early sowing and proper crop plan explored possibility of double cropping through maize-horsegram/sesamum rotation in rainfed upland rice area with much higher and assured net return than that of sole rice.

**Table 7 : Rice equivalent yield of double crops (Maize-horsegram/sesamum rotation)**

Treatments	Yield of first crop, maize(kg ha <sup>-1</sup> )			Yield of second crops, kg ha <sup>-1</sup> (Horsegram/ Sesamum)			Rice equivalent yield (kg ha <sup>-1</sup> ) of double crops			S.E.m (±)
	2000	2001	2002	2000	2001	2002	2000	2001	2002	
Maize-horsegram (line sowing)	5350	4380	4508	610	720	590	6875	6180	5983	270.5
Maize-sesamum (line sowing)	5350	4380	4508	320	590	330	6310	6150	5498	248.3
Maize-horsegram (broadcasting)	5350	4380	4508	520	590	490	6650	5855	5733	287.4
Maize-sesamum (Broadcasting)	5350	5350	4508	270	470	250	6160	6760	5258	436.5
Rice (Farmers' practice)	1025	2910	1230	-	-	-	1325	2910	1230	544.8
S.E.m (±)				0.8	0.5	0.7	1042.3	681.2	885.8	



Photo-11: Sesamum (line sowing) as second crop after maize in upland rice field.



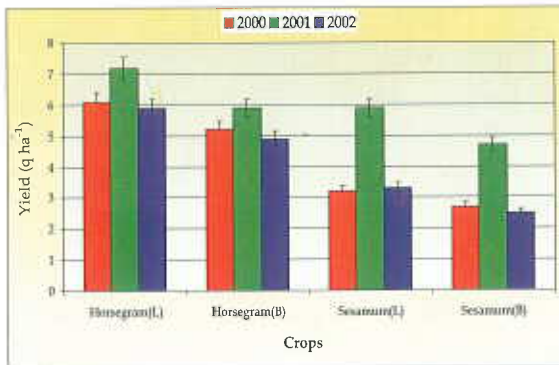
Photo-12: Horsegram (line sowing) as second crop after maize in upland rice field. -



Photo-13: Sesamum (broadcasting) as second crop after maize in upland rice field.



Photo-14: Horsegram (broadcasting) as second crop after maize in upland rice field.



(L) = Line sowing, (B) = Broadcasting sowing

Fig.12 : Grain yield of second crops (sesamum and horsegram) after maize in upland rice soils.

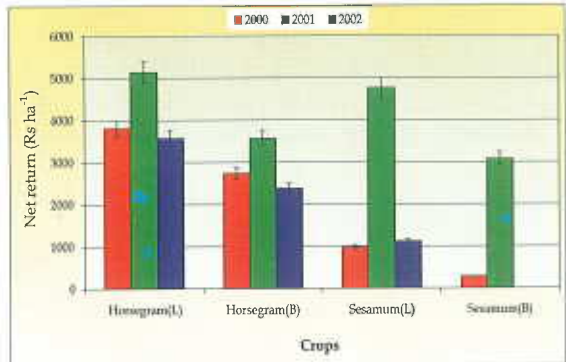


Fig.13: Net return from sesamum and horsegram after maize in upland rice soils.

#### 6.4.2 Rainwater use efficiency (RWUE)

In the UN Millennium summit in September, 2000, UN Secretary-General Kofi Annan echoed a slogan 'more crop per drop' i.e. increasing productivity per unit of rain or irrigation water.

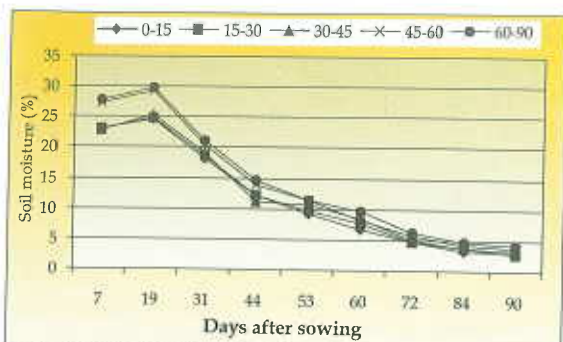


Fig. 14(a): Soil moisture depletion during second crop growth period (horsegram) after cessation of rainfall during 2000

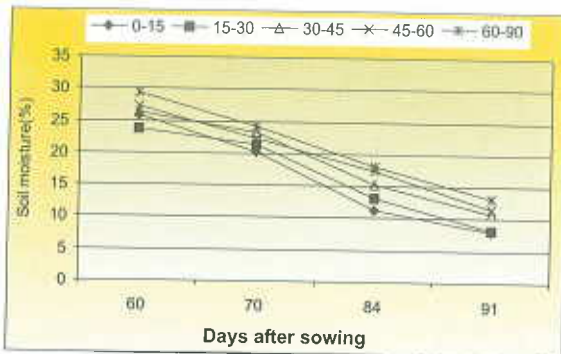


Fig. 14(b): Soil moisture depletion during second crop growth period (horsegram) after cessation of rainfall during 2001

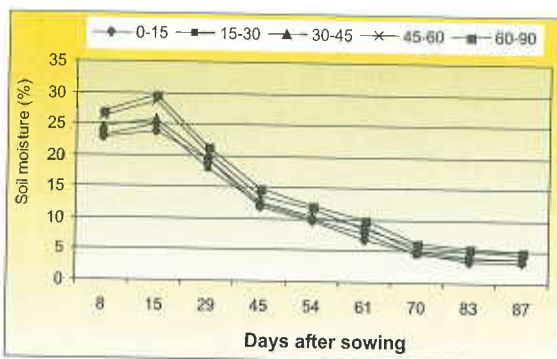


Fig. 14(c): Soil moisture depletion during second crop growth period (horsegram) after cessation of rainfall during 2002

Relationships between rainfall or crop water use and yield have received a great deal of study throughout the world and rainwater use efficiency (RWUE) or crop water use efficiency (CWUE) is now widely estimated and used by scientists, consultant and farmers for maximizing its efficiency. Improvement of RWUE or CWUE can be achieved through several measures which includes early sowing, improved cultivation practices, introduction of better crops/cropping systems, minimizing water loss and conservation of water etc. WUE measurements are now promoted as a way of comparing or benchmarking the efficiency of rainfall use, and identifying factors that limit the efficiency of use of soil moisture or available rainfall. In this study 'more crop per drop' i.e. higher rainwater use efficiency (RWUE) was achieved through early sowing and improved crop and water management practices. RWUE in terms of rice equivalent yield [rice equivalent yield ( $\text{kg ha}^{-1}$ ) produced, per drop (mm) of rainwater received during the growth period] of introduced diversified cropping system was computed and compared with that of sole rice to visualize its enhancement due to new cropping system and improved cultivation practices.

#### 6.4.2.1 RWUE of rice substituted sole crops in rainfed upland rice area

The study revealed that in the first rain deficit year (2000), rain water use efficiency (Table 8 & Fig.15) in terms of rice equivalent yield (yield per mm of rainfall received) was highest in maize cob ( $13.4 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ), followed by maize grain ( $8.30 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ) and groundnut ( $6.3 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ) and the lowest was in case of rice ( $1.61 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ). Highest rainwater use efficiency (in terms of

**Table 8 : Rainwater use efficiency of diversified crops in upland rice soils**

Treatments (Crops)	Rice equivalent yield (kg ha <sup>-1</sup> )			Rainfall received (mm)			Rain water use efficiency (in terms of rice equivalent), (kg ha <sup>-1</sup> mm <sup>-1</sup> )			S.E.m (±)
	2000	2001	2002	2000	2001	2002	2000	2001	2002	
Maize grain	5450	4400	4300	651	1099	639	8.37	4.00	6.72	1.2
Maize (cob), No.	8125	7312	6500	605	1049	595	13.42	6.97	10.92	1.8
Pigeonpea	5550	5081	5268	945	1458	886	5.87	3.48	5.94	0.8
Groundnut	5640	6240	5480	889	1159	780	6.34	5.38	7.02	0.4
Blackgram	4200	4900	3787	614	955	601	6.84	5.13	6.30	0.5
Cowpea	2800	3600	2400	635	1100	639	4.40	3.27	3.75	0.3
Rice	1010	2850	1215	631	1085	619	1.60	2.62	1.96	0.2
S.E.m (±)							1.3	0.5	1.0	

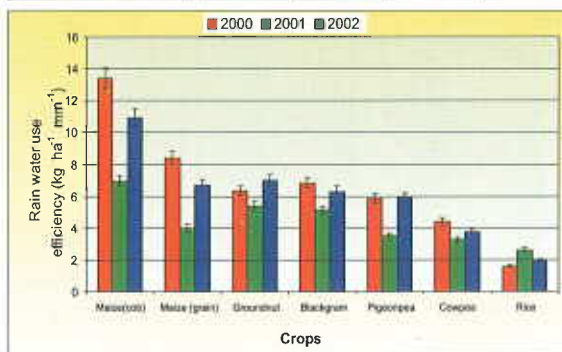


Fig.15: Rain water use efficiency (in terms of rice equivalent yield) from diversified upland sole crops.

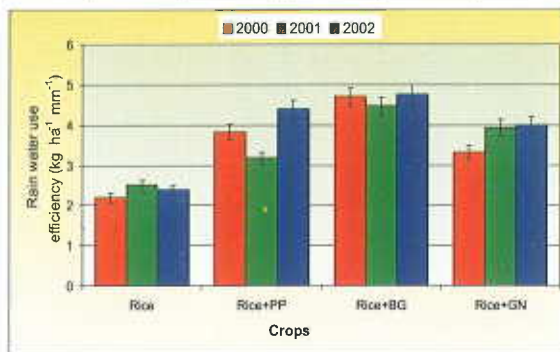


Fig.16: Rainwater use efficiency (in terms of rice equivalent yield) from rice based intercropping.

PP = Pigeonpea, BG = Blackgram, GN = Groundnut



Photo-15(a) : Rice substitution with pigeonpea in rainfed upland rice field.



Photo-15(b) : Rice substitution with cowpea in rainfed upland rice field.



rice equivalent yield) in rainfall excess year (2001) was also achieved from maize cob ( $6.91 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ), followed by groundnut ( $5.3 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ) and blackgram ( $5.1 \text{ kg ha}^{-1} \text{ mm}^{-1}$ ).

#### 6.4.2.2 RWUE of rice based intercropping in rainfed upland rice area

Rain water use efficiency (in terms of rice equivalent weight) of rice based intercropping revealed that in rain deficit year (2000), it enhanced from  $2.2 \text{ kg ha}^{-1} \text{ mm}^{-1}$  in sole rice to  $3.81 \text{ kg ha}^{-1} \text{ mm}^{-1}$  in rice + pigeonpea, and  $4.7 \text{ kg ha}^{-1} \text{ mm}^{-1}$  in rice + blackgram,  $3.3 \text{ kg ha}^{-1} \text{ mm}^{-1}$  in rice + groundnut inter-cropping (Table 9 & Fig. 16) under integrated weed management practices ( $W_3$  treatment). In second year (rainfall excess year, 2001), under that treatment, rain water use efficiency (in terms

**Table 9: Rainwater use efficiency and net return from rice based intercropping.**

Treatments	Rain water use efficiency ( $\text{kg ha}^{-1} \text{ mm}^{-1}$ )			Net economic return (Rs. $\text{ha}^{-1}$ )			Weed dry biomass at harvest ( $\text{g m}^{-2}$ )		
	2000	2001	2002	2000	2001	2002	2000	2001	2002
Sole rice									
W1	1.71	2.16	1.80	Nil	4400	Nil	63	120	91
W2	1.92	2.37	2.26	Nil	4800	Nil	30	44	45
W3	2.20	2.53	2.46	Nil	5500	Nil	12	30	32
Rice + Pigeonpea(4:1)									
W1	3.04	2.46	3.20	6504	10428	6544	58	125	86
W2	3.31	2.93	3.77	7048	11600	7880	28	55	39
W3	3.82	3.17	4.39	8472	12500	9564	24	44	34
Rice+ Blackgram (4:1)									
W1	3.34	3.66	3.60	3208	9000	3640	55	115	82
W2	3.89	3.98	4.12	4060	9740	4400	30	68	47
W3	4.70	4.46	4.75	5560	11040	5400	28	45	35
Rice + Groundnut(4:1)									
W1	2.66	3.39	3.17	4480	10756	4920	65	135	93
W2	3.11	3.75	3.83	5584	11924	6460	45	65	57
W3	3.33	3.93	4.00	5880	12220	6500	30	20	27

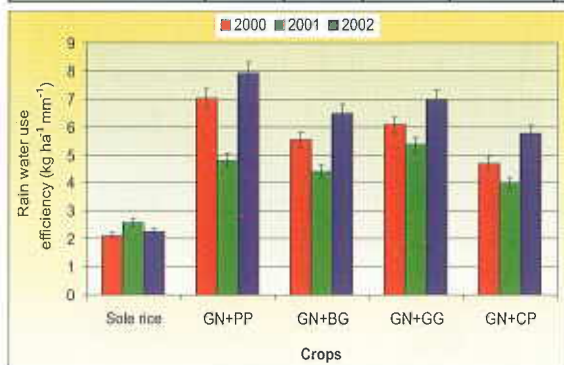
of rice equivalent yield) were 2.5, 3.1, 4.4 and  $3.9 \text{ kg ha}^{-1} \text{ mm}^{-1}$  in sole rice, rice + pigeonpea, rice + blackgram and rice + groundnut, respectively. In the third crop year also (2002, rain deficit year), when rice yield was adversely affected in light textured upland soils and its sole crop cultivation was found uneconomical due to occurrence of dry spell, higher RWUE was achieved from rice based intercropping. Based on this study farmers are advised to adopt rice based intercropping who can not afford to leave rice even in rainfed upland which will ensure higher RWUE.

#### 6.4.2.3 RWUE of legume based intercropping in rainfed upland rice area

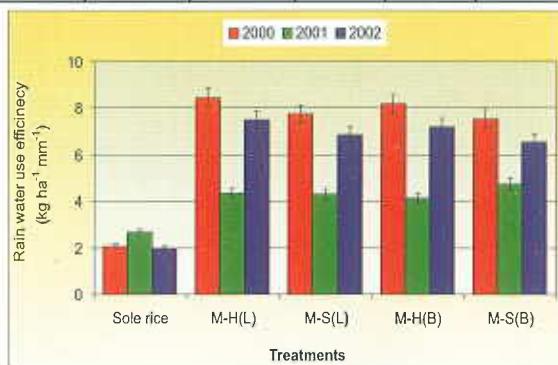
The rainwater use efficiency in terms of rice equivalent yield ( $\text{kg ha}^{-1} \text{ mm}^{-1}$ ) for groundnut based inter-cropping was computed and are given in Fig. 17. It was also found that for all the groundnut based intercropping combinations, rainwater use efficiency (RWUE) was more in rainfall deficit years (2000 and 2002) as compared to rain excess year with higher values were recorded by groundnut + pigeonpea intercropping. The rainwater use efficiency of this combination

**Table 10 : Rainwater use efficiency and net return from legume based intercropping.**

Treatments	Rainwater use efficiency in terms of rice equivalent yield (kg ha <sup>-1</sup> mm <sup>-1</sup> )			Net return (Rs ha <sup>-1</sup> )			S.E.m (±)	B:C ratio		
	2000	2001	2002	2000	2001	2002		2000	2001	2002
Groundnut + Pigeonpea(4:1)	7.04	4.81	7.91	20124	21592	20704	426.8	3.09	3.32	3.18
Groundnut + Blackgram (4:1)	5.54	4.40	6.49	13220	14692	13768	429.5	2.03	2.26	2.11
Groundnut + Greengram (4:1)	6.08	5.37	6.95	15140	18408	15204	1078.8	2.32	2.83	2.33
Groundnut + Cowpea (4:1)	4.70	4.01	5.76	10220	12076	11500	548.4	1.57	1.85	1.76
Sole rice (Farmers' practice)	2.13	2.58	2.26	Nil	5240	Nil		Nil	0.87	Nil
S.E.m (±)	0.8	0.4	0.9	2079.0	2803.3	1957.8		0.3	0.4	0.3



GN = Groundnut, PP = Pigeonpea, BG = Blackgram, GG = Greengram, CP = Cowpea



MH(L) = Maize-horsegram (line), MH(B) = Maize-horsegram (broadcasting), MS(L) - Maize-sesamum (line), MS(B) = Maize-sesamum (broadcasting)

Fig.17: Rainwater use efficiency (in terms of rice equivalent yield) from groundnut based inter-cropping System.

Fig.18: Rain water use efficiency (in term of rice equivalent yield) from double crops (Maize-horsegram/sesamum)

was 7.0, 4.81 and 7.9 kg ha<sup>-1</sup> mm<sup>-1</sup> in first, second and third years, respectively (Table 10 & Fig. 17). The lowest was achieved by sole rice with the values being 2.1, 2.5 and 2.2 kg ha<sup>-1</sup> mm<sup>-1</sup> in the year 2000, 2001 and 2002, respectively.

#### 6.4.2.4 RWUE from double crops in rainfed upland rice area

The rain water use efficiency in terms of rice equivalent yield was also enhanced with maize-horsegram/sesamum rotation with the values being 8.4, 4.3 and 7.5 kg ha<sup>-1</sup> mm<sup>-1</sup> in first (2000), second (2001) and third years (2002), respectively from maize-horsegram (line sowing). Whereas, from maize-sesamum (line sowing) cropping system the rainwater use efficiency was 7.7, 4.3 and 6.0 kg ha<sup>-1</sup> mm<sup>-1</sup> in first (2000), second (2001) and third (2002) years, respectively (Fig. 18 & Table 11). Based on this study farmers are advised to adopt this cropping system (maize-horsegram/

sesamum) as one of the alternatives for upland rice field which will not only increase the productivity of upland rice ecosystem but cropping intensity and rain water use efficiency as well. When the RWUE in terms of rice equivalent yield was compared with sole rice, it was much lower in case of sole rice with the values being 2.1, 2.6 and 1.9 kg ha<sup>-1</sup>mm<sup>-1</sup>, in the year 2000 (rain deficit), 2001 (rain excess) and 2002 (rain deficit), respectively, (Table 11).

**Table 11 : Net return and rainwater use efficiency (in terms of rice equivalent yield) from double crops (Maize-horsegram/sesamum)**

Treatments	Net return from double crops (Rs. ha <sup>-1</sup> )			Rainwater (mm) received, (maize+ horsegram/sesamum)			Total rainwater use efficiency from two crops (in terms of rice equivalent yield) (kg ha <sup>-1</sup> mm <sup>-1</sup> )			S.E.m (±)
	2000	2001	2002	2000	2001	2002	2000	2001	2002	
Maize-Horsegram (line sowing)	17500	14720	13932	813.6	1414	795	8.4	4.3	7.5	1.23
Maize-Sesamum (line sowing)	15240	14600	11992	815	1420	801	7.7	4.3	6.8	1.02
Maize-Horsegram (broadcasting)	16600	13420	12932	813.6	1414	795	8.1	4.1	7.2	1.21
Maize-Sesamum (broadcasting)	14640	17040	11032	815	1420	801	7.5	4.7	6.5	0.81
Rice (Farmers' practice)	-	5640	-	631	1085	619	2.0	2.6	1.9	0.21
S.E.m (±)	647.8	195.1	622.3				1.1	0.35	1.0	

From the crop diversification trials in rainfed upland rice area it is revealed that 'more crop per drop' i.e. enhanced rainwater use efficiency was achieved by introduced crops/cropping systems on such land. Low water requiring crops like maize, groundnut, blackgram, greengram, pigeonpea, cowpea etc. ensured effective in-situ rainwater utilization even with less rainfall and in soils with low water retention and available water capacity.

## 7. TECHNOLOGY DISSEMINATED TO IMPROVE PRODUCTIVITY OF UPLAND RICE AREA

Success of any generated technology ultimately depends on its effective dissemination to and adoption by farming community. Hitherto the rate of adoption of the new production technology was relatively poor in rainfed areas as compared to the irrigated areas. The possible reasons were many. Farmers were either unaware of the new technology due to lack of proper extension activities or farmers were averse to change because they could not afford the high input required by the new technology. The new technology was developed for 'maximum productivity' rather than for 'maximum profit'. Hence in the present study, results of the demand driven, problem solving, participatory on-farm research trials were disseminated through organizing 'farmers' fair'/'field day' near the on-farm research site (Arnapurnapur village, Dhenkanal). The crop diversification and improved rainfed farming awareness programme were also conducted to appraise the socio-

economic, scientific and technological relevance of the technology. Training was also imparted to progressive framers and state agricultural development officers of the study district regarding rice substitution and crop diversification technology to improve productivity of rainfed upland rice area. Different extension activities performed to disseminate the generated technology are discussed below.

### 7.1 Organizing 'farmers' fair' / 'field days' near the on-farm experimental site

To demonstrate the improved crop diversification technology, two 'farmers' fair' / 'field days' were organized on 05.09.2000 and 25.08.2001 at the experimental site. (Photo - 16 to 22). In those farmers' fair/field days, several hundred of farmers, government officials including Collector and District Magistrate of Dhenkanal District, Deputy Director of Agriculture (DDA), Directors from different ICAR institutes, Dean Research of Agricultural University were present and interacted with the farmers regarding their opinion on crop diversification technology in upland rice area.



Photo-16: Release of extension bulletin in local language by then District Collector and Chief Guest, Mrs. R. Chopra during farmers' fair on 5.9.2000.



Photo-17: Demonstration of crop diversification trials by P.I. Dr. G. Kar in front of District Collector, Director of WTCER and farmers on 5.9.2000 on upland rice field.



Photo-18: Several hundreds of farmers attended farmers' fair and field day on 5.9.2000.



Photo-19: Organizing second farmers' fair on 25.8.2001 near the experimental site (Dr. H.P. Singh, Director of CRIDA, the Chief guest on that occasion)

### 7.2 Organizing district level training programme for better research-extension-farmers' linkages

To train and create awareness among the farmers, a district level crop diversification training/ awareness programme was organized on the 18<sup>th</sup> and 19<sup>th</sup> April, 2002 at Dhenkanal, Orissa where progressive farmers, State Agricultural Development Officers of all block of the district participated



*Photo-20: Large number of farmers gathered during farmers' fair on 25.8.2001 at Arnapurapur village.*



*Photo-21: Visit of District Collector of Dhenkanal, Mr. N. Mohanty, Director of CRIDA, Dr. H.P. Singh along with large number of farmers to rice substitution and crop diversification site.*



*Photo-22 : Demonstration of rice based intercropping trials during field day on 25.8.2001.*



*Photo-23: Journalists' interaction with farmers regarding adoption of crops diversification technology in upland rice area at Arnapurapur village during 2002.*

(Photo- 24 to 26). During interaction with the farmers it was found that they were enthusiastic to adopt the crop diversification technology to improve productivity of rainfed upland rice area. The State Agricultural Officers were also appraised regarding improved package of practices of the technology and its socio-economic, scientific and technological relevance. The World Bank team (NATP) also visited the site on 16.10.2000 and appreciated the technology generated to improve productivity of rainfed upland rice eco-system based on demand driven, problem solving and participatory on-farm research trials.

### **7.3 Organizing crop diversification awareness campaign**

The crop diversification awareness programme was also organized in the state. Three extension bulletins on improved rainfed farming practices entitled (i) "Water, soil and crop management technologies to increase cropping intensity in rainfed rice area" (ii) "Watershed management strategies for year round food production and employment generation in Orissa" and (iii) 'Soil and water quality testing for increased productivity' were published in local (Oriya) language and widely circulated to farming community during crop diversification awareness campaign and farmers' field day. The complete package of practices of crop diversification technology in upland rice area of eastern India were circulated widely to the farming community of the state in



Photo-24: Organizing district level training programme On 18th and 19th April, 2002 at Dhenkanal, Orissa. (Dr. H.K. Pandey, retd. Director of CRRI, the Chief Guest)



Photo-25: Several Hundreds of farmers and State Agricultural Officers participated the crop diversification training at Dhenkanal on 18 & 19<sup>th</sup> April, 2002.



Photo-26 (a) : Participation of then District Collector, Dhenkanal, Mrs. R. Chopra during field day on 5.9.2000.



Photo-26 (b) : Participation of present District Collector, Dhenkanal, Mr. N. Mohanty during field day on 25.8.2001.



Photo-27: Adoption of maize in large area by replacing upland rice at Arnapurnapur village, Dhenkanal during 2002.



Photo-28: Adoption of second crop (horsegram) after maize on the same land.

the form of leaflets in three languages (English, Hindi and Oriya). The technology generation, its dissemination, adoption and success story were also covered by several national English and Regional (Oriya) newspapers (News 1 to 11). The technology generation, its scientific and socio-economic relevance were also broadcasted in local television, D.T.V. on 24.4.2002. As per the requirement, crop diversification technology in upland rice area was handed over to Special



*Photo-29: Rice substitution with blackgram in rainfed upland rice field during 2002.*



*Photo-30: Adoption of groundnut in large area at Jiral, Dhenkanal during 2002.*



*Photo -31 : Large scale adoption of groundnut+pigeonpea at Jiral, Bhuban Block, Dhenkanal during 2003.*



*Photo - 32 : Adoption of maize in large scale in upland rice area by farmers of Arnapurapur village, Kamakhyanager Block, Dhenkanal during 2003.*

Relief Commissioner, Government of Orissa for minimizing the effect of drought and to obtain higher and assured net economic return from rainfed upland rice area of the state.

## **8. TECHNOLOGY ADOPTION AND SUCCESS STORY**

During 2002, the Orissa state faced acute drought when 25 – 60 % less rainfall occurred in different districts in two critical months (July and August) of growing rice. The upland rice was damaged totally and transplanting of medium and low land rainfed rice was delayed considerably. In that year, the net economic return from rainfed upland rice was almost nil or negative for traditional rice growers but those who adopted recommended crop diversification and rice substitution technology in rainfed upland rice field, received higher net economic return ( approx Rs. 10,000 to 20,000 ha<sup>-1</sup> from different rice substituted crops) irrespective of occurrence of drought in the state.

The on-farm crop diversification trials with the advancement of sowing dates in light textured rainfed upland rice ecosystem has created a great impact among farmers of the rainfed rice areas of the state for mitigating drought and obtaining higher and assured return. Crop diversification on such area is the need of the hour which has been realized by researchers, policy makers and farmers of the state. Farmers of study area have already started to adopt recommended crop

diversification and rice substitution technology which can be seen from the photo 27 to 32. Studies of adoption of crop diversification technology (Based on proportionate sampling method) revealed that maximum farmers preferred groundnut+pigeonpea intercropping and maize-horsegram/ sesame rotation as a possible alternative of rainfed upland rice owing to their assured return with less rainfall and having better market prices. Among 5 study villages, adoption rate was higher (80 to 84 %) during 2002 (rain deficit years) at Arnapunapur and Jiral villages for groundnut+pigeonpea intercropping which includes some sole groundnut. In the current rainy season (2003) adoption was still higher (90 to 93 %) in those two villages (Table 12). Farmers also preferred maize-horsegram/ sesame crop rotation and sole blackgram and highest adoption percentage for these crops was 63.3 during 2002 (rainfall deficit year) and 66.6 during 2003 at Arnapunapur village, Dhenkanal (Table 12). The technology adoption and success story were also covered by different English and Local (Oriya) daily newspapers (News 1 to 11).

**Table 12 : Adoption of crop diversification technology by different study villages of Dhenkanal**

Year 2002 (Deficit rainfall year)								
Villages	Sole groundnut and Groundnut+Pigeonpea intercropping				Maize-horsegram/ sesame rotation			
	Total no. of farmers sampled	No. of farmers adopted the technology	Adoption (%)	Area (ha)	Total no. of farmers	No. of farmers adopted the technology	Adoption (%)	Area (ha)
Arnapunapur	30	24	80	20	30	19	63.3	10
Jiral	50	42	84	20	50	13	26	4
Parjang	40	15	37.5	2	40	10	25	5
Noagao	20	6	30	2	20	6	30	6
Kingol	40	12	30	2	40	9	22.5	10
Year 2003 (Normal rainfall year)								
Arnapunapur	30	28	93.3	18	30	20	66.6	15
Jiral	50	45	90	32	50	15	30.0	5
Parjang	40	15	37.5	5	40	12	33.0	6
Noagao	20	5	25	3	20	6	31.0	7
Kingol	40	13	32.5	2	40	12	33.3	8

## 9. VALUE ADDITIONS BY REMOTE SENSING AND GIS FOR EFFECTIVE DISSEMINATION OF GENERATED TECHNOLOGY

Development of alternate site specific land and crop use plan and its implementation to large agricultural area requires generation and gathering of precise information on a number of natural resources parameters like existing land use/land cover, geology, geomorphology, hydrology, soils, drainage pattern, climate etc. and overlaying of these resources to get action plan map. Survey techniques and manual methods to be adopted in getting derived information are time consuming and tedious. With the introduction of modern advance tools like remote sensing and GIS, integration of natural resources data and depicting their spatial distribution and area are much



easier because of its capacity to design and organize an error free digital base of natural resources in the form of spatial layers.

As a future approach of study an attempt was made to identify similar adaphic and hydrologic conditions for the dissemination of the generated crop diversification technology in large area on the basis of hydrological boundary (watershed) using advance tools like remote sensing and GIS. The study was undertaken in Kadalipal watershed, Dehenkanal district, Orissa State for which spatial natural resources were collected and analysed, using GIS tools. The base map and slope maps were prepared from Survey of India toposheet (No. 73 H/9) on 1:50,000 scales. The soil texture, land/use land cover map were prepared from visual interpretation of remote sensing imagery of IRS-1D (LISS-III) along with extensive ground survey. The soil pH, nutrient status (organic carbon), water holding capacity etc. map were prepared from profile survey and laboratory analysis along with soil maps prepared by National Bureau of Soil Survey and Landuse Planning, Nagpur.

After mapping all these existing natural resources, composite land development unit (CLDU) map was prepared by integrating all these spatial resources through GIS and action plan for alternate sustainable land use development map was prepared based on CLDU (Fig. 24). The GIS coverage of land use map revealed that study area was dominated by rainfed *khari* rice with all land ecosystems (upland, medium land, low land). The organic carbon of the watershed varied from 0.3 to 0.8 % (Fig. 20) and available water holding capacity ranged between 8 and 31 % in different land ecosystem of watershed (Fig. 23). Majority of the area (Fig. 21) was under gentle slope (1-3 %) and dominant soil texture was sandy clay loam (Fig. 22).

In the action plan map, alternate sustainable crops/cropping system like rice substitution and crop diversification technology, intercropping, double cropping, agroforestry, horticulture etc. were suggested in different parts of watershed based on some decision rules. In the light textured rainfed upland rice soils, rice was discouraged and crop diversification with legume or rice based intercropping was suggested and implemented. In the medium land, instead of existing monocropped rice, rice based double cropping system was suggested through effective utilization of residual moisture and runoff recycling at critical crop growth stages. In the low land valley fill double cropping was suggested with proper tilling and seeding practices. In the upland where crop cultivation was not possible alternate sustainable production system such as agro-forestry, agro-horticulture and silvipasture were advocated.

This study has amply demonstrated the potential of remote sensing and geographic information system (GIS) in inventorying existing natural resources and development of action plan on alternate sustainable crops/cropping system in large agricultural area on hydrological boundary (watershed) basis.

## 10. SOCIO-ECONOMIC RELEVANCE OF THE TECHNOLOGY GENERATED

Against the backdrop of increasing population world over, it is imperative that global food production and policy should receive utmost attention to avoid any food in-security in future. It is high time to think of attaining sustainable agricultural productivity and nutritional security through optimum utilization of natural resources otherwise human prosperity may be at stake in the years to come. Looking to the serious issues of food, nutrition and environmental security, the outcome of the present research has direct relevance for socio-economic upliftment of the country by improving production, productivity, profitability and sustainability of rainfed upland rice area of eastern India.

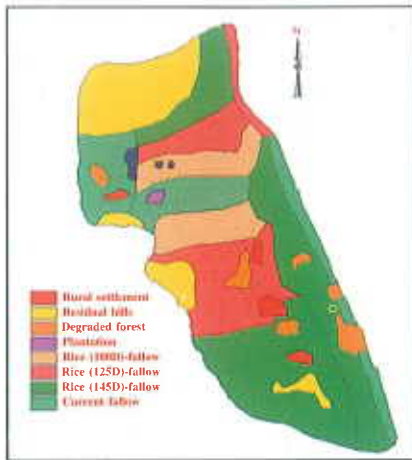


Fig. 19 : Existing land use pattern.



Fig. 20 : Distribution of organic carbon (%).

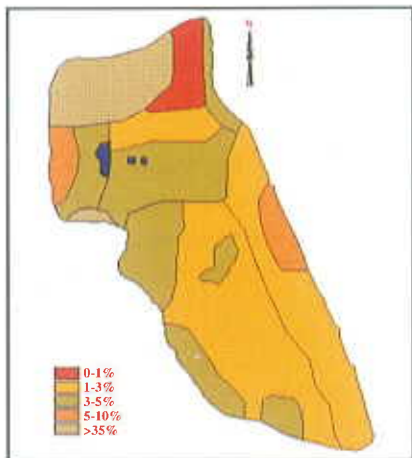


Fig. 21 : Slope (%) variation in watershed.

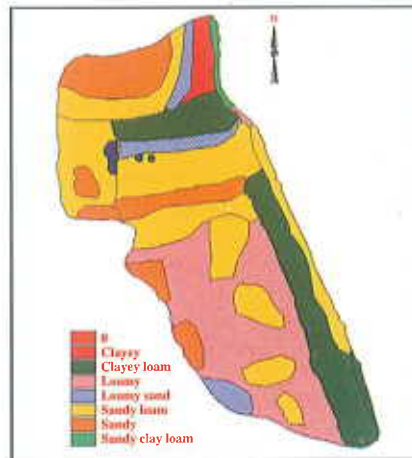


Fig. 22 : Soil texture variation in watershed.

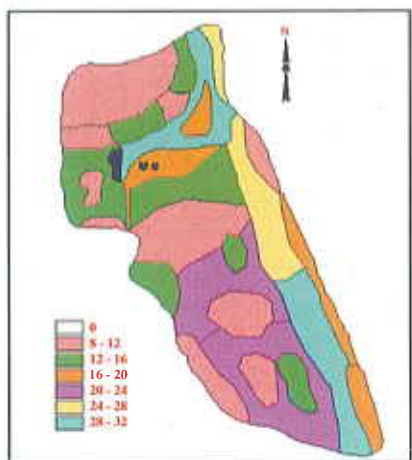


Fig. 23 : Variation of available water capacity (%).

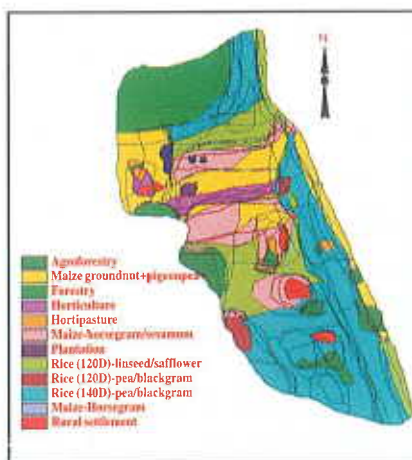


Fig. 24 : Proposed land use system.

### **10.1 Rice substituted crops in rainfed upland rice area increases productivity and cropping intensity with assured return.**

Since the crop water requirements of short duration, low duty crops like maize, blackgram, greengram, groundnut, cowpea are low as compared to rice, these can overcome 3-4 dry spells during growth period, resulted in assured return (atleast Rs. 10,000 ha<sup>-1</sup> per annum) even under rainfall deficit situation. Pulses have also inherent capacity to trap the moisture from the lower strata of the soil, therefore, they are considerably moisture stress tolerant and fit well under rainfed condition. Since in eastern India vast rainfed upland rice area are existed (4.3 mha), so there is a scope to increase productivity and cropping intensity of such land through crop diversification and rice substitution.

### **10.2 Ensuring food, nutrition and environmental security**

Crop diversification with legumes not only provides food security but also nutritional and environmental security as well. Pulses are the cheap sources of vegetative protein required for human health as compared to other sources. The cost of protein for pulses comes around Rs. 100 kg<sup>-1</sup> whereas for eggs, milk and fish/meat the cost is around Rs. 200, Rs. 300, Rs. 450 kg<sup>-1</sup>, respectively. The average adult man would require 60 g and adult women 50 g of protein per day. But the decreasing per capita availability of pulses from 60.7 g in 1951 to 35.9 g in 2000 is of great concern in the Indian context where most of the people are vegetarian. (Chaturvedi and Masood Ali, 2002). For balance diet at the end of Xth plan, India may need 103.5 million ton of rice, 84.3 million ton of wheat, 34.4 million ton of coarse grain, 21.5 million ton of pulses and 9.5 million ton of oilseeds. This can be realized only through efficient site and location specific diversified cropping system with legumes, oilseeds or low water requiring cereals and millets. Different pulses can also fix huge amount of nitrogen through symbiosis and thus minimize dependency on chemical fertilizer, which lead to environmental pollution.

### **10.3 Increasing income for small and marginal farm holdings**

One of the major problems of agricultural economy in India is the dominance of marginal and small farmers. More than 75 % farm holdings are below 2 ha and a large rural population belongs to these holding size categories. It is hardly disputed that the income of these farmers can not be raised to a desired level to suffice alleviation of poverty unless the existing crop production system are diversified through inclusion of high value crops or introduction of other farm enterprises as a compliment to crop production. Farmers can also earn money in lean period (August–September) through early sowing and harvest of short duration rice substituted crops in upland ecosystem such as from green cob of maize.

### **10.4 Regulating labour requirement and checking labour migration**

Since mono culture rice based agriculture is highly season specific and time bound, the intensity of labour requirement increases during sowing time and harvesting time of crop. For rest of the time farmers sitting idle if they do not have any farm activities. The effective rainwater utilization through crop diversification will ensure double cropping in rainfed upland rice ecosystem, which keeps the whole farm family busy for longer period, as a result labour migration will be checked. The crop diversification in rainfed upland rice ecosystem also regulates labour requirement during the season. Instead of big labour demand for field preparation and transplanting of rice during

July and August, farmers can finish their sowing of upland rice substituted crops and weeding in June itself before shifting to medium and low land rice transplanting. In this way they are also utilizing rainfall of the month of June which otherwise be wasted as runoff because farmers of the region wait till first week of July for rice sowing/transplanting when sufficient water accumulates in the rice field.

#### **10.5 Mitigating aberrant weather conditions and reducing risk factor**

The agriculture in eastern India is fully south west monsoon dependent, which is quite erratic and fluctuating over a period of cropping season or from year to year. The single crop based agriculture is always endangered due to natural hazards like drought, cyclone, flood and epidemic diseases. Adoption of diversified cropping system would reduce the risk involved in failure of single crop/cropping system based agriculture.

#### **10.6 Building up sustainable and productive system with assured return**

Now the challenge before the agriculture in eastern India is to transform rainfed farming into more sustainable and productive system through efficient use of natural resources. Hence, improving rainwater use efficiency and productivity through site specific crop and land use planning by crop diversification holds the key for sustainable development of agriculture in rainfed areas. Introduction of legumes for grain, fodder or green manures through sole or inter-cropping improves soil fertility and soil physical health.

#### **10.7 Crop diversification and rice substitution in upland rice ecosystem creates water harvesting potential**

Crop diversification with low water requiring crops create water harvesting potential for providing supplementary irrigation to the same crops during dry spells in rainy season or to second crops at critical growth stages during post rainy season. Study reveals that at 75 % probability level 263 mm runoff may occur during four monsoon months, so proper mechanism should be created to harvest runoff water. With rice cultivation in light textured upland rice ecosystem that amount of water might have lost due to high evapotranspiration and percolation loss.

#### **10.8 Crop diversification along with integrated farming system provides quality food basket and enhances farm income**

After meeting the cereal requirements of burgeoning population of the country, time has come to endow with balanced food demand of the entire Indian malnourished population. By following ICMR recommended dietary standard in 1990, total cereal consumption would be 5 % lower but consumption of milk, eggs and meats would be nearly doubled. This situation justify the needs of farming system which has several components like dairy, poultry, goatry, fisheries etc. along with diversified crop production in different rainfed rice ecosystem. In this way, farming system (diverseified cropping system plus) would not only meet the food demand but also cater the need of protein, fat, vitamins and minerals required for good health. Farming system could be proved as effective means in eliminating poverty as it provides higher income, regular employment, balanced and quality food, besides mitigating aberrant weather situation. As the farming system comprises of several farm enterprises like livestock, fisheries, poultry etc. in

addition to diversified crops, it provides opportunity to farmers to have a 'basket of complementary options' for reducing the risk involved in single commodity based agriculture.

### **10.9 Dynamic cropping system concept**

In summary, crop diversification and rice substitution in rainfed rice field covers key factors of dynamic cropping system which includes (i) diversity (increase in the type and number of crop), (ii) adaption (willingness to take advantage of new opportunities and enhance production practices, (iii) reduction of input (greater net return for each rupee invested), (iv) eco-friendly and sustainability.

## **11. SOCIO-ECONOMIC PRIORITIES IDENTIFIED FOR SUCCESSFUL DISSEMINATION AND ADOPTION OF TECHNOLOGY**

### **11.1 Consolidation of holdings in rainfed areas**

In rainfed farming investment, risk is more when holdings are scattered particularly in case of small and marginal farmers. Risk can be minimized by consolidating the holdings which will ensure mass cultivation of diversified crops in rainfed upland rice area.

### **11.2 Synchronous delivery of credit, input and technology**

Due to non-synchronous delivery of credit, input and technology, farmers get very little time for precision farming. Since success of cultivation of rainfed upland crops depends on on-set and performance of south west monsoon, sowing at right time is very much crucial. Slightly delay in sowing causes reduction of yield significantly. To overcome this problem synchronous delivery of credit, input and technology under one umbrella at Panchayet level are the need of hour.

### **11.3 Research-Extension-Market-Farmer Linkage**

Proper linkage should be developed between Research, Extension, Farmers and Markets for successful adoption of technology and receiving good return. Close linkages and interactions among research institutes, seed producing organizations/companies and development agencies may ensure better seed replacement rate of pulses and oilseeds in rainfed upland rice area.

### **11.4 Minimizing distress sale of agricultural produce**

Production of value added products by establishing processing mills and assured procurement of processed products such as 'dal', 'edible oil' from mills / processing units and their distribution through fair price shops will ensure better price to farmers. This mechanism will minimize distress sale of agricultural produce.

### **11.5 Input costs subsidy**

Every year cost of inputs is increasing; sometimes it is beyond the purchasing power of small and marginal rainfed farmers. Subsidy to be provided for the inputs of most viable production and protection rainfed farming technology as incentives to the farmers those who intend to adopt crop diversification technology in rainfed upland rice area.

### **11.6 Value added products**

Emphasis should be given for value added products like processed 'dal' from pulses, 'edible oil' from oilseeds or 'pop corn' from maize etc. to fetch more money, instead of selling raw products directly.

News 1: 'The Indian Express' on 19.10.2002.

## Intercrops a success in Dhenkanal district

Express News Service

Dhenkanal, Oct. 19: Despite drought situation in the district, cultivation of intercrops through crop diversification system has become successful with the cooperation and guidance of the Water Technology Centre for Eastern Region (WTCER) and the Indian Council of Agricultural Research (ICAR) in various parts of the district, said Gouranga Kar, senior scientist of WTCER.

Talking to media persons recently, Kar said complete substitute of paddy by intercrops like groundnut, maize, sesame and blackgram on rotation basis is effective to obtain good

yield in 30 hectares in Annapurnapur, Jiral, Kingal, Jansagar and Nungun villages.

World Bank has been providing assistance to five villages and organising farmers' training programme through WTCER since last three years and it has proved fruitful this year, Kar added.

World Bank has introduced crop diversification system in these villages without affecting existing "use system" to improve productivity and economic condition of the farmers, a WTCER press release said.

However, the farmers want irrigation facility to cultivate the intercrops round the the year.

News 2: 'The Hindustan Times' on 4.9.2001.

## Crop management holds key to rural incomes

HT Correspondent  
Dhenkanal, September 4

IN A fair of farmers organised recently by Water Technology Centre for Eastern Region, Bhubaneswar, in Annapurnapur village of Kamakhyanagar, Dhenkanal, most of the scientists stressed on crop management strategies in rain-fed areas to increase rural income.

Attending the fair as chief guest, Dr H P Singh, director of Rain fed Agro-Ecosystem and Central Research Institute for Dryland Agriculture, Hyderabad, said the Centre has incurred a loan of Rs 280 crore from the World Bank to implement research project in scientific

cropping in rain-fed areas. Meanwhile, the project has been initiated successfully in 700 districts of the country.

Delivering the introductory speech on the occasion, scientist Dr G Kar said that, Indian Council of Agricultural Research has introduced National Agricultural Technology Program at Annapurnapur in Dhenkanal district since May 99.

The main objective of the project is to educate the farmers to adopt scientific cropping system in rain fed areas.

However, Water Technology Centre for eastern region is working as a branch of Indian Council of Agricultural Research to carry out the project.

News 3: 'The Indian Express' on 8.9.2000.

## Multi-cropping system good for rain-fed areas

Express News Service

Dhenkanal, Sept. 8: Multi-cropping system followed for crops other than paddy is more lucrative in rain-fed rice areas, stressed AC Rout, deputy director of Agriculture, Dhenkanal.

Speaking at a farmers' fair organised by Water Technology Centre for Eastern Region (WTCER) in Annapurnapur village, Rout pointed out that farmers could profit by adopting new technologies and cropping systems for kharif crops like maize, groundnut and blackgram in upland areas.

He revealed that in Dhenkanal district 4,200 acres of paddy crop had been damaged due to lack of rain this year. Farmers should cultivate non-paddy crops like groundnut which do

not require much water, he suggested and urged scientists and farmers to keep in touch.

Project leader and scientist, WTCER, Dr G Kar said Indian Council of Agricultural Research was executing a project called 'Crop management strategies to increase cropping intensity in rain-fed rice areas' through the National Agriculture Technology programme in the district.

The project aims to utilize scientific water and crop management practices and identify suitable cropping systems on different types of land, Kar added. Others who spoke included district collector Ranjana Chandra, director CRRI BN Singh, Shakti Sugar DGM R Venugopal, WTCER director Dr HN Varma and scientist Dr R Singh.

News 4: 'The Indian Express' on 23.4.2002.

## Scientists stress upland crop diversification

Express News Service

Dhenkanal, April 23: Effective rain water utilisation through upland crop diversification is possible and it has proved successful in Dhenkanal district. This was revealed by a group of scientists of the Indian Council of Agricultural Research (ICAR), Ministry of Agriculture, at Dhenkanal Science Centre recently.

Addressing farmers during a two-day farmers' Training cum District Crop Diversification Awareness Programme organised by the Water Technology Centre for Eastern Region (WTCER), the scientists emphasised on sowing immediately after the onset of monsoon, crop diversification in upland area and cultivation of crops like maize, groundnut and blackgram.

Appreciating the role of WTCER in Dhenkanal, Deputy Director of Agriculture

DEEPAI, Dhenkanal, Ghanshyam Das highlighted on rain fed farming implements, need for technology dissemination and farmers' awareness programme and stressed that these were important for increasing cropping intensity and produce (dry) in rainfed rice-growing areas.

At present, WTCER sponsored projects under Indian Council of Agricultural Research (ICAR) are running in five villages - Annapurnapur, Jansagar, Kingal, Jiral and Pissagan in Kamakhyanagar, Dhanan and Pajung blocks.

Other scientists informed the farmers that several crops like pea, sunflower, wheat, mil-lower, gram and mustard have been introduced in different villages of the district during research trial.

Among others, DGM of Shakti Sugars Dr. R Venugopal and Dr. H Singh addressed the farmers.

## Water technology centre holds fair

**Dhenkanal:** The Eastern Region Water Technology Centre, Bhubaneswar recently organised a fair of farmers at national Agriculture Technology Projects site of village Kadalpal in Kamakshyanagar.

On this occasion district collector Ms Ranjan Chopra revealed that though 90 per cent people in India depend on agriculture while 20 per cent of our total land are irrigated. She stressed on the need of adoption of scientific methods in farming.

Deputy director of agriculture A. C Rout advised the farmers that they should not depend on a single crop.

Among others director of WTCEK Dr. Harsenath Verma and DGM Shakti Sugar R. Venugopal spoke on the occasion. Scientist Dr. Rabindra Singh delivered vote of thanks.

## ICAR initiates pilot project in Dhenkanal

By K. SUSHMA KUMAR MISHRA

**Dhenkanal, Sept. 12:** In order to make agricultural practice more economical and for better utilisation of land and water resources in rain-fed areas, the India Council of Agricultural Research has initiated a pilot project in Dhenkanal through the National Agriculture Technology Programme, informed ICAR's Dr Gauranga Kar at a press conference here recently.

Information about the project he said that the project would aim at deployment of "efficient scientific water and crop management practices." The project would also identify suitable cropping systems under different land situations, they added.

He further informed that several experiments had already been conducted on paddy, gram, sunflower, wheat, ground nut and maize in the rabi season of 1999-2000 for the project.

"Farmers have got good economic returns by adopting the recommended technology of the project executives," Dr Kar said.

## Dhenkanal one of 240 districts in WMS

EXPRESS NEWS SERVICE

**Dhenkanal, Sept. 1:** Water Management System (WMS) has been implemented in Dhenkanal district. It is the only district of Orissa to have the system. The project has been implemented in 240 districts all over the country with assistance from the World Bank.

This was announced at a Farmers fair organised at Arnapurnapur of Kamakhyanagar block organised by Water Technology for Eastern Region, Bhubaneswar, recently.

Sources said Rs 260 crore including Rs 120 crore for Dry Land farming has been sanctioned by the World Bank for dryland farming. Speaking on the occasion, rainfed agro-ecosystem (NATP) and Director

of Central Research Institute for Dryland Agriculture (CRIDA) Dr HP Singh said that water management is essential for increasing production to feed the ever increasing

**During the current Kharif season the project has covered five villages in three blocks, Bhuban, Arnapurnapur and Bharatkota**

population.

Agrometeorologist Dr G Kar said that Water Technology Center (Union Ministry of Agriculture) for Eastern Region, a branch of Indian Council of Agriculture Research

(ICAR) has been executing the project through National Agriculture Technology Programme in Dhenkanal since May 1999.

During the current Kharif season the project has covered five villages in three blocks, Bhuban, Arnapurnapur and Bharatkota. Dr Kar further said that apart from the crop diversification and substitution, experiments are being done to improve the productivity of the rice.

Among others, Dean of CRIDA UK Mishra exhorted the farmers to grow varieties of crops with assistance from farmers and has asked the farmers and scientists to cooperate with each other.

Among others, director of CRRI Dr BN Singh was also present.

News 8 : 'The Dharitri' on 24.12.2000.

News 9 : 'The Samaj' on 26.8.2000.

### ସ୍ୱଚ୍ଛ ବୃଷ୍ଟି ଅଞ୍ଚଳରେ କୃଷି

ପୂର୍ଣ୍ଣ ବୃଷ୍ଟି ପ୍ରଦାନ କରୁଥିବା ଅଞ୍ଚଳରେ କୃଷିର ଉତ୍ପାଦନ ବୃଦ୍ଧି ପାଇବାର ସମ୍ଭାବନା ରହିଛି । ଉତ୍ତମ ଉତ୍ପାଦନ ପାଇଁ ଉଚିତ ଉପାଦାନ ଯୋଗାଇ ଦିଆଯାଉଥିବା ସମୟରେ କୃଷିର ଉତ୍ପାଦନ ବୃଦ୍ଧି ପାଇବାର ସମ୍ଭାବନା ରହିଛି । ଉତ୍ତମ ଉତ୍ପାଦନ ପାଇଁ ଉଚିତ ଉପାଦାନ ଯୋଗାଇ ଦିଆଯାଉଥିବା ସମୟରେ କୃଷିର ଉତ୍ପାଦନ ବୃଦ୍ଧି ପାଇବାର ସମ୍ଭାବନା ରହିଛି ।



କୃଷିର ଉତ୍ପାଦନ ବୃଦ୍ଧି ପାଇଁ ଉଚିତ ଉପାଦାନ ଯୋଗାଇ ଦିଆଯାଉଥିବା ସମୟରେ କୃଷିର ଉତ୍ପାଦନ ବୃଦ୍ଧି ପାଇବାର ସମ୍ଭାବନା ରହିଛି । ଉତ୍ତମ ଉତ୍ପାଦନ ପାଇଁ ଉଚିତ ଉପାଦାନ ଯୋଗାଇ ଦିଆଯାଉଥିବା ସମୟରେ କୃଷିର ଉତ୍ପାଦନ ବୃଦ୍ଧି ପାଇବାର ସମ୍ଭାବନା ରହିଛି ।

### ଦେଶର ୨୪ଟି ଜିଲ୍ଲାରେ କୃଷି ପ୍ରାଦେଶିକ କାର୍ଯ୍ୟକାରୀ ହେଉଛି

କୃଷିର ଉତ୍ପାଦନ ବୃଦ୍ଧି ପାଇଁ ଉଚିତ ଉପାଦାନ ଯୋଗାଇ ଦିଆଯାଉଥିବା ସମୟରେ କୃଷିର ଉତ୍ପାଦନ ବୃଦ୍ଧି ପାଇବାର ସମ୍ଭାବନା ରହିଛି । ଉତ୍ତମ ଉତ୍ପାଦନ ପାଇଁ ଉଚିତ ଉପାଦାନ ଯୋଗାଇ ଦିଆଯାଉଥିବା ସମୟରେ କୃଷିର ଉତ୍ପାଦନ ବୃଦ୍ଧି ପାଇବାର ସମ୍ଭାବନା ରହିଛି ।

କୃଷିର ଉତ୍ପାଦନ ବୃଦ୍ଧି ପାଇଁ ଉଚିତ ଉପାଦାନ ଯୋଗାଇ ଦିଆଯାଉଥିବା ସମୟରେ କୃଷିର ଉତ୍ପାଦନ ବୃଦ୍ଧି ପାଇବାର ସମ୍ଭାବନା ରହିଛି । ଉତ୍ତମ ଉତ୍ପାଦନ ପାଇଁ ଉଚିତ ଉପାଦାନ ଯୋଗାଇ ଦିଆଯାଉଥିବା ସମୟରେ କୃଷିର ଉତ୍ପାଦନ ବୃଦ୍ଧି ପାଇବାର ସମ୍ଭାବନା ରହିଛି ।

## AGRICULTURE IN RAINFED AREAS

### ସ୍ୱଚ୍ଛ ବୃଷ୍ଟି ଅଞ୍ଚଳରେ କୃଷି

The 'green revolution' for enhancing agricultural production was confined to country's well-irrigated areas but agricultural development in vast 92 million ha rainfed area of the country is still neglected. Orissa's share of rainfed area are 53.10 lakh ha, out of 66 lakh ha agricultural cultivable land. Major portion of pulses, oilseeds, all kinds of millets, cotton are produced in rainfed areas. Besides maximum live stock products such as milk, meat and wool are also produced in these areas. The Orissa receives 1400 mm average annual rainfall but it is confined to four monsoon months (June to September). In that season rainfall occurs with heavy downpour, results substantial flood whereas in other season agricultural droughts of varying intensities limit the crop production potential. In the last 33 years, there are 15 times drought and 6 times both drought and flood occurred in the state. It is, therefore, necessary to develop improved crop, water and soil management technologies for improving the productivity of vast rainfed area of the state. Since immediate expansion of irrigated areas is not cost effective, emphasis has to be given for improved rainfed farming technology for 'more crop per drop'. In this context, for the economic improvement of rainfed farmers, Water Technology Centre for Eastern Region (WTCER), Bhubaneswar has initiated a National Agricultural Technology Research Project (NATP) at Dhenkanal for developing modern, technically sound rainfed farming and water management technology on watershed basis. Recently the project is in operation at the Dhenkanal, district under the supervision of Dr. H.N.Verma, Director, WTCER and Dr.G.Kar, Agricultural Scientist. The main objectives of the project are to obtain higher agricultural production with more net economic return through scientific cultivation crops in rainfed areas.

(Translation of News 8)

## NATP IN 240 DISTRICTS

### ଦେଶର ୨୪ଟି ଜିଲ୍ଲାରେ କୃଷି ପ୍ରାଦେଶିକ କାର୍ଯ୍ୟକାରୀ ହେଉଛି

Dhenkanal 26/8: In a farmers' fair at Arnapurnapur village, Dhenkanal, organized by Water Technology Centre for Eastern Region (ICAR), Bhubaneswar, Dr. H.P Singh, Director, CRIDA, Hyderabad said the National Agricultural Technology Project (NATP) has been implemented in 240 districts throughout the country with Rs.260 crores World Bank Assistance. In the farmers fair Dr. H.N. Verma, Director, WTCER Gave the preliminary information on the objectives of the project initiated at Dhenkanal. On that occasion, Dr. Gourang Kar, the project investigator reported about the ongoing activities of the project which covers five villages of Dhenkanal district viz., Arnapurnapur village of Kamakhyanager Block, Kingol and Jiral villages of Bhuban Block, Janapada village of Parjang Block. Dr.B.N. Singh, Director, CRRI advised intercropping of pigeonpea with 90 days Vandana rice to improve productivity of rainfed rice soils. Mr. R. Venugopal, GM, Shaktisugar briefed about the benefits of growing sugarcane. On that occasion, Mr. Nityananda Mohanty, Collector, Dhenkanal advised the local farmers to be self-employed by taking training from agricultural scientists. Dr.U.K. Mishra, Dean of Research OUAT, Bhubaneswar Dr. S.K. Mohanty, Principal Scientist CRRI appraised the farmers regarding improved rainfed farming technology. Dr. R.Singh, Principal Scientist gave vote of thanks.

(Translation of News 9)



News 10 : 'The Sambad' on 26.8.2000.



**TECHNOLOGY DISSEMINATION PROGRAMME CONDUCTED TO EXTEND THE ON-FARM AGRICULTURAL RESEARCH RESULTS TO THE RAINFED FARMING COMMUNITY**  
**କୃଷକ ଜ୍ଞାନକୌଶଳ ଓ କୃଷି ଅନୁସନ୍ଧାନ ଗଞ୍ଜକୂଳ ପାଖରେ ପହଞ୍ଚାଇବା କୃଷି ମେଳାର ଉଦ୍ଦେଶ୍ୟ**

Dhenkanal 26/8 (EMS): A farmers' fair was organized on 25th August, 2002 in the Armapurna village of Kadalipal Panchayat of Kamakhyangar sub division, Dhenkanal, Orissa by the Water Technology Centre for Eastern Region (ICAR), Bhubaneswar. In that farmers' fair Chief Guest Dr. H.P. Singh, Director CRIDA appraised the main objective of the NATP which aims at refinement of rainfed farming technology in the farmers' field so that they can participate in planning and implementation process and can adopt the evolved modern agricultural technology for obtaining higher and assured return. He also informed that at present Rs.120 crore has been invested throughout the country through World Bank assistance for implementing different National Agricultural Technology Projects (NATP) at 240 districts.

On that occasion, Special Guest Dr. B.N.Singh, Director, CRRI, Cuttack said farmers should adopt proper crop and water management technologies like in situ water conservation, runoff recycling, growing of short duration high yielding crop (varieties) etc. for more productivity and net return. The Collector and District Magistrate of the Dhenkanal district, Mr. Nityananda Mohanty was present on that occasion and he told that rural youths should trained themselves with modern agricultural technology through participation in this type of farmer's fair/field days and making interaction with agricultural scientists by which they will be self employed. He also emphasized the formation of self help group for women farmers' for becoming economically independent.

In this fair DGM Shakti Sugar, Dhenkanal, Mr. R. Venugopal briefed about improved sugarcane cultivation technology. The Deputy Director of Agriculture, Mr. G.S.Pal appraised the farmers regarding subsidy facilities of dry land crop cultivation. Dr. U.K. Mishra, Director of Research, OUAT, Bhubaneswar and Mr. S.K. Mohanty, Facilitator of the Project & Pr. Scientists, CRRI, Cuttack briefed about some improved rainfed agricultural technology and their usefulness for improving productivity.

Dr. Gourang Kar, Project leader informed the results of on-going NATP project at Dhenkanal which was started in the year 1990 at Armapuranapur Village, dhenkanal. The project afterwards extended to another 5 villages of Kamakhyangar, Parjanj and Bhuban block of Dhenkanal District.

In the farmers' fair, more than 700 farmers and 100 departmental government officials participated. Before the starting of the meeting, the guests along with large number of farmers visited the on farm research trials at the project site.

(Translation of News 10)

### ଅନପୂର୍ଣ୍ଣାପୁର ଗ୍ରାମର ସଫଳକାହାଣୀ



କାନ୍ଥ କରାଯାଇଛି । ଗୋଟିଏ ଖେତରେ ମନା ବସାଯାଇ ଦେଲେଇ ସ୍ତ୍ରୀମାନଙ୍କେ ମନା ଅମଳ ପରେ ପରେ ଯେତି ଦୁଇଲେ ନାଶି ଓ ବୋକେ ଥାଏ ଦୁଶାସିକା । ସବଳ ଏବଂ ଦାକ୍ଷିଣ ଏକସଙ୍ଗେ ଲଦାଯାଇଛି । ନରେନ୍ଦ୍ର ପୁଣ୍ୟ ଏହାର ଅମଳ ପରିଲେ ଯେତି ସ୍ଥାନରେ ବର ପରକ ଓ ପରିପରିତା ତାହା କରାଯାଇପାରେ । କର୍ଷାଟକରେ ୯୦ ବିନିଆ 'କରନା' ଧାନତାଣି ବସାଯାଇ ଧାନ୍ତତା ଚେଦାନ ଫର୍ଷିର ପୂର୍ବରୁ ଶୁଣି ପୁରା,

ଦୋଳି ପୁର୍ଣ୍ଣାପୁର ଜଳ ସ୍ତ୍ରୀବୋଧିକା ପ୍ରକଳ୍ପ ନିର୍ଦ୍ଦେଶକ ବଃ କର୍ମୀ ସୁଦାଶ ନଦୀଇଡ଼ି । ଜମିର ଅଢ଼ୁତା ଏଂକ୍ଷଣ, ନନ୍ଦନ ପୁଷ୍ପନ ଦମ୍ବିଯୋକ, ଧାନ୍ତକାହିଁର ଗନ୍ଧ ଅମଳ ପଞ୍ଚକ ଏକ ଜଳି ବାଷ ନଦୀତାର ସ୍ୱତନ୍ତ କୌଶଳ ମାଧ୍ୟମରେ ଦୃଷ୍ଟିପୁଷ୍ଟ ଖୁଞ୍ଚି କରିରେ ମଧ୍ୟ ଅନାୟାସରେ ତୁଳତ ଅର୍ଥକର ପରକ ଜିପତି ଅମଳ କରାଯାଇପାରିବ, ତାହା ଏତି ପ୍ରକଳ୍ପ ଜନିଆରେ

ସୁପରିଦାକ୍ଷୀନାସର ଦୌଶଳ ଏତି ପ୍ରକଳ୍ପ ଜନିଆରେ ବାକ୍ଷୀମାନଙ୍କୁ ଶିକ୍ଷା ଦିଆଯାଇଛି । ବାକ୍ଷୀମାନଙ୍କ, କୁଳନ ଓ ପଦକର ଦୁଇ ଅର୍ଥକର ଅନପୂର୍ଣ୍ଣାପୁର, ବୈରାକ, ନୁଆବା, କେତାଳ ଓ ଜନୁତକା ଗ୍ରାମଙ୍କେ ଏତି ପ୍ରକଳ୍ପ ବାଧ୍ୟକରା କରାଯାଇଛି । ଏଥିପାଇଁ ତାହାନି ଓ ଦର୍ମଶାଳନ ଅସ୍ତ୍ରୋକନ ବରାଯାଇଛି । ଏଥିରେ ପ୍ରାୟ ୧୦ ଘର, ଆଜିପତି ପରାକୁ ଉକ୍ତ ପରକଯୋଜନା, ଜଳ ଓ ପୁଷ୍ଟିକାର ପୁଣ ପରକଣ ଏକ ତଦନୁଯାୟୀ ପରକ ଓ ବାନ ପରିକାଳନା, ପରକ ଉପାଧିକରା ଦୁଇ ପାଇଁ ପରକ ଜଳ ପରିକାଳନା, ଯୋଗ ଓ ଗୋଡ଼ ନିବାଣଣ ଆଡ଼ି ପୁଷ୍ଟିକାର ପ୍ରକଳ୍ପର ବାକ୍ଷୀମାନଙ୍କୁ ଅନବିଚ୍ଚ କରାଯାଇଛି । କେବଳ ତିନୁଜା ଦୃଷ୍ଟିପୁଷ୍ଟ ଅଞ୍ଚଳରେ ଦୁଇ ବାକ୍ଷୀ ଅଭାବ ଏକ ତର ସମତ୍ୟା । ଏଥିପାଇଁ ଦୁଇ ଚକପାଟି, ବୈବନ, ଯାନ, ବାକ୍ଷୀମାନଙ୍କୁ ପୁଷ୍ଟ ଓ ଦୃଷ୍ଟିକା ଆଡ଼ି ଅସ୍ତ୍ରୋକନ କରାଯାଇଛି । ପଦକରନା ଓ ବୟୋଧିତ ବାକ୍ଷୀମାନ ଏହାକୁ ପୁଣ୍ୟ ଧାର୍ଯ୍ୟ କେତା ଏକ ନି ପାଇଁ କଡ଼ା ବ୍ୟବସ୍ଥା ନିଜେ କରୁଛା । ଏହା ଦେଖିଯାଣିରେ ପ୍ରକଳ୍ପର ବାଧ୍ୟକରାଦିତା ଧାର୍ଯ୍ୟାୟା କେତା ଯେ ଅନପୂର୍ଣ୍ଣାପୁର ଗ୍ରାମ ଅନ୍ୟମାନ ବାକ୍ଷୀ ଦେଖାଯାଇଛି । - ଟପକ୍ସ



କ୍ରମ ଓ ମରଜ କୁଶାୟା କମିର ଜପତିକାଣ୍ଡି ଦୁଇ ସହ ବାକ୍ଷୀର ଅମଳ କୁଡ଼ି କରାଯାଇପାରିବ । ଏ ସୁମାର ବ୍ୟବସ୍ଥା ଦ୍ୱାରା ବାକ୍ଷୀର ଆର୍ଥିକ ଜନତି ପରକ ଓ ପୁରାମ ଦୋଳପାରିଛି । ସ୍ତ୍ରୀମାନଙ୍କେ ଯୁକା ବିକାସ ପ୍ରାକ୍ଟିକ ଜରୁତୀୟାନର ଉଦ୍ଦତି କରାଯିବା ପାଇଁ ବ୍ୟବସ୍ଥା କୁଡ଼ି

ଅନପୂର୍ଣ୍ଣାପୁର ଗ୍ରାମର ବାକ୍ଷୀମାନଙ୍କୁ ଶିକ୍ଷା ଦିଆଯାଇଛି । ପ୍ରକଳ୍ପ ପଞ୍ଚକ୍ଷେତ୍ରିକ ପଦାମର୍ଶ ଦିଆଯାଇ ବାକ୍ଷୀମାନଙ୍କୁ ସ୍ୱାକ୍ଷରଣ କରାଯାଇପାରିଛି । ଦୃଷ୍ଟିପୁଷ୍ଟ ଜିପତି ଅଞ୍ଚଳରେ ବଡ଼ାଇତା ପାଇଁ ଜଳ, ମୃତ୍ତ୍ତିକା ଓ ପରକଳ

### SUCCESS STORY OF ARNAPURANAPUR VILLAGE

#### ଅନପୂର୍ଣ୍ଣାପୁର ଗ୍ରାମର ସଫଳ କାହାଣୀ

A National Agricultural Technology Project (NATP) has been initiated since last two years at Annapuranapur village of Kusumjodi Panchayat of Kamakhyanagar block, Dhenkanal District, Orissa under the supervision of Dr. H.N. Verma, Director, Water Technology Centre for Eastern Region (ICAR), Bhubaneswar and Dr. G. Kar, project leader and Scientist, WTCER.

Since the most of the agricultural land of our century are rainfed, the project aims at increasing productivity of those land for increasing higher productivity and more net return. Through proper water, soil and crop management two to three crops can be raised in a year even under rainfed areas which includes effective in-situ water utilization and runoff recycling. To improve the productivity of rainfed upland rice area, this year as per the recommended technology of WTCER, Bhubaneswar about 45 acres of rice upland of Annapuranapur village have been covered by rice substituted crops like maize, pigeonpea, groundnut, sesamum, horsegram cowpea etc, (through sole or intercropping). Double cropping on such land was also possible through maize-horsegram/sesamum rotation after early harvest of rainy season maize. Pigeonpea and groundnut were raised through intercropping. The production of rainfed upland rice area can also improved by adopting rice varieties of 90 days duration (eg.Vandana) and greengram, blackgram can be sown after early harvest of rainy season rice.

In an interview, Dr. H.N. Verma, Director, WTCER, informed that through scientific water harvesting on watershed basis, growing of two to three crops are possible in rainfed areas which were made known through the project to the farmers of Annapuranapur village. The farmers have been made self-dependent by adopting the technical guidance of project. Farmers have been educated regarding improved water, soil and crop management technologies to improve productivity of rainfed rice area.

Presently, five villages viz., Annapuranapur, Jiral, Nuagaon, Kingol, Janapada of Kamakhyanagar, Bhuban and Parjang block of Dhenkanal district have been covered by that project. Under that project training was also imparted to farmers on different aspects of rainfed farming like role of natural resources and local climate for crop planning, water and soil testing, fertilizer management, crop production technologies, integrated disease and pest management etc.

The Government should take sufficient measures to make the inputs available at proper time for better adoption of generated technology. The crop insurance, the minimum support price of crop and proper marketing facility are the real needs for getting sustainability of the objectives of the project.

(Translation of News 11)

### 11.7 Continuous up gradation of skill of the farmers

To increase the efficiency of rainfed farmers, continuous up gradation of their skill are required by imparting training etc. These will have dramatic impact in augmenting productivity and profitability of the small and marginal farmers and providing employment opportunity to the farming community, living in in-hospitable environment.

### 11.8 Infrastructure development for *Krusak Bazar*

Proper infrastructure should be developed for *Krusak Bazar* (Farmers' market), so that producers can directly sale their produce in the market by avoiding middlemen.

### 11.9 Custom hire services

Introduction of modern agricultural implements like tractor/power tiller, seed drill, seed – cum-fertiliser drill on co-operative basis/custom hiring are needed, which will ensure timely agricultural operation reducing drudgery of farmers.

### 11.10 Precision farming

Site and agro-climatic zone specific alternate sustainable land use and cropping system plan, proper technology packages and synchronus delivery of input, credit and technology will ultimately ensure precision farming in the vast rainfed upland rice area of eastern India.

## 12.. CONCLUSION

From the on-farm crop diversification research trials in rainfed upland rice area, it can be concluded that rice substitution with low water requiring crops like maize, blackgram, greengram, pigeonpea, groundnut, cowpea etc. were more profitable and sustainable. Among the crops/ crop combination studied, groundnut+pigeonpea was found the best followed by sole groundnut and sole pigeonpea for improving productivity and profitability of rainfed upland rice soils. For traditional rice farmers those who can not afford to leave rice even in rainfed upland, for them rice+pigeonpea was the best combination for ensuring higher and assured return than that of sole rice on such land. Double cropping in rainfed upland rice area was explored through maize-horsegram/seasamum rotation with higher and assured return. It is also revealed that productivity rice substituted crops did not differ much in rainfall deficit or excess year. In rainfall deficit years when productivity from rainfed upland rice field was nil or negative, good net economic return (Rs.10,000 - 20,000 ha<sup>-1</sup> per annum) was obtained from different rice substituted crops.

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#### 14. ACKNOWLEDGEMENT

Authors sincere thanks are due to Collector and DDA, Dhenkanal,, B.D.O., Kamakhya nagar, KVK, Dhenkanal, Central Rubber Board, Dhenkanal for their support to undertake the programme in Dhenkanal district and supplying required data for analysis and villagers of Arnapurapur, Dhenkanal for their active participation during study. We are also grateful to authorities of IMD, Pune and New Delhi Meterological Centre, Bhubaneswar and DDA Office, Dhenkanal for supplying rainfall data for analysis.

## A word of Appreciation....

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I am extremely happy to hear that Water Technology Centre for Eastern Region (I.C.A.R.), Bhubaneswar is going to publish a research bulletin 'Crop diversification technology in rainfed upland rice area of eastern India for increased productivity and rainwater use efficiency' based on the findings of on-farm trials conducted at Dhenkanal district. I had an opportunity to visit twice at the on-farm research and implementation site to attend the field days/farmers' fair, organized by the centre and found farmers were very much enthusiastic to adopt the technology. I found that rice substituted crops performed very well in rainfed upland rice field where productivity of rice was low, because of erratic monsoon. This crop diversification technology gave higher and assured early return even in drought affected years (2000 and 2002), therefore it will be useful for drought mitigation specially in context of Orissa where drought is the frequent feature. The farmers of this district (Dhenkanal) have already started to adopt the technology and fetching good economic return.

I appreciate the effort of Dr. Gouranga Kar, Project Leader and Dr. H.N. Verma, Director, W.T.C.E.R., Bhubaneswar for developing crop diversification technology through on-farm trials which has direct relevance of improving productivity, profitability and sustainability of rice upland of Eastern India.

I hope that the efforts of scientists of ICAR will help the farmers of Dhenkanal district to augment their income by growing non-paddy crops in a big way.

I wish them all success.

(NITYANANDA MOHANTY)