Technical Report

Salient
Findings
(NATP, RRPS-3)

DIVERSIFICATION IN RAINFED RICE AREAS FOR DROUGHT MITIGATION AND AUGMENTING RURAL INCOME

Gouranga Kar
R. Singh
H. N. Verma

Water Technology Centre for Eastern Region
(Indian Council of Agricultural Research)
Bhubaneswar- 751 023, India

WTCER

December, 2004

Diversification in rainfed rice areas for drought mitigation and augmenting rural income

Gouranga Kar
R. Singh
H.N. Verma

Water Technology Centre for Eastern Region
(Indian Council of Agricultural Research)
Chandrasekharpur, Bhubaneswar - 751 023, India

December, 2004

Correct Citation:

Kar G., Singh R. and Verma H. N., 2004. Diversification in rainfed rice areas for drought mitigation and augmenting rural income. Salient findings, NATP/RRPS-3. Water Technology Centre for Eastern Region, Bhubaneswar, 751023, Orissa, India

Published by:

Director, Water Technology Centre for Eastern Region,
Chandrasekharpur, Bhubaneswar
Pin : 751 023, Orissa

Principal Investigator of the project from WTCER centre:
Dr. Gouranga Kar, Scientist (s.s.), Agrometeorology

Printed by:

Sanjukta Creations
Rasulgarh, Ph : 9861014236, 9937386797

LIST OF CONTENTS

EXECUTIVE SUMMARY

The study was aimed at optimum utilization of the potentialities of existing natural resources (climate, soils, topography, hydrology) through agricultural diversification in **rainfed rice areas**. The recommended **crop diversification technology** (groundnut + pigeonpea, maize-horsegram/sesamum) has the potential to enhance productivity of **4.3 mha upland rainfed rice area of eastern India from average 0.75 t/ha rice yield** to about **7.5 t/ha rice equivalent yield** with average net return of atleast **Rs. 15,000/ ha/annum**. Besides, increased productivity and profitability, the technology has potential **to mitigate drought,** provide **regular employment,** supply **balance and quality food** and sustain **soil health.** The participatory on-farm trials revealed that with improved management and available genotypes, productivity of **rainfed lowland** *kharif* rice could be enhanced from existing **1.4 t/ha to 5.3 t/ha.** Feasibility of double cropping was explored in **rainfed lowland** rice fallow under different land situations with intensive cropping and efficient water use. Through adoption of second crops on such land, **cropping intensity of 12.9 mha rainfed rice area of eastern India can be raised to 200 %** with net return of atleast **20,000/ha/annum** from double crops. Water productivity and net return of available water resources were optimized using linear programming through agricultural diversification (fish, vegetable, field crops).

After disseminating the technologies by organizing farmers' fair, field days, training, etc., the study has become the **success story of the state of Orissa, which has been** widely covered by **print and electronic media**.

1. INTRODUCTION

Eastern India, the rice-dominated region of the country, accounts for about 63.3% (26.8 million hectare) of the India's total rice area (nearly 45.0 million hectare), out of which about **78.7% (21.1 mha) is rainfed**. Although annual rainfall over the region varies from 1000-2000 mm, the rainfed rice area is mainly mono-cropped (cropping intensity varies from 110-130%) with low productivity (0.8 t/ha in upland to 1.4 t/ha in lowland).

Out of the total rainfed rice area (21.1 million hectare) in eastern India, about **20.3 % (4.3 million-hectare) is under rainfed upland rice**, where productivity is very low (<1 t/ha) and unstable due to erratic rainfall, dry spells during growing season but farmers of the region grow rice traditionally on such land. The soils of upland rice areas are also light textured with low water holding capacity, acidic and severe nutrient deficiencies, which result in low and unstable rice yield. Weeds are also important biological constraints for rainfed upland rice cultivation followed by diseases and pests. **Crop diversification** with **low water requiring** but **high value crops** may be one of the options in the hands of farmers for **drought/dry spell** mitigation and to improve productivity of such rainfed ecosystem. Replacement of rice on such rainfed land is also socio-economically feasible because due to unstable productivity, farmers neither expect yield certainty nor depend for food security from such rice ecosystem. Growing of rice on such rainfed land after creating irrigation facilities is also not cost effective. Further, absence of ponded water in rainfed rice upland does broaden the scope of crop diversification.

On the other hand, **12.9 million-hectare (61.1% of total rainfed rice area of eastern India) area is under rainfed medium and lowland** which are heavier in texture with better moisture holding capacity, though able to support a good second crop with residual soil moisture, utilizing soil water upward flux (in land with shallow water table) or by providing supplementary irrigation from **harvested excess rainwater of rainy season**, are mainly mono-cropped. Rice is grown on such land only during rainy (*kharif*) season with very low productivity (1.4 to 1.9 t/ha). For food and livelihoods, farmers of the eastern India are heavily dependent on this rainfed rice ecosystem and therefore, on such land emphasis has to be given to improve productivity of rainfed rice during *kharif* for ensuring food security and to grow diversified crops in rainfed rice fallow with improved water and crop management to increase cropping intensity and profitability. Agricultural diversifications options (oilseeds, pulses, vegetables, fisheries, horticulture etc.) are to be explored in rainfed rice areas with available water resources in village pond or tank for optimizing productivity and profitability, which are presently under utilized.

Keeping the importance of above aspects in view to improve the productivity of **rainfed rice area of eastern India,** the present project was conceptualized with the following *broad objectives:*

- Appraisal of agro-climate, soils, water table, and socio-economic situation for crop diversification in **rainfed upland rice areas** to achieve higher and stable yield.

- Productive and profitable management of **rainfed medium and lowland rice areas** through intensive cropping and efficient water use.

Sub objectives of the project

- Appraisal of agro-climatic situations and diagnostic survey on soil, land and water table situations.
- To study socio-economic and management issues for non adoption of package and practices of double cropping.
- To find out suitable crops/varieties as pure and inter-crop for crop diversification during *kharif* and *rabi* seasons.
- To develop techniques for alternative seeding/planting methods for facilitating double cropping on the basis of available residual soil moisture under rainfed medium and lowland.
- To conserve residual soil moisture and improve water utilization efficiency of succeeding crops by modifying the soil microclimate.
- Harvesting and utilization of stored rainwater for introduction of high value crops in medium and lowland.
- To develop empirical relationship among the soil, plant and climatic factors and development of crop growth model under rainfed situations.

2. METHODOLOGY AND PLAN OF ACTION

The research work was conducted by Water Technology Center for Eastern India, Bhubaneswar through. Rainfed Rice Production System subproject 3 under National Agricultural Technology Project "Crop management strategies to increase cropping intensity in rainfed rice area" from **1999 to 2004** through on-farm trials at 5 villages (Arnapurnapur, Jiral, Kingol, Noagao and Parjang) of Dhenkanal district, Orissa. In **1999-2000** demand driven, participatory, on-farm research work in different rainfed rice ecologies were first started **at Arnapurnapur village (Kadalipal watershed), Dhenkanal, Orissa** after analyzing long term rainfall (variability, probability, wet/dry spells), soil physical and chemical properties, ground water table situation and socio-economic conditions of the study village. On the farmers' request **from 2000-01 onwards**, the on-farm trials were extended to another 4 villages (Jiral, Kingol, Noagao and Parjang) of that district. **The project impact was evaluated in 2003-04 and 2004-05** after collecting feedback from different categories of rainfed rice farmers (small, marginal, tribal, women, rich) of study villages.

Different approaches followed to fulfill the objectives of the project are given below.

2.1 Approaches to increase productivity of rainfed upland rice area were:

2.1.1 Complete rice substitution through crop diversification

Crop diversification with sole crops (pigeonpea, groundnut, blackgram), legume based intercrops (groundnut+pigeonpea/blackgram, rice based intercrops (rice+pigeonpea/ blackgram/greengram), double crops (maize-horsegram/sesamum). The productivity and water use efficiency of these were compared with that of sole rice (control).


Photo.1: Crop diversification trial in upland.

Photo.2:Groundnut+pigeonpea trial in upland

2.1.2 Partial substitution of rice with integrated weed management

Since weeds are one of the main biological constraints for successful rice cultivation in rainfed upland, partial substitution of rice with rice based intercropping trials (rice+pigeonpea/ blackgram/greengram) were tried with different weed managements (one manual weeding at 35 DAS/ two manual weeding at 20 & 45 DAS/early post application of Pendimethalin @ 1.0 *a,i.* Kg ha $^{-1}$ followed by a hand weeding at 30 DAS). Water use efficiency and productivity of rice based intercropping were compared under different weed management treatments.

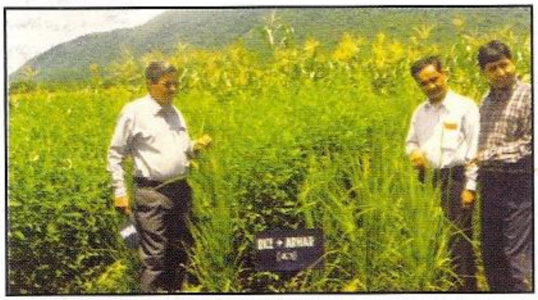


Photo.3: Rice+pigeonpea in upland with integrated weed management


Photo.4:Visit of peer-review team

2.1.3 Exploring possibility of double cropping in rainfed unland

To achieve successful double crops that too in rainfed upland, selection and sowing time of first crops are vital because slight in delay in sowing and harvesting may lead to drastic reduction of both the crops. In the study maize was sown first (with three cultivars viz., Vijoy, Novjyot and Deccan) with three dates starting from second week of June. Two pre-winter rainfed crops *viz.*, horsegram and sesamum were sown as second crops after harvesting maize.

The non-rice crops were grown following ridge and furrow methods for easy draining out of rainwater during heavy down pour. The same furrows were utilized for in-situ water harvesting during low rainfall periods.

Photo.5: First crop maize by substituting rice in upland

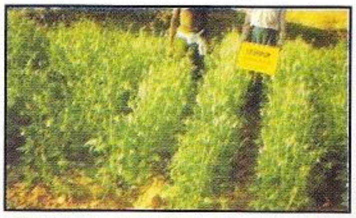


Photo.6: Growing of sesamum as second crop after maize

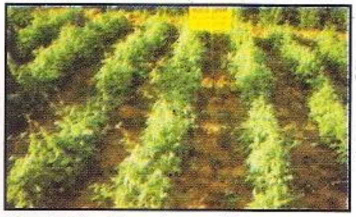


Photo.7: Growing of horsegram as second crop after maize

2.2 Approaches to increase overall productivity, profitability and cropping intensity of rainfed lowland rice ecosystem were:

2.2.1 Technologies for enhancing the productivity of rainfed lowland rice during *kharif* with integrated nutrient and other improved management practices.

In rainfed lowland, rice (cv. Gayatri of 145 days duration) was transplanted with 20 x10 cm spacing and nutrient in the ratio of 80:40:40 (N_2: P_2O_5: K_2O) was supplied through integrated nutrient sources [75 % NPK through inorganic fertilizer+25 % NPK through green manures (dhanicha)/press mud/ farm yard manures]. Pre-emergence herbicide application of Butachlor @ 1.5 kg *a.i.* /ha was applied in transplanted rice field at 3-5 days after transplanting (DAT) followed by a hand weeding at 45 DAT. Rice was also grown with farmer's practice as control. During *winter/rabi* season three pulses *viz.*, pea, blackgram and greengram were taken in that rice fallow on residual soil fertility and soil moisture.

Photo.8: Rice grown with green manures, dhaincha

Photo.9: Rice grown with press mud

Photo.10: Rice grown with farmyard manure

Photo.11: Rice with inorganic fertilizer only.

2.2.2 Growing of second crops in rainfed lowland rice fallow utilizing soil water upward flux, through soil surface modifications and with better seeding/tilling practices.

- **Utilization of soil water upward flux for growing second crops in rainfed rice fallow (with shallow water table).**

  After harvesting of *kharif* rice (cv.Lalat of 120 days duration), four crops *viz*., groundnut, blackgram, greengram and chickpea were grown on 3rd week of November in rainfed lowland rice fallow with shallow groundwater table (0.58-1.05 m) utilizing residual soil moisture and soil water upward flux. One supplementary irrigation was given at pod formation stage of these crops to visualize the yield enhancement as compared no irrigation.

Photo.12: Measurement of soil upland flux under shallow water tables situation.

Photo.13: Growing of blackgram in rainfed lowland with shallow water table.

- **Utilization of residual soil moisture through relay cropping and other seeding/tilling methods.**

  To utilize the residual soil moisture for growing second crops in rainfed lowland rice fallow, four pulses *viz*., lathyrus, blackgram, pea and chickpea were grown with relay/utera cropping and productivity with this seeding practice was compared with that of some alternative seeding/tilling practices (one ploughing and seeding on same day/two ploughing in different days and seeding after second ploughing/conventional tillage/zero tillage). Under relay cropping soaked seeds of different crops were broadcasted 10-15 days before harvest of rice in muddy or well moistened

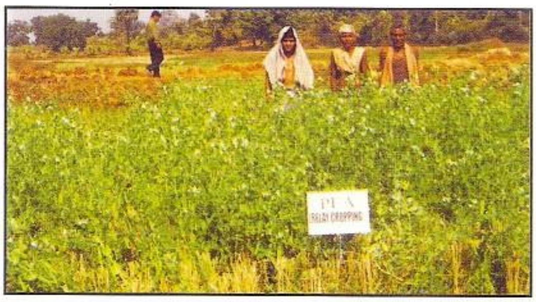


Photo.14: Field Pea crop with relay cropping

Photo.15: Blackgram with minimum tillage

soils. The high yielding rice (cv. Gayatri of 145 days duration) was grown during *kharif* as first crop with improved management practices.

Photo.16: Blackgram with the two ploughing

Photo.17: Blackgram under relay cropping

- **Enhancing water-use-efficiency through soil surface modifications**

  Five winter crops *viz*., blackgram, gram (chickpea), pea, lathyrus and safflower were grown during 3rd week of November in rainfed rice fallow after harvesting *kharif* rice (cv. swarna of 125 days duration). To reduce evapo/transpiration loss, straw mulching @ 6 t ha^{-1} and soil & stubble mulching were applied to all crops at 12 days after sowing; the water use efficiency was compared between mulched and non-mulched plots.

Photo.18 & 19: Pulses with mulching.

2.2.3 Growing of second crops in rainfed lowland rice fallow by providing supplementary irrigation and optimization of productivity of harvested rainwater through agricultural diversification.

- From 1999-2000 to 2003-04 on-farm trials were conducted on diversified crops like vegetables, (potato), cereals (wheat, maize), oilseeds (sunflower, safflower, linseed, mustard, groundnut) and pulses (pea, blackgram, greengram, lathyrus, chickpea) in lowland rice fallow by providing supplementary irrigation at critical growth stages from **harvested rainwater of existing pond**. Among these crops, sunflower, potato, wheat, maize and groundnut were grown with two, three and four irrigation. Linseed, safflower, chickpea, pea, mustard were grown with one, two and three irrigations. In each irrigation, 60 mm of water was applied. High yielding rice (cv.Lalat) was grown during *kharif* as first crop with improved management practices.

Photo.20: Harvested rainwater in village pond

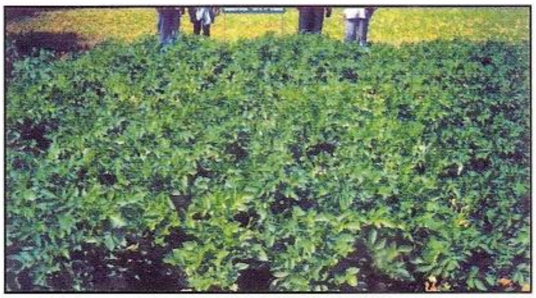


Photo.21: Potato with four irrigation

Photo.22: Sunflower with two irrigation

Photo.23: Sunflower with four irrigation

As a case study, an existing pond of 9120 m^3 area was selected for optimization of its productivity and net return using linear programming through pisciculture, and by growing cereal (winter maize, X1), oilseed (sunflower, X2), vegetables (water melon, X3 ; cucumber, X4) and pulses (Pea, X5). After studying water balance of the pond, area allocation under each of these crops was made within two hectare of area. The rest water was used for fisheries and domestic purpose. The objective functions for optimization of water productivity of the pond through agricultural diversification (profitable field crops and vegetables) are given by,

$$z = \sum_{i-1} c_i x_i$$

where, c_i = Net return ha^{-1} (Rs.) of i^{th} crop and x_i = Area (ha) covered by i^{th} crop.

Subject to constraints:

(1) Area constraint: $\sum_{i=1} x_i \le 2$

x_i = Area (ha) covered by the i^{th} crop

(2) Water constraint: $\sum_{i=1} w_i x_i \le w_d$

where, w_d = Water available, w_d = Water requirement ha^{-1} by the i^{th} crop and x_i = Area (ha) covered by the i^{th} crop

(3) Nutrient constraint: $\sum_{i=1} n_i x_i \le n_d$

where, n_d = Nutrient content of rice, n_d = nutrient content by the i^{th} crop and x_i = Area (ha) covered by the i^{th} crop

(4) Labour constraint: $\sum_{i=1}^{5} l_i x_i \le l_d$

where, l_d = labour requirement ha^{-1} of rice, l_d = labour requirement ha^{-1} by the ith crop and x_i = Area (ha) covered by the ith crop.

(5) Production constraint: $\sum_{i=1}^{5} y_i x_i \le P$

where, P = production of rice, y_i = productivity of the ith crop and x_i = Area (ha) covered by the ith crop

(6) Non-negative constraint:

$x_i \ge 0$, i = 1,2,..,5.

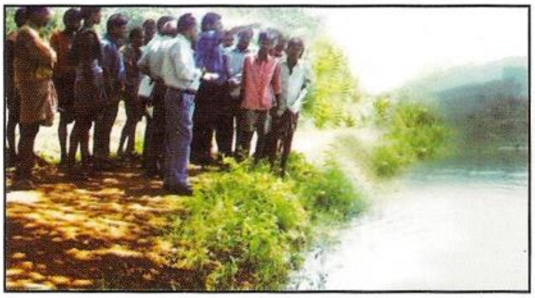


Photo.24: Visit of project review team to water harvesting site pond in the study village

Photo.25: Growing of maize with two irrigation from harvested rainwater of pond

Photo.26: Growing of Cucumber from harvested rainwater after rainfed rice

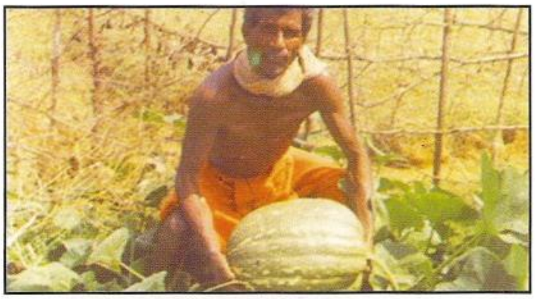


Photo.27: Bumper pumpkin crop utilizing harvested rainwater after rainfed rice

Photo.28: Water melon from harvested rainwater after rainfed rice

Photo.29: Ginger in shaded area of pond bund

Photo.30 : Farmers are catching fish at early stage from the water harvesting pond at Arnapurnapur village, Dhenkanal

Photo.31 : Harvested fish from the water harvesting pond of Arnapurnapur

In addition to the generation of demand driven rainfed farming technologies, innovative extension approaches were adopted to transfer the technology through organizing field days, farmers' fair, training, scientists-farmers' interaction at the trial sites itself by involving farmers, district administrations, state governments' line departments, NGOs, local ICAR institutes and agricultural universities. After effective dissemination of knowledge, training and circulating technology package leaflet in local language (Oriya), the study has become the success story of the state of Orissa, which was highlighted by different national and regional newspaper. A training manual entitled "Agricultural diversification options for drought mitigation in rainfed rice area" was prepared in English and local language (Oriya) to impart training to broad target groups.

3. SIGNIFICANT FINDINGS OF ON-FARM RESEARCH OFTHE PROJECT

Significant findings of different on-farm research to improve overall productivity, profitability, cropping intensity and sustainability of rainfed rice areas of eastern India are given point wise below.

3.1 Significant findings of agro-climate, soils, water table and socio-economic analysis of the study area for crop diversification in rainfed upland rice area

- The mean date of onset of effective monsoon was found to be 15th June and southwest monsoon generally ended on 27th September. The initial probability of receiving 20 mm or more rainfall first exceeded most dependable limit (70% probability) in the 24th standard meteorological week, when final land preparation and sowing of upland crops can be performed. Study revealed that at 75 % probability level, 181 mm rainfall occurred during June, which is enough for sowing of direct seeded, low water requiring non rice crops (maize, pigeonpea, groundnut, blackgram etc.) in the 24th standard week (11-17th June) with the commencement of southwest monsoon in the region. Maximum amount of rainfall occurred during July. i.e. 163 and 237 mm at 90 and 75% probability, respectively. This higher amount of rainfall at 75 % probability level could be utilized for rice transplanting starting from first fortnight of July in medium and low land rainfed rice ecosystem after completion of sowing of diversified crops in upland rice area in the month of June itself.
- The soils are light textured with available water capacity of the soils varied from 0.110 to 0.149 $cm^3\ cm^{-3}$ at different depths and saturated hydraulic conductivity (K_s) of soil ranged between 0.68 and 1.19 $cm\ h^{-1}$. The fertility status was also very low (organic carbon of the soils varies from 0.52 (0-0.15 m depth) to 0.23% (0.90-1.20 m depth).
- Water table depth of upland was deeper (4.8 m to 7.8 m).
- Traditional rice growers, lack of knowledge about improved cropping systems, non availability of inputs and varieties at proper time, dominance of marginal and small farmers, lack of resources and low literacy levels, lake of proper

production and protection technology, distress sale of rice at non-remunerative prices are some of the socio-economic constraints for low productivity and profitability from rainfed rice areas.

3.2 Significant findings of on-farm research to improve productivity of rainfed upland rice area

3.2.1 Achieved higher and stable productivity and net return through complete rice substitution in rainfed rice upland by mitigating drought.

- In deficit rainfall years (2000 and 2002) when rice yield from rainfed upland area was adversely affected, much higher rice equivalent yield per annum was obtained through crop diversification with maize cob (6500-8125 kg ha^{-1}) followed by groundnut+pigeonpea (5268-5550 kg ha^{-1}), sole groundnut (5480-5640 kg ha^{-1}), sole pigeonpea (5268-5550 kg ha^{-1}). There was no significant reduction in yield of non-rice crops between deficit (2000, 2002) and excess rainfall years (2001, 2003). Whereas, average yield of rice was 1010-1215 kg ha^{-1} in rainfall deficit years (2000 and 2002) to 2850 kg ha^{-1} in normal rainfall years (2001 and 2003).
- Much higher net economic return was obtained from maize cob (Rs. 19,500 to Rs. 26,000 ha^{-1}), followed by groundnut+pigeonpea (Rs. 20,124 to Rs. 21,592ha^{-1}), sole groundnut (Rs. 15,420 to Rs. 18,960 ha^{-1}), sole pigeonpea (Rs. 13,325 to Rs. 16,200 ha^{-1}), sole blackgram (Rs. 9,648 to 11,650 ha^{-1}) than that of sole rice (nil to Rs. 5400 ha^{-1}) in different years of study.

Photo.32 : Crop diversification in rainfed upland

Photo.33 : Comparison of productivity of maize and rice in rainfed upland

3.2.2 Enhanced water use efficiency (WUE) and productivity were achieved through partial substitution of rice with integrated weed management

- The enhancement of rice equivalent yield of 16-20 %, 17-28% and 13-20% was observed with rice+pigeonpea, rice+blackgam, rice+groundnut, respectively (based on 2000 and 2001 data), with integrated weed management (chemical weeding with 1.0 kg *a.i.* Pendimethaline + manual weeding at 30 DAS) than that of farmers' practice (only one manual weeding at 30 DAS). Rainwater use efficiency was higher with different rice based intercropping (3.17 to 4.75 kg ha^{-1} mm^{-1}) than sole rice (2.2 to 2.53 kg ha^{-1} mm^{-1}) with combined weed control treatment.

- Results of a deficit (2000) and an excess (2001) year revealed that sole rice yield was badly affected in light textured upland due to occurrence of dry spells in 2000. However, intercropping of pigeonpea, blackgram and groundnut with rice gave rice equivalent yield of 4119,, 2890 and 2970 kg ha^{-1} with net returns of Rs. 10470 ha^{-1}, Rs. 5560 ha^{-1}, and Rs. 5880 ha^{-1}, respectively when combination of chemical and manual weed control methods were adopted.


Photo.34 : Rice+pigeonpea intercropping trial in rainfed upland


Photo.35 : Visit of Dr. H.P. Singh (Former-director, CRIDA) and district collector, Mr. N. Mohanty to rice based intercropping site.

3.2.3 Possibility of double cropping was explored in rainfed upland rice areas

Based on rainfall probability and effective monsoon analysis, early sowing date (24th standard week, 11-17th June) of non-rice crop (maize) was predicted on rainfed upland, which facilitated to grow a second crop (maize-horsegram/sesamum) with residual soil moisture and subsequent rainfall on the same land. Maize cob was found more remunerative than grain with upto net return of Rs. 34000 to Rs. 38400 per hectare (with variety Vijoy) when sowing was done in 24th standard week. From second crop, net economic return of Rs. 3080 to 4200 ha^{-1} was obtained in line-sown horsegram and Rs. 1800 to 5840 ha^{-1} in line sown sesamum in rainfed upland with residual moisture and subsequent pre-winter rainfall when these crops were sown on second week of September.

3.2.4 Obtained fastest return per unit area per unit time from rainfed upland

Rice substituted crops mainly from maize cob fastest return per unit area per unit time was obtained that too in lean period (August-September), when farmers face financial crisis. The average net return (pooled data of 1999-2003) from maize cob was Rs.23391 per ha in 70 days ie. Rs. 314/ha/day net return was achieved. Whreas, sole rice returned only Rs. 52.3/ha/day. The per day per ha net return was Rs. 120, Rs. 100, Rs. 150 and Rs. 277 from groundnut, blackgram, greengram, pigeonpea and fish, respectively in normal rainfall year.

3.2.5 Enhanced rainwater use efficiency was achieved with diversified crops in upland

Highest rain water use efficiency [RWUE (in terms of rice equivalent yield), kg $ha^{-1}mm^{-1}$)] was obtained from maize cob with the values being 13.4, 6.9 and 10.9 kg ha^{-1} mm^{-1} in

2000 (rain deficit year), 2001 (rain excess year) and 2002 (rain deficit year), respectively. Higher RWUE was also obtained from groundnut+pigeonpea (4.8 to 7.9 kg ha^{-1} mm^{-1}), groundnut+blackgram (4.4 to 6.4 kg ha^{-1} mm^{-1}), sole pigeonpea (3.4 to 5.9 kg ha^{-1} mm^{-1}), sole groundnut (5.3 to 7.0 kg ha^{-1} mm^{-1}) than that of sole rice (1.6 to 2.6 kg ha^{-1} mm^{-1}) in different years of study.

3.2.6 Introduction of maize-horsegram rotation and other low water requiring legumes in rice fallow sustained soil fertility.

By the early harvest of rice or non-rice crop, short duration low water requiring crops like cowpea, horsegram, blackgram were grown in upland. Mineral nitrogen accumulation (NH_4 and NO_3-N) of 25-34 kg/ha was recorded from different crops and land ecologies. The N concentration in dry matter of those pulses varied from 2.1 to 2.4%.

3.2.7 Inclusion of legumes in the cropping system improved soil physical conditions

Crop diversification with legumes in *kharif* in rainfed upland rice area improved physical conditions of soils. The soil porosity was enhanced from 30.7% in 1999 to 38.5% in 2004 after substituting rice with legumes (sole/intercrops). The hydraulic conductivity and available water capacity were enhanced by 26 and 23 %, respectively in 2004 after replacing rice in rainfed upland with legumes.

3.3 Significant findings of on-farm research to improve productivity and profitability of rainfed lowland rice area

3.3.1 Enhancement of rice yield during kharif in rainfed lowland with improved practices

Grain yields of rice could be significantly influenced due to application of fertilizer (NPK) in conjunction with different sources of organic matter (FYM, press mud or green manures) applied to rice. From pooled data of three study years, it is revealed that the highest yield (5,380 kg ha^{-1}) of rice (cv.Gayatri) was obtained when 25 % NPK fertilizer was supplied through green manures (*Dhaincha*). The second highest yield was obtained (5,250 kg ha^{-1}) with 75 % NPK through inorganic fertilizer +25 % NPK through press mud. Whereas, under farmers' management practice only 2990 kg ha^{-1} rice grain yield was obtained.

After harvesting of rice on residual soil fertility and soil moisture, three pulses (pea, blackgram, and greengram) were sown consecutively for three years during rabi/dry season (winter) on the same land. This was done to visualize the effect of NPK fertilizer and organic matter management of rice to the succeeding crops. All the three crops achieved highest yield (490, 463, 438 kg ha^{-1}), when they were raised in the plot, where 75 % of the recommended doses of NPK along with 25 % through green manures (*Dhanicha*) were applied to rice. The highest net return (Rs.21,380 ha^{-1}) was obtained from rice-pea in that treatment. Under farmer's management, only Rs.8,764 ha^{-1}net profit was obtained in that cropping system.

3.3.2 Efficient management of residual soil moisture and soil water upward flux for growing second crops in rainfed rice fallow.

- **Double cropping in rainfed lowland with shallow water table (0.58-1.05 m) utilizing soil upward flux**

In rainfed lowlands with shallow water table (0.58-1.05 m) soil water upward flux contributed 37.1-58.1 %, 36.9-55.6 %, 34.4-52.7 % and 38.1-51.9 % of actual water use in groundnut, blackgrm, greengram and chickpea, respectively in different irrigation treatments. Owing to higher soil upward flux, reasonable yield was obtained even under rainfed conditions with the mean values being 940, 716, 720 and 510 kg ha^{-1} in groundnut, blackgram, greengram, chickpea, respectively. Study also revealed that 57.4 %, 51.6%, 38.1% and 42.0% yield was enhanced in four respective crops when one irrigation was applied at pod formation stage as compared to no irrigation. Through double cropping with one irrigation to second crops Rs. 29445 ha^{-1}, Rs. 25320 ha^{-1}, Rs. 23055 ha^{-1} and Rs. 20405 ha^{-1} net return per annum was obtained from rice-groundnut, rice-blackgram, rice-greengram and rice-chickpea, respectively. (crops of both *kharif* and *rabi* seasons were grown with improved practices).

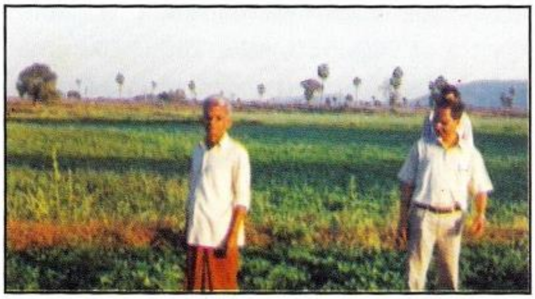


Photo.36 : Visit of former Director, WTCER (Dr. H.N.Verma) to experimental field with shallow water table

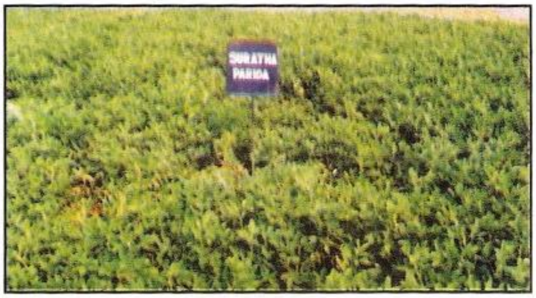


Photo.37 : Bumper crop of groundnut after kharif rice utilizing soil upward flux

- ***Utilization of residual soil moisture for growing second crops in rainfed lowland rice fallow through relay/utera cropping and other alternative seeding/tilling practices***

In well moistened soil with relay cropping in rainfed lowland rice fallow 303, 329, 305 and 323 kg ha^{-1} yield was obtained in lathyrus, blackgram, pea and chickpea, respectively. One ploughing at proper tilth after harvesting rice followed by another ploughing at 5 days later and seeding with proper spacing and depth enhanced yield by 68.5%, 106.6%, 67.5% and 122.7% in lathyrus, blackgram, pea and chickpea, respectively over traditional relay cropping. Economic analysis of alternative seeding/tilling practices revealed that net income per hectare from second crops was increased from Rs. 500, Rs. 1206, Rs. 1800, Rs. 300 to Rs.

1900, Rs. 5300, Rs. 6050, Rs. 3350 in lathyrus, blackgram, pea and chickpea, respectively than that of relay cropping.


Photo.38 : Blackgram with relay cropping


Photo.39 : A farmer carrying maize cob grown with harvested rainwater

- ***In-situ soil moisture conservation through soil surface modifications***

  By modifying soil surface with straw mulch (@ 6 t ha^{-1}) mean grain yield of 835, 1060, 725, 1060 and 1080 kg ha^{-1} was obtained from gram (chickpea), blackgram, lathyrus, pea and safflower, respectively. (From analysis two years' pooled data). Due to application of straw mulch the yield enhancement of 46.1%, 42.9 %, 40.6 %, 50 % and 47 % was observed in respective five crops over non-mulched plots. With soil and stubble mulching, mean grain yield of 580, 680, 480, 730, 710 kg ha^{-1} yield was obtained in gram (chickpea), blackgram, lathyrus, pea and safflower, respectively. With straw mulching 51.7 to 61.5 %, 53.8 to 62.7 %, 61.5 to 61.8 %, 53.1 to 56.3 % and 58.4 to 58.7 % water use efficiency was enhanced in respective five crops than that of non mulch plots.

3.3.3 Supplementary irrigation at critical growth stages and enhancing productivity of harvested rainwater through agriculture diversification

- With four irrigation to second crops in rice fallow Rs. 33565, Rs. 47940, Rs. 28800, Rs. 30650 and 17660, 27340 per hectare net return was obtained from rice-maize (grain), rice-maize (cob), rice-groundnut, rice-sunflower, rice-wheat, rice-potato, respectively. With three irrigation Rs. 17765, Rs. 30155, 19690, Rs. 25135, Rs. 22885 net return was obtained from rice-linseed, rice-safflower, rice-chickpea, rice-pea and rice-mustard, respectively. The first crop rice was grown with improved practices.

- The water balance study of the existing pond of 9120 m^3 revealed that in 2002 total 14601 m^3 runoff was received, out of which 5181 m^3 (35.1%) and 2248 m^3 (15.3%) were lost as seepage and evaporation, respectively. For irrigating to *rabi* crops 3460 m^3 was utilized and rest 3712 m^3 was utilized for pisciculture and domestic purpose. In 2003, total 15878 m^3 runoff was received, out of which 5718 m^3 (36.1%) and 2718 m^3 (17.1%) was lost as seepage and evaporation, respectively. For

Photo.39(a) : Fish grows 500-700 gm in 8 months

irrigating *rabi* crops 3688 m^3 of water was utilized and rest 3753 m^3 was kept for rearing fish and domestic purpose. Based on profitability, area allocation was optimized and in 2003 net return of Rs. 10,000, Rs. 3422, Rs. 15400, Rs, 9500 and Rs. 1000 were obtained from maize cob (0.5 ha), sunflower (0.2 ha), cucumber (0.7 ha), tomato (0.5 ha) and pea (0.1 ha), respectively. From left out water (3712 m^3), Rs. 20460 was received through pisciculture. Through optimization of land use and water productivity net return of Rs.59782/- was obtained from field crops, vegetables and fishes from a pond of 9120 m^3. Based on the study agricultural diversification options and package for enhancing water productivity were suggested.

4. TECHNOLOGY DISSEMINATION

The technology will be not be effective if it is not properly disseminated to target groups. Hitherto the rate of adoption of technologies, developed at research farm for improving productivity of rainfed area was poor. Either farmers were unaware of the new technology due to lack of proper extension activities or they are averse to the change because they cannot afford the high input required by the new technology. The new technology has been developed for maximum productivity rather than for 'maximum profit'. To overcome these problems the viable technologies were disseminated by organizing farmers' fair, field day, workshop, training, awareness programme etc. in the experimental sites itself by involving farming community, NGOs, district administration, state agricultural officials, scientists of ICAR, state agricultural university, press and electronic media. Different technology dissemination programm organized are described:

- On 5.9.2000 we organized a field day where 750 progressive farmers of different villages and 50 scientists from ICAR Institutes, state agriculture universities and representatives from print, electronic media were present. On that day we invited Mrs. R. Chopra, District Collector, Dhenkanal, Mr. G. Rout, Deputy Director of Agriculture, Dhenakanl to evaluate the experience of farmers. District Collector presided over farmers' meeting and released three extension bulletins on improved rainfed farming in local laguage (Oriya) on the occasion of field day (Photo 40-42).
- To demonstrate crop diversification research trials, we organized again a 'field day' on 25.8.2001, which was attended by approx. 500 progressive farmers and state agricultural officers of the district. On that day we invited Dr. H.P. Singh, Former director, CRIDA, Dr. U. K. Mishra, Director of Agriculture, Govt. of Orissa,

Photo.40: Mrs. R. Chopra, Collector (then), Dhenkanal releasing extension bulleting on rainfed farming on 05.09.2000

Photo.41: Large number of farmers' gathered in farmers fair on 05.09.2000

Photo.42: Visit of District Collector (then) Mrs. R. Chopra to crop diversification site on 05.09.2000

Mohanty, Collector, Dhenkanal, Dr. B.N. Singh, former-Director, CRRI, Mr. G. Paul, Deputy Director of Agriculture, Dhenkanal to visit the field and they interacted with the farmers regarding viability and sustainability of technology (Photo 43-46).

Photo.43: Organizing farmers' fair on 25.08.2001, Dr. H.P. Singh, former-Director, CRIDA the chief guest

Photo.44: Dr. U.K. Mishra, Director of Agriculture, Govt. of Orissa (then) addressing farmers in the farmers' fair organized in the project village

Photo.45: Dr. H.P. Singh, former Director, CRIDA, delivering lectures on improved rainfed farming technologies

Photo.46:Mr. N.Mohanty, Collector, Dhenkanal addressing a farmers' fair, organized under the project

- After two years of trials, technology was fine tuned by organizing a brain storming session at the center on "Increasing cropping intensity in rainfed rice area of eastern India" from 13-15th June, 2001 to improve productivity and cropping intensity in rainfed rice area where resource persons from local ICAR institutes, state agricultural university and associated scientists of the project from IGKV, Raipur, JNKV, Rewa, BAU, Ranchi, OUAT, Bhubaneswar were attended (Photo 47).


Photo.47: Brain Storming session organized at the centre on 13th-15th June, 2001

- On 18th and 19th April, 2002 the center organized a district level training programme at Dhenkanal, Orissa under the project where 250 progressive farmers and state government officials were trained on improved rainfed farming technology (Photo 48-49). In that training in addition to resource persons from Orissa, Dr. H.K. Pandey, former-Director, CRRI, experts from others states like Prof. M.S. Gill from Punjab Agriculture University, Prof. B.K. Mondal, of Bidhan Chandra Krishi Viswavidyalaya, West Bengal, shared their experiences with the farmers. As a result of effective dissemination of viable technology of crop diversification and drought mitigation, farmers of neighbouring villages of project site started to adopt these from 2002, which were witnessed by NATP world Bank team, peer review team, project evaluation and monitoring team, Directors of WTCER and other local ICAR institutes, chairman, Research Advisory Committee and members, SAP, Dr. I.C. Mahapatra.


Photo.48: Organizing training programme on 18-19th April, 2002 to disseminate crop diversification technology


Photo.49: Large number of progressive farmers and agriculture officers attended the training at Dhenkanal

- For the benefit of farming community of state on their request, we organized a training programme again on 19.3.2004 at Dhenkanal, which was attended by 300 progressive farmers of the state. In the inaugural session of the training, Dr. I. C. Mahapatra, former-Vice Chancellor, OUAT, recommended some strategies for successful adoption of technology. On that occasion Mr. N. Mohanty, Collector, Dhenkanal, Mr. K. Naik, Deputy Director of Agriculture were present as special invitee (Photo 50-51).

Photo.50: Dr. I.C. Mahapatra, Chief guest on the occasion of farmers' training on 19.03.2004

Photo.51: Large number of farmers and state agricultural officers attended training on 19.03.04

- **We again organized a training programme under the project on "Agricultural diversification options for drought mitigation in eastern India" on 11-12 October, 2004 where 100 farmers, NGOs were trained. On that occassion we prepared a Training Manual on " Agricultural diversification options for drought mitigation in rainfed rice area" in English and Oriya to impart training to state agricultural officials, NGOs as well as farmers of the state (Photo**

Photo.52: Large number of farmers and NGOs attended the training on agricultural diversificaiton options for drought mitigaiton on 11-12th October, 2004

Photo.53: Organizing farmers' training on 11-12th October, 2004 (Dr. I.C. Mahapatra, Chief guest on the occassion)

Photo.54: Project evaluation team under the chairman of Dr. I.C. Mahapatra interacting with farmers

Photo.55: Visit of project evaluation team in the study village

5. TECHNOLOGICAL IMPACT

The recommendations to improve productivity, profitability and cropping intensity of **rainfed rice area** have been accepted by wider categories of farming community (small, marginal, rich, tribal, women), state agricultural officials and NGOs owing to their ability to enhance production, profitability and sustainability as can be assessed from the Director's reports of success story & survey, media reports, feedback reports from farmers etc. As a result of wider adoption, following socio-economic and technological impacts have been observed in the study villages (Arnapurnapur, Naogao, Jiral, Parjang, Kingol of Dhenkanal district, Orissa).

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

The enhanced and stable productivity and profitability through crop diversification has changed the outlook to all section of farmers (large, marginal, small, tribal, women) to shift from traditional cropping system (rice-fallow) to sustainable productive cropping system viz., groundnut+pigeonpea, maize-horsegram/sesamum, sole groundnut, sole blackgram (Table-1).

Table-1: Increased trend of adoption of rainfed crop diversification technology in rainfed upland rice area (Surveyed in *kharif* 2003 and 2004)

	kharif 2003 (Normal rainfall year)							
Villages	**Small and marginal farmers**				**Rich farmers**			
	Total farmers	**No. of farmers adopted**	**Adoption (%)**	**Area (ha)**	**Total no. of farmers**	**No. of farmers adopted**	**Adoption (%)**	**Area (ha)**
Arnapurnapur	30	28	93.3	20	10	10	100	12
Jiral	50	45	90	50	122	65	53.2	105
Parjang	40	15	37.5	25	45	22	48.8	10
Naogao	37	5	13.5	15	40	15	37.5	19
Kingol	45	13	28.8	40	72	20	27.7	8
	kharif 2004 (Deficit rainfall year)							
Arnapurnapur	30	30	100	25	10	10	100	19
Jiral	50	45	90	55	122	105	86.1	175
Parjang	40	21	52.5	40	45	25	55.5	15
Naogao	37	13	35.1	22	40	15	37.5	25
Kingol	45	19	42.2	45	72	37	51.3	16

(b) Introduction of second crops (after rice or non-rice crops) with residual soil moisture and limited irrigation from harvested rainwater increased cropping intensity.

After our interventions farmers are growing double/triple crops in different rainfed rice ecologies. The cropping intensity of different study villages (whole village was surveyed)

Photo.56: Adoption of maize in large area by substituting upland rice at Arnapurnapur, Dhenkanal

Photo.57: Adoption of groundnut+pigeonpea in large area at Jiral, Dhenkanal

Photo.58: Visit of experts and farmers in rice+pigeonpea adopted site

Photo.59: Adoption of sole groundnut in large area at Kamakhyanagar block, Dhenkanal

52-53).

has been increased from 108 %, 115%, 110%, 110 % and 117% to 177 %, 171 %, 136 %, 167%, 142% in Arnapurnapur, Noagao, Kingol, Jiral, Parjang, respectably of Dhenkanal district, Orissa at the terminal year of the project, 2003-04.

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

Through adoption of crop diversification and improved rainwater management technologies, the productivity and net economic return in rainfed rice area were

Photo.60: Visit of lead P.I, Dr. R. S. Tripathi adoption and Director, WTCER, H. N. Verma to site with shallow water table

Photo.61: Adoption of relay cropping with field pea

Photo.62: Director WTCER, Dr. H.N. Verma interacting with a farmer regarding sustainability of the rice based cropping system

Photo.63: Uniform germination of groundnut with residual soil moisture

Photo.64: Experts are encouraging farmers for adoption of viable rainfed farming technologies

Photo.65: Happy women farmers' of the study village, (Arnapurnapur) who are generating more income and getting more employment now.

(d) Reduction of household property sale for food security in drought years

Due to yield and income stabilization, the property sale (land, livestock and other assets) at household level in drought years has been reduced (Table-3). Non farm activities were also reduced because of farm works.

(e) 'More crop per drop' was achieved in rainfed rice area

More crop per drop' i.e. higher rainwater use efficiency was observed with non-rice crops as compared with that of sole rice. Study found that water use efficiency (in terms of rice equivalent yield) was mulch higher with maize cob, groundnut+pigeonpea, groundnut+blackgram, sole groundnut, sole pigeonpea with the values being 7.1, 5.3, 5.1, 6.8, 4.1 kg ha^{-1} mm^{-1}, respectively, while the water use efficiency of sole rice was only '2.5 kg ha^{-1} mm^{-1}.

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

Rice substituted crops mainly from maize cob fastest return per unit area per unit time was obtained that too in lean period (August-September), when farmers face financial crisis (Table-4). The average net return from maize cob was Rs. 23391 per ha in 70 days ie. Rs. 314/ha/per day net return was achieved. After harvesting of cob,

Table-2. Increased and stable productivity through crop diversification rainfed rice upland.

	Before adoption					After adoption				
		Drought Year		Normal Year			Drought Year (2004)		Normal Year (2003)	
Village	**Crops**	**Productivity (kg ha^{-1})**	**Net return (Rs ha^{-1})**	**Productivity (kg ha^{-1})**	**Net return (Rs ha^{-1})**	**Crops**	**Productivity (kg ha^{-1})**	**Net return (Rs ha^{-1})**	**Productivity (kg ha^{-1})**	**Net return (Rs ha^{-1})**
Arnapurnapur	Only rice	1014	Nil	2050	170	Gnut	4550	11700	5050	13700
						G.nut+PP	5980	17420	6380	19020
						BG	3720	8380	4200	10300
						M(c)+HG	7568	23772	7620	23980
						Rice+PP	2880	5020	3857	8928
Jiral	Rice	1200	Nil	2250	2500	Gnut	4890	13060	5456	15324
						Gnut+PP	5460	15340	6245	18480
						M(c)+HG	6540	19660	6897	21088
Parjang	Rice	1020	Nil	2005	1520	Gnut	4889	13056	5370	14980
						Gnut+PP	5238	14452	5890	17060
						M(c)+HG	6670	20180	6875	21000
Naogao	Rice	1420	Nil	2550	370	M(c)+HG	6780	20620	6590	19860
						Gnut+PP	5459	15336	5985	17440
Kingol	Rice	1120	Nil	2380	3020	M(c)+HG	5870	16980	6250	18500
						Gnut+PP	5255	14520	5556	15724

**Gnut= Groundnut, PP= pigeon pea, M (c)= Maize (cob), HG= Horse gram, BG= Black gram, GG= green Gram*

The productivity and net return of drought and normal years after adoption were analysed based on 2003 (normal) and 2004 (drought) years' data.

Photo.66: Happy farmers of adopted village who are generating income in lean period by growing maize at Dhenkanal

Photo.67: Adoption of groundnut in large area by substituting upland rice at Kingol, Dhenkanal

Photo.68: Rice substitution with sole pigeonpea at Arnapurnapur, Dhenkanal

Photo.69: Rice substitution with cowpea at Arnapurnapur, Dhenkanal

second pre-winter crops like horsegram, sesamum can be grown successfully on such land. Whereas sole rice returned only Rs.50.1 ha^{-1} day^{-1}. The per ha per day net return was Rs.137.9, Rs.111.0, Rs.80.1 and Rs. 277 from groundnut, blackgram, pigeonpea and fish, respectively in normal rain fall year (year 2003).

Table-3: Average income (Rupees) per household during normal and drought years before and after full adoption

Sources income	Before adoption		% of change	After full adoption		% of change
	Normal year (Rs.)	Drought years (Rs.) or years of dry spells		Normal years (Rs.)	Drought years (Rs.) or years of dry spells	
1.Crop	17048	8780	45.2	49924	47170	5.5
(a)Rice	14880	7270	51.1	18065	15165	16.1
(b)Non-rice crop	1268	1510	-29.2	31859	28005	12.1
2.Farm labour	4378	1185	72.9	0	0	-
3.Non-farm activities	4080	6880	-68.6	480	705	4.6
4.Other sources	1410	1380	2.1	1480	1450	2.7
5.Total income	**26916**	**18225**	**29.6**	**51884**	**49325**	**4.9**
6.Sale of livestock	0	1380	-	0	0	-
7.Sale of land	0	2750	-	0	0	-
8.Sale of other assets	0	2010	-	0	0	-
9.Mortgage/ borrowings	0	3280	-	0	0	-
10.Total (asset sale+borrowing)	**0**	**9420**	**-**	**0**	**0**	**-**

The data are based on survey of output of 40 households in the terminal year (2003-04) at Arnapuranapur village, Dhenkanal.

Table-4: Fastest return per unit time per unit area (computed based on 2003 data)

Crops	Net return (Rs/ha)	Duration (days)	Net return/ (Rs/ha/day)
1.Maize (cob)	23391	70	314
2.Maize (grain)	12560	110	114.1
3.Groundnut	16550	120	137.9
4.Blackgram	11100	100	111
5.Pigeonpea	12010	150	80.1
6.Solerice	5010	100	50.1
7.Groundnut+ pigeonpea	18775	150	125.2
8.Rice+PP	10160	150	67.8
9.Fish	75000	270	277.7
10.Maize-horsegram	26365	140	188.3
11.Maize(c)-sesamum	26462	140	189

(g) Enhancement of productivity of rainfed lowland rice

Due to improved management with high yielding varieties, the productivity of rice in rainfed lowland was enhanced from 1.4 to 2.4 t/ha to 3.6-4.1 t/ha in different study villages (Arnapurnapurr, Noagao, Kingol of Dhenkanal district).

(h) Checked labour migration.

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

(i) Introduction of second crops (after rice or non-rice crops) with residual soil moisture and limited irrigation from harvested rainwater enhanced productivity and income.

Because of more profit, huge market demand, among different crops farmers adopted maize, groundnut, and sunflower with supplementary irrigation from harvested rainwater. With 4 irrigation, farmers were earning about Rs. 31,000, Rs. 15,000, Rs. 17,000, per hectare per annum from maize (cob), groundnut and sunflower, respectively. By utilizing soil upward flux and with residual soil moisture farmers adopted groundnut in large rainfed rice fallow and earning Rs. 8,000-12,000/ha/annum.

Photo.70: Rainwater harvesting in village pond at study village (Arnapurnapur)

Photo.71: Adoption of sunflower after rice in large area with harvested rainwater

Photo.72: Adoption of potato in rice fallow with harvested rainwater

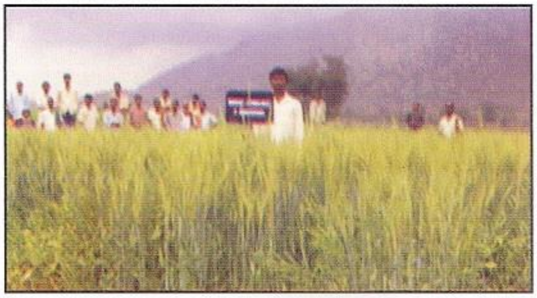


Photo.73: Adoption of wheat after rice with harvested rainwater

(j) Introduction of maize-horsegram rotation and other low water requiring legumes in rice fallow sustains soil fertility.

By early harvest of rice or non-rice crop short duration low water requiring crops like cowpea, horsegram, blackgram were grown in upland and medium land. Mineral nitrogen accumulation (NH_4 and NO_3-N) of 25-34 kg/ha was recorded from different crops and land ecologies. The N concentration in dry matter varied from 2.1 to 2.4%.

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

Crop diversification with legumes in *kharif* and introduction of legumes in rice based cropping system improved physical conditions of soils. The soil porosity was enhanced from 30.7% in 1999 to 38.5% in 2004 after substituting rice with legumes (sole/intercrops). The hydraulic conductivity and available water capacity were enhanced by 26 and 23 %, respectively, after replacing rice in rainfed rice upland (Table-5).

Table-5: improvement of soil physical parameters after changing the cropping pattern in rice upland.

Physical parameters	**Existing crops**			
	Year 1999	**Year 2004**		
	Rice	**Groundnut + Greengram**	**Groundnut + Pigeonpea**	**Groundnut + Blackgram**
Soil porosity (%)	30.7	37.3	38.5	34.2
Available water capacity (m^3/m^3)	0.139	0.171	0.169	0.157
Hydraulic conductivity (cm hr^{-1})	1.23	1.55	1.53	0.149
Bulk density (mg m^{-3})	1.59	1.49	1.51	1.51
pH	6.4	6.5	6.7	6.7
Electrical conductivity (dS m^{-1})	0.11	0.12	1.1	0.12
Water stable aggregates (%)	17.8	21.7	22.8	19.2

(l) Enhanced productivity of available water resources in the existing pond

Earlier the pond at Arnapurnapur village was mainly utilized for domestic purposes. Presently they are utilizing it for irrigating dry season crops and fish rearing, as can be assessed from media report.

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

Due to above mentioned impacts; the cropping system in different rice ecologies of the study villages has been changed from traditional cropping system to sustainable cropping system (Table-6).

Photo.74: Adoption of groundnut in large area in shallow water table

Photo.75: Happy farmers showing groundnut pod from his field, grown utilizing soil upland flux after rainfed rice experimetal and neighbouring villages

Table-6: Changed cropping system in the (surveyed in 2003-04)

Village	Before project			After project		
	Upland	Medium land	Low land	Upland	Medium land	Low land
Arnapurnapur (Full village adoption)	Rice	Rice, Sugarcane	Rice	Maize, horsegram, Groundnut + Pigeonpea,	Rice, Sunflower, Vegetables (cucumber, water melon, potato, groundnut, winter maize with limited irrigation).Fish in village pond, Papaya, Banana on pond bund.	Rice, blackgram, lathyrus and vegetables (cucumber, tomato)
Jiral (Full village adoption)	Rice	Rice	Rice	Maize, horsegram, Groundnut + Pigeonpea,	Rice, groundnut, greengram	Rice, blackgram, lathyrus and vegetables
Kingol (Full village adoption)	Rice	Rice	Rice	Maize, horsegram, Groundnut + Pigeonpea,	Rice, groundnut, greengram	Rice, blackgram, lathyrus and vegetables
Naogao (Full village adoption)	Rice	Rice	Rice	Maize, Horsegram, Groundnut + Pigeonpea,	Rice, groundnut, greengram	Rice, groundnut and vegetables
Parjang (Full village adoption)	Rice	Rice	Rice	Maize, horsegram, Groundnut + Pigeonpea,	Rice, groundnut, greengram	Rice, maize, groundnut, potato
Bijadi (Partial adoption)	Rice	Rice	Rice	Rice, Maize, Groundnut	Rice	Rice
Alujharna (Partial adoption)	Rice	Rice	Rice	Rice, Maize, Vegetables	Rice,potato, pulses	Rice, Potato, Lathyrus and Black gram (relay)
Alnabereni (Partial adoption)	Rice	Rice, Sugarcane	Rice	Rice, Maize, Groundnut	Rice, Sugarcane	Rice
Katni (Partial adoption)	Rice	Rice, Sugarcane	Rice	Rice, Maize, Vegetables, Groundnut, Groundnut + Pigeonpea	Rice, Sugarcane	Rice, Lathyrus and Blackgram (relay)

The Statesman on 7.4.2004

Farmers carry sunflower heads to their houses after a bumper harvest in Annapurnapur in Dhenkanal. — BN Seth

Annapurnapur expects a bumper crop this season

Statesman News Service

DHENKANAL, April 6. — The villagers of Annapurnapur in Kamakshyanagar subdivision are expecting a bumper crop even in a drought season and have, as a result, stopped migrating to urban areas in search of work, thanks to the efforts of the scientists of the Water Technology Centre for Eastern Region, a branch of the Indian Council of Agriculture Research.

Crop diversification initiated by the scientists in the rain-fed upland has made the village self sufficient and it has witnessed an unexpected produce within two years of WTCER's experiment. Farmers were overjoyed when the WTCER selected Arnapurnapur village for their experiment. The scientists planted crops over four acres of land in 2000. They also involved some farmers in the experiment.

The aim was to replace the cultivation of the rain-fed upland paddy with maize, pigeon pea. groundnut, black gram and cow pea, during the kharif seasons of 2000-02. The experiments proved that the farmers would be more benefited if they followed inter-cropping like rice and pigeon pea, groundnut and pigeon pea and groundnut and green gram. The second series of crops horse gram and sesame would be cultivated with maize.

Initially seeds, fertilizer and even technical knowhow were provided to some farmers. But after the success of the experiment, hundreds of farmers in the village have cultivated cash crops over 150 to 200 acres and the success stories have spread to nearby villages too. Cash crops like sun flower, maize, pigeon pea, horse gram, cucumber and other vegetables cultivated as per the intercropping system have earned them lakhs of rupees.

Thus instead of migrating to other areas for work, the village, in turn, has provided engagement to labourers from nearby villages. Farmer Mr Sivaram Sahoo said many farmers used to go to districts like Cuttack, Jagatsinghpur and Angul after the harvesting of paddy in search of work but with the inter-cropping and crop diversification over the last two years, they are never in dearth of employment. One farmer, Mr Kailash Roul, proudly said he spent more than five hours in his land and added his investment was only around Rs 1,000 to 1,500 for maize and groundnut in 2.8 gunth of land. In return he got Rs 35,000 after 80 days, he said. Mr Roul said his five sons now help him something which they were reluctant to do earlier. He said he has advised them not to bribe officials or brokers for a job in the cities. Another farmer, Mr Hrushikesh Nayak, has planted maize this year. Nayak invested Rs 900-1,000 for maize in 15 gunth of land which showed high yield and earned him Rs 15,000 with limited use of water. The farmers can also market their produce more easily now. They have thanked MP Mr KP SinghDeo for providing assistance for a check bundh as water from the bundh area has helped them to irrigate their crops.

WTCER senior scientist Dr Gouranga Kar said crop diversification is the need of hour in the rainfed upland rice area. WTCER has made efforts to help farmers in Jiral and Dahanbili villages in Kamakshyanagar subdivision. Dr Kar said the success can spread to other villages if the district administration extends cooperation with active support of the deputy director of agriculture and horticulture department at the district level. The WTCER always aims not to alter the existing ground system and the available infrastructure and resources of the farmers.

The Indian Express on 03.04.2004

They no longer migrate for livelihood

By Biranchi N. Seth

Dhenkanal, April 2: There is no rain, no water, yet there is a bumper harvest.

And people of Arnapurnapur village in Kamakshyanagar sub-division have stopped migrating to urban areas in search of livelihood. For they are self-sufficient now.

Thanks to Water Technology Centre for Eastern Region (WTCER) under Indian Council of Agriculture Research (ICAR), that has brought prosperity to the village.

Besides, helping them grow, WTCER scientists have boosted the self-confidence of farmers.

With the scientists' advice in 2000, the farmers took to crop diversification in rainfed uplands and output was beyond their expectation. Trials on crop diversification were conducted during kharif seasons from 2000 to 2002. The crops were maize (Navjot), pigeon pea, groundnut, black gram and cow pea. The farmers received more returns when they combined growing two crops -- rice and pigeon pea, groundnut and pigeon pea, groundnut and green gram.

The second crop, horse gram and sesame were grown after maize.

Initially, seeds, fertiliser and technical knowhow were provided to some farmers at the beginning of experiment.

After success of the experiment, many farmers of the villages, started growing cash crops. Now the success stories have spread to neighbouring villages.

The cultivation of cash crops have made the farmers self-reliant. And instead of going to other places in search for work, they provide work to labourers of neighbouring villages.

COMING BACK

Sivaram Sahoo, a farmer, said many farmers used to go to districts like Cuttack, Jagatsinghpur and Angul in search of work after the harvest of paddy, but now due to success in inter-cropping methods and crop diversification, they get work throughout the year.

Another farmer Kailash Roul said he invested only Rs. 1500 for maize and groundnut cultivation and received yield worth Rs. 35,000.

Farmer Hrushikesh Nayak who invested Rs. 1000 for maize cultivation, has received returns worth Rs. 15,000.

Farmers do not face marketing problems. As soon as the harvest is over, they are picked up by local businessmen and poultry firm owners.

When asked about the success, WTCER senior scientist Dr. Gouranga Kar said crop diversification is the need of hour in rainfed upland areas to increase productivity because of drought.

The Statesman on 22.03.2004

Scientists urged to create jobs

Statesman News Service

DHENKANAL, March 21. — DC Mr Nitya Nanda Mohanty has urged the scientists of Western Technology Centre for Eastern Region to explore and help create employment opportunities in the district. The WTCER works under Indian Council of Agriculture Research. About 47 per cent of the people live below poverty line in Dhenkanal.

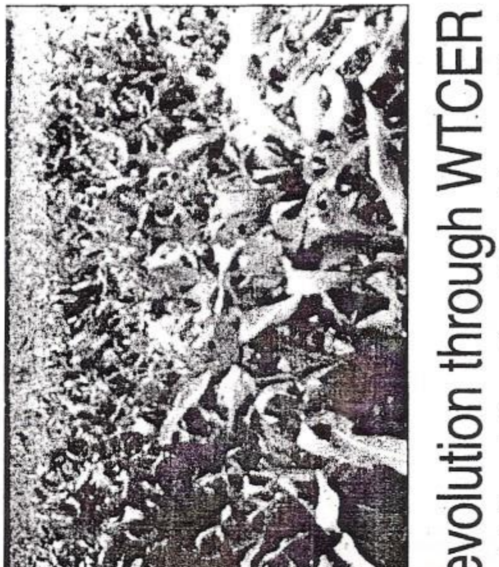
Addressing a farmers' training programme conducted by WTCER here recently, Mr Mohanty said the administration has launched watershed development projects and water harvesting structures in different places. Ample resources are available and potential sources employment opportunities can be created in the district, he said.

The district collector requested agriculture scientists to evolve measures through which farmers and youth get better economic returns and more employment avenues. Appreciating efforts of the WTCER on increasing production through crop diversification and intercropping in Kamakshyanagar subdivision over the past three years, he suggested replication of the same in other parts of the district.

Former vice-chancellor of Orissa University of Agriculture Technology Mr Iswar Chandra Mohapatra emphasised upon improved coordination between scientists, farmers and extension officers for better results in intercropping system and crop diversification in rain fed areas. Educated farmers should spot their problems and discuss them with scientists and agricultural experts on the spot, he said.

Senior scientist and WTCER (Dhenkanal) unit in-charge Dr G Kar highlighted the success of crop diversification and intercropping in Jiral, Kadalipal and other areas of Kamakshyanagar, which have become a success story in other parts of state.

The Statesman on 24.06.2004



Farm revolution through WTCER

The green revolution has helped increase food production especially in the assured water supply region. Studies reveal that rainfed agriculture supports 40 % of the India's 1003 million population and contributes 44 % to the national food basket. Keeping the importance of scientific crop and water management in rainfed area to increase the rural income, the Water Technology Centre for Eastern Region, Bhubaneswar, a branch of ICAR has been executing a project through National Agricultural Technology Programme (NATP) at Dhenkanal.

The NATP has put major thrust for refinement of technologies at the district through on-farm trial for improving productivity of different rice ecosystem. The project started in the year 1999 and several trials were conducted on 'effective rainwater utilization through upland crop diversification', 'in-situ moisture conservation', 'relay cropping', 'limited irrigation scheduling', 'conservation tillage' etc. Successful trials and demonstrations under farmers management condition have convinced local farmers to grow successful crops of maize, groundnut, pigeon pea, blackgram, groundnut + pigeon pea inter-cropping in light textured upland where traditional paddy yielded less and unstable return. Several cash crops likewinter maize, pea, sunflower, wheat, safflower, gram, mustard have been introduced in different villages of the district through research trials.

Presently the projects are undergoing at 5 villages viz., Arnapurnapur, Janahpara, Kingol, Jiral and Noagaon, belongs to 3 blocks (Kamakhyanagar, Bhuban and Parjang) of the district.

The actual impact of the recommendations by WTCWR, Bhubaneswar under the project in different rainfed rice ecosystem has been reflected both in terms of (I) Improving productivity of and cropping intensity of rainfed rice upland (II) Improving productivity of rice during rainy season in medium and lowland rice area (III) Increasing cropping intensity through adoption of second crops in rainfed medium and lowland rice -fallow. As a result of adoption of double cropping technology of wheat, sunflower, winter maize etc. in different rainfed rice based ecosystem with harvested water, residual moisture the cropping intensity increased from 108 to 177% in Arnapurnapur, from 115% to 171% in Noagao from 111 to 136% in Kingol of the study district, Dhenkanal.

Success of any generated technology ultimately depends on its effective dissemination to and adoption by farming community. To disseminate different recommended technology following technology dissemination programme were organized from 2000-2003.

Four export-farmers interactive meetings and on field training-cum demonstration programme were organized in the project village.

As per the requirements, crop diversification technology in rainfed upland rice area was handed over to special Relief Commissioner, Government of Orissa, progessive NGO's of Orissa for minimizing the effect of drought and to obtain higher and assured return from rainfed upland rice area of the state.

The Indian Express on 22.03.2004

Training focuses on better cropping ideas

Dbenkanal, March 21: Agriculture scientists were asked to guide farmers for a better yield and in creating employment opportunities, at the farmers training programme conducted by Western Technology Centre for Eastern Region (WTCER) here.

District Collector Nitya Nanda Mohanty, in his address, urged WTCER scientists to explore employment opportunities and help reduce poverty in the district. He informed that the administration has launched watershed development projects and water harvesting structures in different parts of the district.

Watershed development projects have been launched in the district

Appreciating the efforts of WTCER in increasing production by crop diversification and inter-cropping system in Kamakhyanāgar sub-division in the last three years, he suggested spread of this movement to other parts of the district. He advised farmers to adhere to scientific methods of farming and cultivate cash crops instead of traditional ones.

Former vice-chancellor of OUAT Iswar Chandra Mohapatra said there should be coordination among scientists, farmers and extension officers for better results through inter-cropping and crop diversification in rain-fed areas.

Senior scientist and WTCER Dhenkanal unit in-charge G. Kar highlighted the successful crop diversification and inter-cropping in Jiral, Kadalipal and other areas of Kamakhyanagar. Deputy Director of Agriculture K. Nayak and scientists R.C. Sribastav and R. Singh spoke • ENS

The Hindustan Times on 05.09.2001

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, at 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 260 crore from the World Bank to implement research project in scientific cropping in rain-fed areas. Meanwhile, the project has been initiated successfully in 240 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.

The Statesman on 15.09.2004

Statesman News Service

Statesman News Service

DHENKANAL, Sept. 14. — Rain or no rain, you may indeed expect a bumper harvest! Sounds incredible but not improbable thanks to a new green revolution of sorts. Villagers are happy that they are now able to produce a bumper crop even during drought.

Agricultural prosperity has reportedly been achieved through scientists' innovative ideas and locals' interest to implement them in villages of Kamakshyanagar subdivision in the district. Cultivation of cash crops like maize, pigeon pea, ground nut, blackgram, sunflower and other crops goes on round the year ceaselessly.

There has been no wholehearted support from the local administration or state government yet the villages managed to prosper.

Water arrangements, government support, both financial and technical, may be the reasons for the Green Revolution but with the absence of those facilities farmers have to toil hard for a living. Migrating to other districts in search of jobs is not considered a viable option. While speaking to mediapersons scientists said they had made the impossible possible. The villages like Kadalipal, Arnapurnapur, Jiral, Aluajharan, Kateni and other neighbouring villages in Kamakshyanagar subdivision are reaping the benefits of a farm revolution brought about in 1999. To sustain soil fertility farmers grow vegetables through intercropping and crop diversification and multicrop farming in upland areas. Besides, farmers have also taken to papaya cultivation and fish farming. Cultivation of cucumber and ladies finger are considered more profitable.

Now a section of the farmers wants to give up paddy cultivation and turn to other crops instead for a steady and higher income. Under the guidance of scientists many of them who have switched over are earning more than what they used to do and with less labour and investment. A farmer, Sipuna Mohanty, said he used to grow paddy for years but after incurring losses owing to drought he switched over to maize cultivation. He has grown maize in phases. He invested only Rs 150 per gunth on seeds, a small quantity of fertilizer and cleaning and got Rs 4500 to 5000 in return within 60 to 80 days from six gunths. Another elated farmer Bainsidhar Nayak thanked scientists of the Water Technology for Eastern Region (WTCER) for the prosperity he brought to his family. He could now send his children to school, feed them properly and look forward to a brighter future for them. A group of farmers claimed they are now self-reliant and have stopped borrowing money from money lenders who used to charge a hefty interest and often threaten them with dire consequences for not getting their money back in time.

Maize is supplied to Dhenkanal, Angul and Cuttack from the villages which produce a bumper crop. The farm revolution came about in 1999 after a group of scientists selected the villages in the subdivision for their new experiment at a bumper crop.

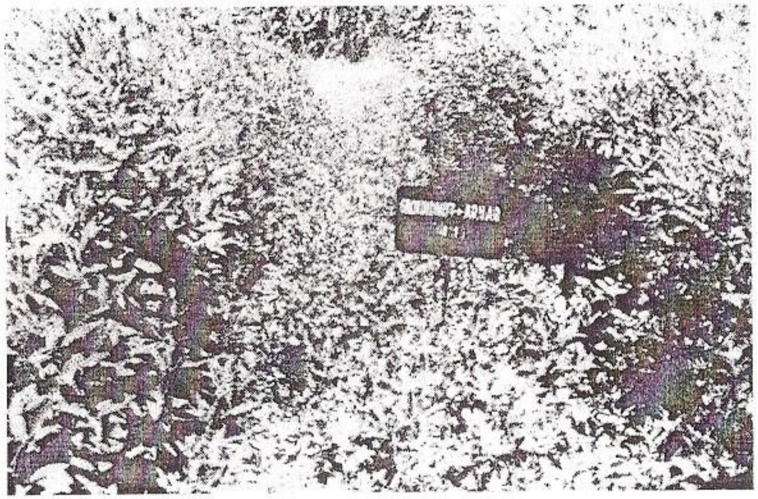
They chose the villages considering the people's interest. However, farmers lament they could not get seeds on time and agriculture and horticulture departments do not provide quality seeds. Had they got seeds in time they could have spread the crops to other areas of the subdivision.

The Dhenkanal sub-collector, Mr Surath Chandra Mallick, visited Kamakshyanagar villages and interacted with farmers, scientists and saw crops recently.

His visit was intended to encourage farmers in Dhenkanal and Gandia constituencies.

Expressing satisfaction, Mr Mallick said scientists really had elevated the status and dignity of farmers who had never dreamt of it earlier. He has invited WTCER scientists who consented to extend cooperation and technical guidance.

A WTCER scientist Dr Gouranga Kar said every drop of water and inch of land is precious. Rainfed farming is lucrative and should be taken up to stop migration of labourers in villages, he said.



The Indian Express on 14.09.2004

Good harvest ? No problem, now

Farmers reap confidence as scientists come to their aid

By Biranchi Seth

Dhenkanal, Sept. 13: Heavy rains do not scare the farmers of Kamakshyanagar sub-division and drought does not compound their worries. They are a confident lot, who believe nothing can stop them from achieving a bumper harvest, irrespective of the varying moods of Weather God.

And, their morale has received a boost due to the efforts of the scientists of Water Technology Centre for Eastern Region (WTCER), who have taught them to bring about a green revolution on their own, with the help of scientific techniques. The result has come in the form of the farming prosperity, seen all around Kamakshyanagar. In fact, cash crops like maize, pigeon pea, groundnut, black-gram, sunflower and many more are now cultivated non-stop round the year.

Groundnut and arhar crops grown together (Right) Farmers standing near a maize field at a village under Kamakshyanagar.

The dedication of scientists and people's participation in some of the villages under the sub-division have added to the farmers' prosperity. To sustain soil fertility, the farmers now grow vegetables through inter cropping, crop diversification and multi-crop farming in upland areas. Besides, the farmers have planted papaya along the embankments of the village ponds and are into fish farming, particularly in Kadalipal village and its neighbouring villages.

Interestingly, leaving behind paddy crops, many farmers are concentrating on non-paddy crops under the guidance of scientists and are also earning two to three times with less labour and investment. "I have been growing paddy for years but during rains, I always incurred losses. Now I have grown maize in phases and have earned more than double of what I invested," says Sipuna Mohanty, a farmer.

Similarly, another farmer, Bansidhar Nayak said, the scientists of WTCER had not only brought about prosperity in his profession but also in his family. "I can now send my children to school and look forward for their bright future," he added.

Besides, the entire process has brought about many other positive changes. While some farmers, who were earlier thinking of migrating to other states in search of jobs, have driven away these thoughts from their minds, others, who were tired of money lenders are heaving a sigh of relief after reaching a level of self-reliance.

In fact, the changes started rolling in 1999 when the WTCER scientists selected some villages in the sub-division to carry out their experiment.

Dhenkanal Sub-Collector Surath Chandra Mallick recently visited the villages and interacted with farmers and scientists. Expressing satisfaction over the sincere efforts of the scientists, Mallick said, he wanted the farmers in other blocks of Dhenkanal and Gandia constituencies to follow the same path.

Mallick told this paper that he has requested the WTCER and ICAR scientists to visit the 'tomato' village (Majhisahi) near Saptasajya to provide technical advice to the farmers for growing vegetable crops other than tomatoes.

FEEDBACK FROM FARMERS OF DIFFERENT ADOPTED VILLAGES UNDER THE PROJECT

VILLAGE - ARNAPURNAPUR (ଗ୍ରାମ - ଅନ୍ନପୂର୍ଣ୍ଣାପୁର)

[illegible]

(We the following farmers of Arnapurnapur village, Dhenkanal were growing only rice in all up, medium and lowlands. In upland productivity of rice was low and unstable. After learning from the project, the productivity of upland has been increased through crop diversification with maize, groundnut + pigeonpea, blackgram, horse gram, In medium and lowland rice yield was enhanced with 3.5 t / ha and 5t / ha, respectively. After rice in medium and lowland we are growing maize, sunflower, vegetable, groundnut wheat, backgram with limited irrigation or residual soil moisture. We are getting Rs.20,000/- per acre from maize cob, Rs.10,000/- acre from sun flower and Rs.8000/- acre from groundnut)

Binod Bihari Mahabhoi

Bholeswar Samal

(Bidya Dhara Nayak)
(Akhila Mohabhoi)
(Sanjay Nayak)
(Binod Bihari Mohabhoi)
(Kailash Ch. Sahu)
(Pratap Roula)
(Prasant Samal)
(Dibakar Behera)
(Sibram Sahu)
(Pradeep Samal)
(Bholeswar Samal)
(Gati Krushna Samal)
(Prasant Roula)
(Ramesh Mohabohi)
(Dharma Nanda Khuntia)
(Bimal Ku Nayak)
(Pramod Sahu)

VILLAGE - JIRAL (ଗ୍ରାମ - ଜିରାଳ)

[illegible]

(We the villagers of Jiral have learned lot of things from NATP, the results were beyond our expectations. Previously we were taking only one crop, now we are able to grow 2-3 crops partcularly in medium and lowland. In about 250 ha of upland rice area was diversified with maize, groundnut, groundnut +pigeonpea, horsegram, sesamum etc. In medium land after rice we are growing groundnut, black gram, green gram, potato, brinjal, cauliflower etc. In low land after rice (cr. Gayatri) we are growing field pea, gram, blackgram as paira crops.)

Sanatan Raoul

Benu dhar Rout

Abhi manyu Sahu

(Dayanidhi Rout)
(Balakrushna Lenka)
(Dolo Govinda Mohanty)
(Chakra Dhar Nayak)
(Sanatan Raoul)
(Raghab Sethy)
(Padan Mohanty)
(Benudhar Rout)
(Abhimanu Sahu)
(Niranjan Panda)
(Digambar Das)
(Jaykrushna Rout)
(Kalandi Ch. Swain)
(Ghanashyam Nayk)
(Gagabandhu Rout)
(Pitapas Behera)

(Ramesh Ch. Sahu)

(Kalilash Behera)

(Govinda Sahu)

(Chandan Ku Nayak)

(Ganga Dhar Samal)

(Pdamanava Prida)

(Gopinath Parida)

(Mehgha Nada Chatua)

(Banshi Dhar Nayak)

(Nakula Mohabohi)

(Hrusikesh Nayak)

(Prasanta Mohabhoi)

(Antaryami Sahu)

(Madhu Patra)

(Kailash Roula)

(Kailash Sahu)

(Sudarshan Roula)

(Bhanja Patra)

Purandar Khatua

(Purandra Khatua)

(Chakra Dhara Behera)

(Sukanta Ku Sahu)

Suckanta kumar Sahu

(Laxmi Dhar Muduli)

(Buddhimanta Sahu)

(Rabi Behera)

(Rabi Pradhan)

(Rama Chandra Rout)

(Ananta Patra)

(Maguni Sahu)

(Harihara Patra)

(Antaryami Patra)

(Iswar Pradhan)

(Daya Sethy)

(Nisha Samal)

Arjun Khuntia.

(Arjuna Khuntia)

(Pitabas Sahu)

Ranjati Dash

(Ranjit Das)

(Purna Ch. Rout)

(Sikar Pradhan)

(Natha Roul)

(Manua Lenka)

(Bhalu Parida)

(Ghana Sahu)

Padan Mahanti

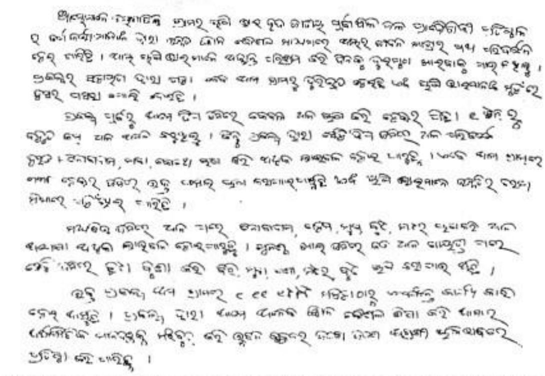
(Ghana Shyama Rout)

(Trilochan Behera)

(Kapileswar Lenka)

(Santosh Nayak)

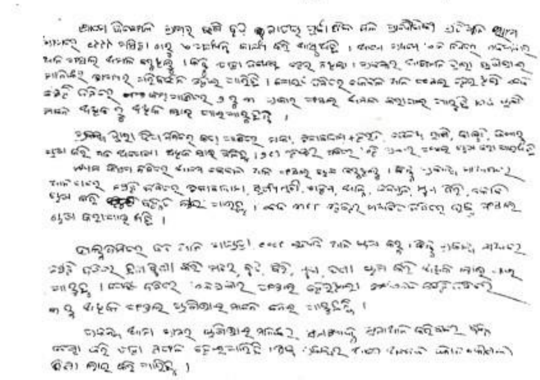
VILLAGE - NUAGAON (ଗ୍ରାମ - ନୂଆଗାଁ)



(We the farmers of Nuagaon (Dahanabil) have been much benefited after getting knowledge about improved agricultural practices through WTCER officials. The project has brought smiles to the farmers of our village. The 338 ha of area of our village is now double cropped with rice-groundnut, rice-balckgram, rice-greengram, rice-gram, maize - horsegram, groundnut + pigeonpea etc.)

(Kishore Ch. Aich)
(Alhad Ku Aich)
(Prakash Ku)
(Babaji Ku)
(Suresh Mohapatra)
(Purusottom Aich)
(Anil Ku Aich)
(Hrudananda Aich)
(Hrushi Kesh Aich)
(Rabindra Kanar)
(Nilamani Kanar)
(Chenni Aich)
(Bichitra Aich)
(Gobinda Kanar)
(Nalini Aich)

VILLAGE - KINGOL (ଗ୍ରାମ - କିଙ୍ଗୋଳ)



(The WTCER NATP is running in our village since 1999. Previously we are growing only rice in upland. Now we are growing maize, groundnut + arhar, horsegram, sesamum, cucumber, pumpkin on that land. In lowland after rice (cr. Gayatri, Savitri) we are growing pea, groundnut, green gram, black gram, lathyrus etc. Through the project our economic status has been improved.)

(Bipin Ku. Raout)
(Bimal Ku. Parida)
(Pradeep Ku. Pradhan)
(Nirmal Ku. Parida)
(Surat Parida)
(Lakshmi Dhara Parida)
(Annarth Mallick)
(Duari Mallick)
(Udaya Parida)
(Kodanda Pradhan)
(Kalindi Patra)
(Parikhata Pradhan)
(Trilochan Pradhan)
(Akadahsi Patra)
(Bata Krushna Patra)
(Pitabasa Sethi)
(Pabitra Pradhan)
(Abhinna Ku. Rout)
(Madhab Sethy)
(Ranjan Ku. Mallick)
(Kulamani Pradhan)
(Harihara Sethy)
(Arjun Ku Mishra)
(Pramod Mishra)
(Ajaya Panda)
(Ranjan Panda)

7. PUBLICATIONS FROM THE RESEARCH WORK (1999-2005)

The publication (Research papers/Research Bulletin/Technology package/ Book chapter/Training manual/Extension leaflet) arising from the project are given below:

(A) RESEARCH PAPER IN REFERRED JOURNAL.

1. **Kar G**. **2005**. Radiation interception, rainwater and radiation utilization efficiency study of legume based intercropping in rainfed upland rice area of eastern India. ***Journal of Agrometeorology***, 7(**1**): 84-89.
2. **Kar G**., Verma H.N. and Singh R. **2005**. Effects of winter crop and supplimental irrigation on crop yield, water use efficiency and profitability in rainfed rice based cropping system of eastern India, ***Agricultural Water Management*** **(Elsevier)**, doi : 10.1016/j. agwat. 2005.03.001
3. **Kar G,** and Verma H.N. **2005.** Phenology based irrigation scheduling and determination of crop coefficient of winter maize in rainfed rice fallow of eastern India. ***Agricultural Water Management.*** **(Elsevier)**. *75(3):169-183*
4. **Kar G**., Singh R. and Verma, H.N. **2004.** Spatial variability studies of soil hydro-physical properties using GIS for sustainable crop planning of a watershed of eastern India and its testing in a rainfed rice area. ***Australian Journal of Soil Research***. 42(**4**): 369-379.
5. **Kar G**., Singh R. and Verma H.N. **2004**. Alternative cropping strategies for assured and efficient crop production in upland rainfed rice areas of eastern India based on rainfall analysis. ***Agricultural Water Management*** **(Elsevier)**, 67(**1**): 47-62.
6. **Kar G**., Singh R. and Verma H.N. **2004**. Double cropping in rainfed light textured upland based on rainfall probability and effective monsoon analysis. ***Indian Journal of Soil Conservation,*** *32*(**1**): 116-123.
7. **Kar G.** and Singh R. **2004**. Soil water retention- transmission studies and enhancing water use efficiency of winter crops through soil surface modifications. ***Indian Journal of Soil Conservation,*** 8(**1**): 18-23.
8. **Kar G**., Verma H.N. and Singh R. **2003**. Enhancing rainwater use efficiency and productivity of rainfed rice uplands through rice based intercropping systems. ***Oryza,*** 40 (**1 & 2**): 27-30.
9. **Kar G**. and Singh R. **2002**. Prediction of monsoon and post monsoon rainfall and soil characterization for sustainable crop planning in upland rainfed rice ecosystem. ***Indian Journal of Soil Conservation***, 30 (**1**): 8-15, 2002
10. **Kar G**. **2002.** Rainfall variability and probability analysis for studying water harvesting potential and crop diversification**. *Indian J. of Agricultural Science,*** 54(**2**): 122-125.

(B) RESEARCH BULLETIN

1. **Kar G.**, James B.K., Singh R. and Mahapatra I.C. **2004**. Agro-climate and extreme weather analysis for successful crop production in Orissa. ***Research Bulletin No.***

22, Pages:1-76. Water Technology Centre for Eastern Region (I.C.A.R.), Bhubaneswar-23, Orissa, India.

2. **Kar G**., Singh R. and Verma H.N. **2004**. Productive and profitable management of rainfed lowland rice area through intensive cropping and efficient water use. ***Research Bulletin No. 17, Pages 1-56***. Water Technology Centre for Eastern Region (I.C.A.R.), Bhubaneswar-23, Orissa, India.
3. **Kar G.**, Singh R. and Verma H.N. **2003**. Crop diversification technology in rainfed upland rice area of eastern India to increase productivity and rainwater use efficiency. ***Research Bulletin No. 13, Pages: 1-50.*** Water Technology Centre for Eastern Region (I.C.A.R.), Bhubaneswar-23, Orissa, India.
4. **Kar G.,** Singh R., Reddy G.P., Kanan K. and Verma H.N. **2002**. Participatory rural appraisal technique for research prioritization to improve productivity of rainfed upland. ***Research Bulletin No. 9,Pages 1-36***. Water Technology Centre for Eastern Region. (I.C.A.R.). Bhubaneswar-23, India.

(C) TECHNOLOGY PACKAGE LEAFLET

1. **Kar G**., Verma, H.N., Singh R. James B.K. **2004**. Crop diversification and profitable management of rainfed lowland rice area of watershed. **Technology package 2/ 2004.** Pages 1-8. Water Technology Centre for Eastern Region. (I.C.A.R.). Bhubaneswar-23, India.
2. **Kar G.,** Singh R. and Verma H.N. **2003.** Crop diversification in rainfed upland rice area of eastern India **(Package of Practices).** Published by Director, Water Technology Centre for Eastern Region, Bhubaneswar.

(D) TRAINING MANUAL PREPARED

1. **Kar G.,** James B.K., Singh R. and Verma H.N. **2004**. Agricultural diversification options for drought mitigation in rainfed rice area. *Training Manual*. **Page: 1-176**. Published by Director, Water Technology Centre for Eastern Region, Bhubaneswar.
2. **Kar G.** and James B.K. **2004**. Purba Bharatara brusti prusta anchalare marudira upasama pai keteka bikalpa. Krushaka prashikhyana pustika. **(Oriya).** *Krushaka Prasikhyana Pustika (Farmers' Training Manual)*. **Page: 1-180**, Published by Director, Water Technology Centre for Eastern Region, Bhubaneswar.

(E) CHAPTERS IN BOOK/ TRAINING MANUAL/ FULL LENGTH PROCEEDINGS

1. **Kar G. 2004**. Alternative land use on watershed basis using remote sensing and GIS to improve productivity of eastern India. In book: Integrating watershed technologies for sustainable development. (Eds. Biplab Bhusan Basu). acb Publication, Kolkata, 112-122.
2. **Kar G. 2004**. Drought in Orissa and some mitigation options: An overview. Training Manual (Eds. Kar G., James B.K., Singh R., Verma H.N.). Published by Director, Water Technology Centre for Eastern Region, Bhubaneswar, **13-25**.
3. **Kar G**., Singh R. and Verma H.N. **2003.** Crop diversification technology in rainfed paddy upland of eastern India to increase its productivity and augment rural income.

Proceedings in the International Seminar on Downsizing Technology for Rural Development, RRL, Bhubaneswar, October 7-9, 2003, 157-166.

4. **Kar G.** and Verma H.N. **2002**. Improved sustainability of rainfed upland sub-humid eco system of watershed based on probabilistic rainfall. In book: Hydrology and Watershed. BSP Publication, Eds. B. Venkateswara Rao, K. Ram Mohan Reddy, C. Sarala and K. Raju, Vol. 1, 318-327.

(F) EXTENSION LEAFLET IN LOCAL LANGUAGE

1. **Kar G.,** James, B.K. Singh R. and Verma H.N. **2004**. Jalachhaya Anchalare Brusti Prusta Khala Dhana Jamira Labhadayak Parichalana. Published by Director, Water Technology Centre for Eastern Region, Bhubaneswar.
2. **Kar G.,** Singh R Verma H.N. **2003** (Oriya). Purva Bharatra Brusti Prusta Dhipa Dhana Jamire Phasal Bibidhata (Chhasa Pranali Sanhita). Published by Director, Water Technology Centre for Easter Region, Bhubaneswar.
3. **Kar G.,** Singh R., Reddy G.P., Kanan K. and Behera M.S. **2000.** Crop management strategies to increase cropping intensity in rainfed rice area. Published by Director, Water Technology Centre for Eastern Region, Bhubaneswar.
4. Singh R., **Kar G.,** Behera M.S. and Verma H.N. **2000.** Adhika Utpadan Pai Mati 0 Jalara Priksha 0 Poarichalana. Publised by Director, Water Technology Centre for Eastern Region, Bhubaneswar.
5. **Kar G.,** Singh R., Reddy G.P., Kanan K. and Behera M.S. **2000.** Rainwater and watershed management for year round food production and employment generation. Published by Director, Water Technology Centre for Eastern Region, Bhubaneswar.

8. CONCLUSION

Study revealed that recommended crop diversification technology has potential to enhance productivity of 4.3 m/ha. rainfed upland of eastern India from average 0.75 t/ha rice yield to 7.5 t/ha. rice equivalent yield with average net return of atleast Rs. 15,000/ha/annum. The technology has potential to mitigation drought, provide regular employment, supply balance and quality food and sustain soil health. Feasibility of double cropping was explored in rainfed lowland rice fallow under different land situations with intensive cropping and efficient water use. In the project, water productivity and net return of available water resources were optimized using linear programming through agricultural diversification (fish, vegetables, field crops)

9. ACKNOWLEDGEMENT

Authors are grateful to Director General, ICAR, Deputy Director General (NRM), ICAR, Additional Director General (IWM), ICAR for their constant encouragement to carry out the study. We are thankful to NATP authorities and world Bank for providing financial assistance to conduct research. We acknowledge our thanks to Director, WTCER, programme leaders for providing facilities at the institute to carry out study.