THIRTY FIVE YEARS OF OPERATIONAL RESEARCH PROJECT FOR DRYLAND AGRICULTURE : ACHIEVEMENTS AND IMPACTS (1976 to 2012)

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ALL INDIA COORDINATED RESEARCH PROJECT FOR DRYLAND AGRICULTURE (AICRPDA)
DIRECTORATE OF RESEARCH
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FOREWORD

Rainfed area account for fifty five per cent of gross cropped area and produces more than half of food grain production of the country. Unlike in irrigated tracts where only three to four crops are predominantly grown, the rainfed areas produce more than 34 crops and devote significant share of area to crops like pulses to an extent of 77 per cent, 66 per cent of oilseeds and 85 per cent of coarse cereals. They account for raring of 78 per cent of cattle, 64 per cent of sheep and 75 per cent of goats in the country. Thus rainfed areas have helped in maintaining the rich bio diversity of the country.

The second green revolution in India has to occur in dry land areas. Dry land areas are characterized by low productivity of crops, water scarcity and continuous degradation of productive resources which often threaten to marginalize dry land agriculture. Development of dry land calls for an interdisciplinary approach to address problems of dry land areas and design interventions for sustainable growth. Integrated Farming Systems approach which suit small and marginal farmers to ensure sustainable production together with establishment of Commodity Based Associations is essential to address End-to-End issues to improve the sustainable income of farmers.

The All India Coordinated Research Project on Dryland Agriculture at GKVK operational since 1971 has addressed various issues pertaining to dry land agriculture through development of watersheds, rain water management, soil and water conservation, soil health management, cropping system, integrated weed management, Integrated farming, alternate land use system, energy management, custom hiring and mechanizing farms. The technologies developed have helped in minimizing risks in dryland agriculture and are widely adopted throughout the State and beyond.

I am happy to know that the Scientific team at Dryland Agriculture and Operational Research Project have succeeded in documenting the achievements, experiences and success stories in the form a report "Thirty Five Years of Operational Research Project for Dryland Agriculture: Achievements and Impacts (1976 to 2012)". I hope the document will serve as a guide to the policy makers, scientists, extension workers, farmers and other stake holders involved in development of dryland agriculture.

I congratulate the project team for their commendable effort in bringing this report.

(K. NARAYANA GOWDA)
Vice Chancellor
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March, 2014
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UNIVERSITY OF AGRICULTURAL SCIENCES, BANGALORE

PREFACE

The Operational Research Project was started with the objective of conducting inclusive research on optimizing the use of natural resources like land and water for sustainable productivity consistent with environmental safety by evolving simple and farmer- friendly technology. The intension was to field-test the proven technologies for their social acceptability and economic viability. It has the purpose of understanding the socio-economic dynamic of the adoption of improved technology for their further refinement and planning future research agenda.

Dryland agriculture plays a crucial role in meeting the challenge of feeding the ever increasing population and it is estimated that the productivity of dryland agriculture has to be increased from the present 1 t ha^{-1} to 2.5 t ha^{-1} to meet the challenge.

All India Co-ordinated Research Project for Dryland Agriculture, Bangalore centre and Operational Research Project since 1971 and 1976 respectively have generated enormous scientific data and developed and released a large number of technologies on rain water management, soil and moisture conservation, soil health management, crops and cropping systems, energy management for reduction of drudgery, alternate land use systems *etc* for increasing the productivity of dryland agriculture on sustainable basis. These technologies have been demonstrated on the farmers' fields by the Operational Research Project for Dryland Agriculture along with National Initiative on Climate Resilient Agriculture. The success stories have been well documented. The book **"Thirty Five Years of Operational Research Project for Dryland Agriculture: Achievements and Impacts (1976 to 2012)"** includes achievements and impacts from past thirty five years of research in dryland agriculture. The information provided in the book would help the officers of the Development Departments like Agriculture, Watershed Development as well as KVK's and NGO's in furthering the cause of dryland research and up-scaling the different dryland technologies for increasing the productivity. I appreciate the efforts of the scientists of ORP and AICRPDA, Bangalore and congratulate them for bringing out an excellent publication.

March, 2014
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(M.A. SHANKAR)
Director of Research, UASB

ACKNOWLEDGEMENT

All India Co-ordinated Research Project for Dryland Agriculture, Bangalore centre came into existence during 1971 under the joint auspicious of ICAR and Canadian International Development Agency (CIDA) to meet the Dryland research needs of the *Alfisol* regions of Karnataka in particular and the country in general. During 1970's, the approach has been sectorial, which gave way to system approach in 1980's, to solve the location specific problems. Further, long-term experiments in major production systems including rainwater management, integrated nutrient management, water productive crops, energy management, cropping system and alternate land use systems have been the key area of research for sustainable dryland agriculture and the findings are validated on large scale plot at farmer's field, through Operational Research Project since 1976 in different districts of the domain ACZ. This has enhanced the productivity of crops apart from upscaling of technologies and increased the confidence level.

The achievements of demonstrations and lessions learnt are documented as "Thirty Five Years of Operational Research Project for Dryland Agriculture: Achievements and Impacts (1976 to 2012)". This book contains the salient findings of on-farm demonstrations which are critically analysed and interpreted with appropriate illustrations. We hope that this information will be useful and user friendly by a novice to the dryland agriculture and watershed management.

The authors express their profound gratitude to Dr. K. Narayana Gowda, Honourable Vice Chancellor, Dr. M.A. Shankar, Director of Research, Dr. D Nuthan, Associate Director of Research, University of Agricultural Sciences, Bangalore, for their encouragement, valuable guidance, professional and administrative support in bringing out this publication. Team is equally grateful to Dr. A.K. Sikka, Deputy Director General (NRM) and Dr. B. Mohan Kumar, Assistant Director General (Agronomy and Agro-forestry) ICAR, New Delhi, Dr. B. Venkateshwarlu and Dr. M. Maheswari former and present Director, CRIDA, Dr. G.R. Maruthi Sankar and Dr. Ch. Srinivasa Rao former and present Project Co-ordinators, AICRP (Dryland Research), and his team at CRIDA, Hyderabad for their valuable suggestions and financial support through National Initiative on Climate Resilient Agriculture project, which helped this publication to see the light of the day.

It is with deep sense of appreciation and gratitude we acknowledge the co-operation and support received directly or indirectly from the former Chief Scientists and Scientists of AICRPDA and ORP, other supporting staff and Senior Research Fellows of Dryland Agriculture Project, UAS, GKVK, Bangalore for their help in the preparation of this book.

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I. INTRODUCTION

Agriculture is the backbone of Indian economy and rainfed agro-ecosystem occupies an important place in Indian agriculture, covering 68 per cent of the cultivated area (96 m.ha) supporting 40 per cent human, 60 per cent livestock population and producing 44 per cent of the food requirements thus playing a pivotal role in India's food security.

Five out of ten Agro-Climatic Zones in Karnataka were classified as dry zones covering 63 per cent of the total geographical area and 71 per cent of the net sown area, with substantial contribution to agricultural production from dry lands. About 57 per cent of food grain production in Karnataka comes from rainfed areas while, 97 per cent of total pulses and 80 per cent oilseeds were produced in dry land areas.

Research on dryland agriculture in the red soil regions of Karnataka was started in 1970 with the establishment of All India Coordinated Research Project for Dryland Agriculture (AICRPDA) at Gandhi Krishi Vignana Kendra (GKVK), Bangalore, as one of the 23 centers located in eight agro-climatic regions of the country with the following objectives.

- To characterize the basic resources of the region regarding rainfall, soil and vegetation.
- To device methods of conserving soil and water resources.
- To device techniques for stabilizing dryland agriculture production through alternative strategies and contingent plans.
- To generate technology for crop production.
- To bring crop improvement for rainfed conditions and
- To test and validate the research findings through on –farm studies.

The technologies developed at research centers are to be transferred through various methods. Realizing the importance of dryland agriculture, it was strongly felt that there should be a direct link between Scientists and farmers in identifying and analyzing the problem / constraints and evolve site specific, need based solutions for dryland situation. With this in view, Operational Research Project (ORP) was launched during 1976-77 by the ICAR to transfer the technologies from research centers to the farmer's field as a joint venture of Indo-Canadian technical collaboration with the following objectives.

- To understand the strength and weakness of the traditional system of dryland agriculture
- To evaluate the performance of each component of dryland technology under the farmers management conditions
- To assess the technology refinement, diffusion and to provide feedback to the scientists of main center

- To identify operational and institutional constraints in the transfer of dryland technology
- To provide consultancy services to the extension agencies for transfer of dryland technology

The Operational Research Project (ORP) for Dryland Agriculture was initiated by the ICAR during 1976-77 under UAS Bangalore, Karnataka. It serves as bridge unit between research station and farmers. The domain area of the operation is detailed in Table 1 and the location map is indicated in Annexure 1..

Table 1. Domain area of operation of Operational Research Project, Bangalore center

Village	Altitude Latitude/ Longitude	Tehsil / District	Year of Start	Year of end
Alanatha cluster	12^0 23` N / $77^0$ 31` E / 968 MSL	Kanakapura taluk, Ramanagara Dist.	2010-11	Continued
Chikkamaranahalli (C.M.Halli),	13 ^{0}6' N / $77^0$19' E / 896-970 MSL	Nelamangala taluk Bangalore Rural Dist	2006-07	2009-10
Malenanayakaranda halli (MN halli)	13^0 24' N / 77^0 30' E / 890 MSL	Doddaballapur taluk, Bangalore Rural Dist	2003-04	2005-06
Doddagangawadi	12^0 47` N / $77^0$ 12` E / 870-980 MSL	Ramanagara Taluk. Bangalore Rural Dist	1998-99	2002-03
Rajanukunte	13^o10"-13^o11" N / 77^o32"-77^o33" E / 862 - 915 MSL	Doddaballapur taluk, Bangalore Rural Dist	1976-77	1997-98

The soil and moisture conservation, water harvesting and recycling, crop varieties, soil health, nutrient management, crops and cropping system based technologies and alternate land use systems developed at main center were evaluated and validated in the project areas on large scale as detailed in Table 2.

Table 2. Area under operation in the domain villages of ORP

Village	Total Area (ha)	Cultivated area (ha)	Operational area (ha)
Alanatha cluster	1190.26	362.09	67.25
Chikkamaranahalli	137.00	117.00	40.60
Malenanayakarandahalli	817.60	128.13	46.46
Doddagangawadi	250.00	160.00	91.00
Rajanukunte	378.00	260.10	151.00

The technical interventions over years improved the socio-economic conditions and generated employment. The impact assessment of each technology adoption was carried out after three to five years of intervention.

The outcome of the technological interventions in the operational areas is presented here under;

II. RAJANUKUNTE-A MODEL MICRO WATERSHED (1976-1997)

The Operational research project was extended in three villages Viz., Singanayakanahalli, Honnenahalli and Rajanukunte in 1976. During the first phase, ORP activities were confined to crops and crop management till 1980. The interventions were introduction of improved varieties, fertilizer and other agronomic management of crops, land development and inter-terrace management, agricultural implements, alternate crops. The following were the technological interventions and the impacts

1. Improved finger millet variety (Indaf-3) performed better over local variety with an yield increase of >100 per cent
2. Line sowing of finger millet recorded higher grain (60%) and straw (43%) yield over control
3. Recommended dose of fertilizer recorded 75 per cent higher grain yield of finger millet over farmers practice
4. Response on finger millet varieties to fertilizer varies greatly. The response to recommended fertilizer (50:50:25kg NPK ha^{-1}) is poor in local varieties (24%) compared to improved verities (65–131%)
5. Recommended management practices (Drill sowing & gap filling) in finger millet recorded 24per cent higher grain yield than farmers practice (Broadcasting in plough furrow and heavy thinning with cross cultivation)
6. Graded border strips recorded higher yield advantage (41%) in finger millet over control
7. In Preparatory tillage, fall ploughing with iron (MB) plough recorded higher grain (37%) and straw (32%) yield than ploughing with wooden plough
8. Maize hybrid Deccan-101 recorded 11 per cent higher grain yield over local variety
9. Maize sowing in flat bed on a grade performed better than ridging
10. Balanced fertilization (3:2:1) in maize resulted in 28 per cent higher yield over control and the response varies with genotypes (24 to 32%)
11. Redgram could be successfully grown with adequate plant protection measures
12. Chilli tried as an alternate crop and observed harvesting green chilli is more useful to the farmers than dry chilli because of early harvesting and proximity to the market
13. Double cropping of fodder maize + cowpea as first crop for fodder followed by finger millet recorded a fodder yield of 12600 kg ha^{-1} in first season. The finger millet yield was 1000 and 1300 kg ha^{-1} under farmer's management and recommended fertilizer level, respectively

14. Crop substitution with cowpea in place of horsegram performed better
15. Intercropping of pegionpea in groundnut and soybean in finger millet was found superior

However, with the emergence of the concept of watershed approach for integrated dryland development in 1980's, the objectives of the ORP were redefined as follows.

- To develop location specific practices
- To conserve natural resources and to improve the productivity of both arable and non-arable lands
- To take up validation and verification trials on the technology developed at research stations
- To provide necessary feed back to the scientist at the research stations
- To develop alternative land use systems
- To organize training programmes for the farmers to acquire latest technical skills in agriculture
- To involve farmers in watershed development programmes and maintenance of developed assets
- To document the changes in production environment

With the revision of the objectives, the ORP activities were shifted to Adde Viswanathapura, Chokkanahalli, Shanubhoganhalli and Rajanukunte from earlier Singanayakanahally by selecting a micro-catchment of 378 hectare during 1981-82. The site is situated at 13°10" to 13°11" N latitude and 77°32" to 77°33" E longitude at an elevation of 862 to 915 m above MSL and about 17 km to the North from the main campus of UAS Bangalore.

Climate and soils

The climate of the area is semi-arid subtropical with a mean annual rainfall of 870 mm in 42 rainy days. The mean annual temperature is 23.6°C and mean maximum and minimum temperature is 33.4 and 15.0°C, respectively.

The soils of the area are red sandy to red loam in texture with low fertility status and water holding capacity is 10 cm per meter depth. Soil crusting is a major problem leading to severe runoff.

Socio-economic features

Bench mark survey of the watershed was conducted during 1980-81 before the project implementation as a part of socio-economic study. The analysis indicated that the area is predominantly agriculture-based and nearly 90 per cent of the holdings are under drylands.

Production constraints

The crop yields in the project area were very low and the continuous degradation process accelerated by unscientific practices had resulted in intensive exploitation of natural resources drastically reducing their productive capacity over time on one hand and high temporal and spatial fluctuations in yield on the other. The major production constraints in the region are;

- The distribution of rainfall is highly erratic with long dry spell observed during July-August affecting crop growth and yields
- Unabated and high velocity runoff resulting in widening and extension of gullies assuming alarming proportion in the area
- Lack of vegetative cover in non-arable lands subjecting them to severe soil erosion
- Soil crusting upon drying not only affected germination, but also resulted in severe soil erosion
- Emerging nutrient deficiencies
- Increasing population pressure forced marginal lands for cultivation
- Small and fragmented holdings, low income and investment capacity hindered adoption of improved practices

Characterization of soils and land capability classification

The watershed is characterized for the land capabilities and presented in Table 3 and Fig. 1. About 68 per cent of the area is under land capability classes of II–IV (Arable land) while the rest (32 %) is under class IV and VIII (Non-arable land).

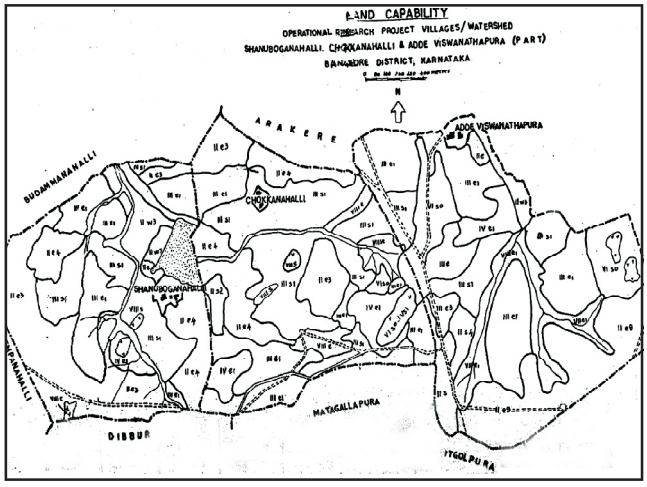


Fig. 1 Land capability classification of Rajanukunte watershed

Table 3. Land capability classification of Rajanukunte watershed

Unit	Description	Area (ha)	Percentage
II	Good cultivable land with problems of erosion, heavy soils	54.63	14.45
II	Good cultivable land, problem of erosion	37.54	9.93
II	Good cultivable land with problems of erosion, low fertility	24.26	6.42
II	Good cultivable land, low moisture retentive capacity	3.09	0.81
II	Good cultivable land, with problems of wetness, heavy texture	12.40	3.28
II	Good cultivable land, with problems of wetness, stagnation of water and high water table	2.13	0.56
	Sub total	**134.05**	**35.46**
III	Moderately good cultivable land with problem of erosion	40.12	10.61
III	Moderately good land with problems of erosion, crust formation	58.49	15.47
	Sub total	**98.61**	**26.08**
IV	Fairly good land with limitations of erosion hazard, shallow rooting depth, low water holding capacity and low fertility	27.44	7.26
IV	Gently sloping mound and mound tops with limitations of high percentage of stones and gravels, shallow rooting depth, severely eroded low water holding capacity and low fertility	53.70	14.21
IV	Gently sloping mound and mound tops with limitations of high percentage of rockout crop; suitable for farm forestry	15.16	4.01
	Sub total	**96.30**	**25.48**
VIII	Highly eroded gullies, gully plugging and stabilization by maintaining grass cover etc.	18.98	5.02
VIII	Rock mound and ridges suitable for recreation	5.09	1.34
	Sub total	**24.07**	**6.36**
	Miscellaneous (habitation, tank etc.)	**25.07**	**6.63**
	Grand total	**378.00**	**100**

Project planning, implementation and performance

A comprehensive 'Master Plan' was prepared identifying site specific and need based treatments. Master Plan was bifurcated into annual action plan initially for a period of five years. The beneficiaries were involved right from the planning stage for identifying the problems and suggestions in developing treatment plans. State Forest Department, Central Fodder Research Institute Hesaraghatta and Watershed Development team, Chitravati were involved in supply of sapling / seeds and other physical facilities during the initial period.

Salient findings

Soil and moisture conservation

The undulating topography, lack of vegetation and improper land and crop management in the project area had resulted in severe soil erosion from both arable and non-arable lands causing gully formation warranting an urgent need for immediate soil conservation measures. Keeping this in view, the following alternate land use systems were taken up to arrest land degradation (Table 4).

Table 4. Impact of technological interventions on land use pattern.

Particulars		Area (ha)	
		Bench mark year 1987	1995-96
I. Arable land (213 ha)			
	i) Agro-forestry	-	25
	ii) Horticulture	-	8
	iii) Agri- horticulture	-	10
	iv) Agriculture	213	170
II. Non-arable land (116 ha)			
	i) Silvi—pasture	-	36
	ii) Silvi-horti pasture	-	49
	iii) Horti pasture	-	5
	iv) Pasture	-	26
	v) Unproductive land	116	-

Non-arable lands

The catchment had about 116 ha under non arable land which was almost devoid of vegetation. They are not only aggravating erosion forming gullies on non-arable lands, but also affecting the adjacent arable lands. In order to prevent further expansion of gullies, diversion drains were provided on the periphery of gullies and ravines as well as between arable and non-arable lands with a carrying capacity of 0.03 cum per sec per ha. A Channel slope of 0.5 to 2 per

cent was maintained for smooth flow of water and drop structures with a combination of both vegetation and stones at vertical intervals of 0.5 to 1 m to check the velocity of water in the drains. The water from these drains was led to natural water courses by stabilizing the waste weirs either by boulder checks or vegetation or both (chutes). The banks of the diversion drains were stabilized by planting agave, kikiyu and khus grasses.

The experience revealed that, the vegetative drop structure functioned as effectively as mechanical structures in the drains under gentle slope. Later were inevitable at points where there was a steep gradient and in turn had to be stabilized with vegetation. Similarly, stabilizing waste weirs with vegetative measures was cost effective and long lasting but had to be complemented with mechanical (boulder) structures during the initial 2-3 years period. Chute spill ways were constructed where the drops were more than 3m incurring an expenditure of about Rs. 6,500 each. When untreated, it was observed that the gullies were extending at a rate of 5-6 m per annum which could be effectively prevented by the diversion from non-arable lands entering the arable lands.

Staggered catch pits (0.5 X 0.5 X 2 m) were provided in the non-arable lands of class VI and VII to increase water storage helpful in providing continued moisture availability to the newly planted saplings.

Staggered trenches and 'V' ditches were opened on contour at 4 m interval for planting silvi-horti saplings which were very effective for *in situ* conservation of soil and moisture. Between the two methods, the contour 'V' ditch proved to be a better technique for conserving moisture.

There was hardly any production from the existing 116 ha of non- arable lands in the watershed area. The area has been developed under various systems in a phased manner over a period of 10 years.

Silvi and silvi-pasture system

Out of the 97 ha of Class VI and VII land, about 36 ha have been brought under silvi / silvi- pasture system. The species like *Acasia auriculiformis, Dalbergia sisoo*, silver oak, *Cassia seamia*, Caliandra, *Vinga dulcea*, neem, pongamia, bage etc., catering to the various needs of the local community have been planted in staggered contour trenches, 'V' ditches. The inter-terrace area as well as the mound have been covered with *Stylozanthus scabra* and *Stylozanthus hamata*, which are nutritionally rich leguminous fodder species. *Acasia auriculiformis* was vigorous and suppressed other vegetation at later stage and its economic utility was limited for fuel.

Silvi-Horti-pature system

An area of about 29 ha of community land around the water harvesting structure was brought under silvi-horti-pasture system by introducing the mango, jambulana, jack, custard

apple, tamarind, emblica, wood apple, teak, mahua, pongamia, casuarina, silver oak in addition to pasture species like *Cassia rotundifolia*, *Stylozanthus scabra*, *Stylozanthus hamata* and napier (NB-21) and signal grasses. Besides, an area of about 5 ha has been brought exclusively under different varieties of mango with *Cassia rotundifolia* as forage component under horti-pastural system. Among the forage species, *S. scabra* and *S. hamata* recorded about 25 MT ha^{-1} of green fodder annually during the initial 3-5 years period against *Cassia rotundifolia* (12 MT ha^{-1}). Further, it was observed that these forage species could act as good soil binding agent apart from enriching the soil with organic matter and nitrogen as they are leguminous.

The remaining part of the non-arable land mainly comprising the gullies and ravines was also brought under planting different species. Thus, almost the entire non-arable land in the catchment has been brought under production by the project. These plant species could establish well giving a good canopy cover and improving the soil health through addition of leaf litter.

Arable land

The holdings were fragmented and scattered with no proper bunding / conservation measures. Nearly 40 per cent of the cultivators were basically *nomads* with their traditional occupation of street players with cows for their livelihood thus, paying little attention to agriculture. The project staff could motivate these people to consolidate their holdings to an extent of about 40 ha and redefine the boundaries to facilitate conservation works to be taken up by the project.

Graded border strips and graded bunds were found suitable on the research station and were recommended to the famers. However, due to small holdings, they were difficult to implement on the farmers' field. Alternatively, it was suggested to strengthen the existing field bunds, adopt land smoothening to provide the required gradient ultimately leading the surplus weirs smoothly to the developed water ways. These suggestions worked well and are being adopted on large scale in the state watersheds. The performance of land treatment on the yield of finger millet is presented in Table 5. The grain and straw yields were increased to an extent of 66.7 to 87.9 per cent and 72.9 to 108.3 per cent, respectively with improved practices with different land treatment.

Table 5. Performance of land treatment on the yield of finger millet (mean of 5 years)

Land treatments	Yield of finger millet (kg ha^{-1})					
	With farmers practice		With improved practice		Percentage increase	
	Grain	Straw	Grain	Straw	Grain	Straw
Graded border strips (GBS)	1490	1560	2800	3250	87.9	108.3
Graded bunds (GB)	1310	1420	2300	2590	75.6	82.4
Strengthening of existing bunds	1230	1330	2050	2300	66.7	72.9
Control	990	1060	1210	1310	22.2	23.6

Water ways: There were little surplusing arrangements in the area and the haphazard runoff had resulted in soil erosion in arable lands. Water ways were provided to the entire arable land for safe disposal of excess runoff from these lands to the natural water courses and were stabilized mainly with kikuyu / *Lotononis* and provided with khus or mechanical structures wherever needed.

Inter-terrace management: Inter-terrace management is crucial as long term soil and moisture conservation works like bunding to ensure uniform and long moisture availability to the crop.

Inter-terrace area was smoothened by cutting the local humps and filling depressions using wooden leveler. Most of the farmers (40 farmers over 60 ha area) have been motivated to take up fall ploughing soon after the crop harvest and deep ploughing with K.M plough at least once a year for better infiltration of water. Small section bunds on contour at an interval of 10 m and a plough furrow at 3m interval are the practices suggested for inter-terrace moisture conservation. Since the pebbles were available in plenty within the area, same has been picked up and used for the erection of the small section bunds.

Farm ponds: Four farm ponds of different capacity ranging from 250 to 800 cu. m. have been excavated to harvest part of the inevitable runoff at the identified locations. One of the pond of 800 cu. m. capacity has been lined with cement and soil (1:8) to reduce percolation losses and has been provided with picota. The pond water was used for raising nursery and fish rearing apart from protective irrigation. The water from other three ponds is being used to grow vegetables on a small patch of land and provide protective irrigation to adjacent newly planted horticultural plants.

The existing land and crop management practices posed lower productivity. Several improved production practices were introduced during the project period to augment increased production on the arable lands. The practices introduced are;

Agro-forestry: About 25 ha of land under contour bunds with open ends were brought under agro-forestry to supplement the returns from agriculture. The tree species viz., *A. auriculiformis*, silver oak, casuarina and caliandra were planted on the bunds as monoculture. Among the four species introduced *A.auriculiformis* established well and fast growing, but was not preferred by the farmers because of high crop interference. While, silver oak and casuarina because of their tall growing nature and having least shade effect were found to compatible with annual crops. However, caliandra, being a leguminous fodder tree prone for grazing found difficult to establish. The lopping from the tree species could yield 10-15 kg of fuel per tree per season after three years. In addition, it has been estimated that, the tree could fetch about Rs.8000-10,000/- per hectare in the seventh year. The yield loss of annual crops due to shade effect of the tree species was compensated from the annual side lopping alone.

Horticulture: About 8.0 ha of unproductive wastelands reclaimed after the nala bunding was brought under horticulture by planting guava, papaya, vegetables and flower crops. The area which was abandoned as worthless is now worth Rs. 10 lakhs per ha.

Agriculture: The major crops of the region are finger millet, groundnut and maize. Field bean, niger, fodder jowar etc., being cultivated as mixed crops with finger millet/groundnut. The rainfall distribution being limited to four months, there is a limited scope for double cropping. Horsegram is cultivated on a limited area as late *kharif* mostly as a contingent crop. The project could introduce new crops/varieties and improved practices.

Introduction of new crops and varieties: Sunflower, pigeonpea, chilli, soybean and dryland tomato were introduced by the project as alternate high value crops in the area. Among the five crops, redgram and dryland tomato have been accepted well in the area. Pigeonpea (TTB-7) has occupied about 10 per cent of the cultivated lands as pure crop apart from being an intercrop in most of the area under finger millet and groundnut (60%), while dry land tomato occupied about 8 per cent of the cultivated area and chilli (Cv.Ceylon and Chikkaballapur local) cultivated in a very limited area. Sunflower and soybean crops could not find place with the farmers due to higher pest menace and lack of market. Dryland mulberry was also tried but could not make noticeable impact and was confined to small area under protective irrigation.

Finger millet being the staple food crop of the area occupied larger proportion of the cultivated land. Nearly 80 per cent of the crop area was under long duration local variety Karikaddi which was low yielder of grain but had relatively higher fodder yield potential. Over the years, the sincere efforts of the project staff have completely replaced the local variety by improved variety. A number of improved finger millet varieties have been introduced with a choice to suit the time of sowing. It was observed that the improved varieties recorded greater (>100%) grain yield than that the local variety and the increase was more pronounced under delayed sowing (Table 6). Indaf-8, MR-1 and HR-911 being long duration varieties were more suited for early sowing (July) while the short duration Indaf-5 and PR-202 were better suited to late sowing (August).

The groundnut variety cultivated in the area was mainly TMV-2 but after the introduction of JL-24 by the project, the latter has occupied the major area under the crop. JL-24 because of its bold seeds and higher yield (15%) it was preferred by the farmers over TMV-2.

Similarly, hybrid maize varieties Deccan-101, Ganga-5 and Ganga-11 have replaced the earlier low yielding local varieties of maize. Among the new cultivars, Ganga-5 was preferred because of higher demand for puff as the location is near to the Bangalore city.

Table 6. Grain yield (kg/ha) of improved finger millet genotypes under different periods sowing (Mean of 3 years).

Sl. No.	Variety	Duration (days)	Time of sowing			
			I Fortnight of July	II Fortnight of July	I Fortnight of August	II Fortnight of August
1	Local	135	835	912	655	116
2	Indaf-8	125	1860	2010	1610	910
3	HR-911	122	2160	2060	1680	1120
4	Indaf-5	109	1560	1860	1910	1980
5	PR-202	112	1280	1610	1690	1720
6	MR-1	121	1910	2120	1660	1280

Intercropping system

The major objective of watershed development is to increase land productivity through better utilization of land and soil moisture. Mixed cropping of local varieties were prevailing in the locality. The concept of intercropping, growing two or more crops simultaneously with definite row ratios were taught as an insurance against uncertain soil moisture situation and various crop combinations (intercropping systems) were tried for achieving higher land use equivalent in the project. The most promising systems for the operational area were groundnut + pigeonpea (8:2), finger millet + pigeonpea (10:2) and maize + pigeonpea (8:2) compared to cowpea, field bean and sunflower intercropped in finger millet and groundnut. These intercropping systems have completely replaced the traditional mixed cropping in the area (Table 7).

Table 7. Finger millet equivalent yield and economics of different intercropping system

Cropping system	(kg ha^{-1})	FM (kg ha^{-1})	GN (kg ha^{-1})	PPFM Eq. Yield (kg ha^{-1})	Input Cost (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net Return
Sole FM	2840	-	-	2840	2200	8520	6320
FM + PP	2380	-	320	3233	2500	9700	7200
Sole GN	-	1320	-	3520	3300	10560	7260
GN + PP	-	1180	310	3973	3500	11.920	8120
Sole PP	-	-	1020	2720	2000	81600	6160

Note : cost of the commodities: FM: Rs. 3.00 kg^{-1}, GN & PP: Rs. 8.00 kg^{-1}

FM: Finger millet PP: Pigeonpea GN: Groundnut

Nutrient management

The soils are highly eroded and have low fertility and moisture holding capacity. Further, the nutrient management was very poor which was one of the reasons for low yields in the area. Demonstrations were conducted on nutrient management like use of balanced fertilizers, placement of fertilizers and resource allocation.

The bench mark survey revealed that, the location was under nourished with lower application of organic manure (about 2-3 tons of FYM ha^{-1}), use of imbalanced and lower dosage of chemical fertilizers (20:30: 0 kg of NPK for cereals and 18:43:0 kg of NPK to groundnut in the form of DAP and Urea).

Trials on resource reallocation by utilizing the same amount of fertilizers by balancing the nutrients, through straight fertilizer like Urea, SSP and MOP indicated that crop yields could be increased by 9-12 per cent. The increase in yield was to the tune of 22-25 per cent when improved soil and moisture conservation measures were combined with balanced nutrition. Mixing finger millet seeds with DAP (1:6 ratio) and placing using seed-cum-fertilizer drill increased the crop yield by about 20-25 per cent compared to the broadcasting of fertilizers. Under different land capability classes indicated that, the crop response was good and the marginal returns were higher than marginal cost even up to 150 per cent of recommended dose in capability Class III and IV, while the response in Class VI was very poor at higher doses (Table 8). Conjunctive use of chemical fertilizers for balanced nutrition in the operational area is achieved over a period of 6 years from 1989 to 1995.

Table 8. Grain and straw yield of finger millet as influenced by fertilizer levels under different land capability classes (Average of four farmers)

Fertilizer levels	Land capability class (kg ha^{-1})					
	III		IV		VI	
	Grain	Straw	Grain	Straw	Grain	Straw
Control	1480	1570	1120	1310	980	1160
50% of recommended dose	1920	2100	1540	1820	1410	1580
100% of recommended dose	2520	2740	2180	2300	1620	1770
150% of recommended dose	2620	3080	2180	2460	1780	1920

Improved implements

A number of bullock drawn improved implements like bent tine hoe, multi-furrow opener, seed-cum-fertilizer drill for both finger millet and groundnut and two tine hoe to suit the local draft power have been designed, fabricated and demonstrated under the project. Use of these implements facilitated efficient, speedy and timely operation, wider area coverage and consequently higher yields. Use of seed cum fertilizer drill in finger millet for sowing has resulted in higher grain (46.5%) and straw (64.9%) yield over control (Table 9). These implements became popular not only in the area of operation but, also expanded horizontally in the other areas as well through State Department of Agriculture.

Table 9. Comparative performances of different methods of sowing in finger millet

Sl. No.	Method of sowing Grain	Yield (kg/ha)		% increase over control	
		Straw	Grain	Straw	
1	Plough furrow	1730	2270	21.8	32.7
2	Seed-cum-fertilizer drill	2080	2820	46.5	64.9
3	Mixing DAP with seed	1890	2600	33.1	52.1
4	Control	1420	1710	-	-

Human Resource Development

As the farmers within the watershed and surrounding areas were not exposed to improved crop production technologies under dryland conditions, the ORP focused its major attention on upgradation of knowledge and skills. People were involved right from resource inventory through planning, implementation and management of developed assets. Village resource committees, youth clubs, mahila mandals, milk producer's co-operative society, custom hiring center, input supply center and local implements fabrication unit were formed for ensuring active community participation in the programme. The groups were also provided leadership opportunity in management and use of developed community assets apart from other community services like animal health camps, liaising with line departments for linkage to credit and inputs in agriculture, horticulture, sericulture, forestry, primary education etc. and many fold rural development programme in terms of roads, street lights, drinking water, nutritional gardens, smokeless chulas etc.

Apart from these, periodic demonstration/training programmes on resource conservation, improved crop production practices, livestock management, integrated forest management, Environmental awareness, plant propagation, harvest and post-harvest technologies etc., under lab to land program, front line demonstration and other similar programmes were organized under the project. Field days and educational tours were also arranged for creating awareness.

Impact assessment

The watershed has been developed as a model depicting all aspects of development of various production system and resource management practice towards sustainable dryland system. The impact assessments of the various technological interventions discussed above were ascertained during 1994 to 1997 considering the yield of major crops between watershed and non-watershed farmers. The yield levels were 46, 48 and 57 per cent in finger millet, groundnut and pigeonpea, respectively considering the mean of four years and 25 farmers due to adoption of seed-cum-fertilizer drill, top dressing and use of plant protection chemicals (Table 10). The watershed is serving as a living example for the user departments for replication and as an

education center for disseminating the concepts of resource conservation and integrated dryland development.

Table 10. Comparative average (25-farmers) yield (kg ha^{-1}) of finger millet, groundnut and redgram in watershed (W) and non-watershed (NW) area over 4 years.

Crop	1994		1995		1996		1997		Mean		% increase
	W	NW	W	NW	W	NW	W	NW	W	NW	
Finger millet	1930	1120	2720	2080	2240	1530	2540	1630	2240	1530	46.0
Groundnut	1120	700	1240	970	920	690	910	680	1100	740	48.0
Redgram	850	400	920	850	720	540	730	480	770	490	57.0

III. Doddaganganawadi sub-watershed (1998-2003)

Consequent to the conclusion of the Rajanukunte watershed programme during 1998 the ORP site was shifted to Doddaganganawadi sub-watershed at Ramanagara Taluk.

The newly selected ORP at Doddaganganawadi is one of the micro-watershed under the NWDPRA, Jalamangal sub-watershed located in the Agro-climatic Zone-V (Eastern Dry Zone). The micro-watershed comprises four villages viz., Veeregowdanadoddi, Channegowdana doddi, Adhishakthihalli and Doddaganganawadi having 250 ha out of 700.12 ha sub-watershed. The micro-watershed has about 68 ha non-arable and 160 ha arable lands, while about 22 ha are under non-agricultural uses (Table 11). The micro-watershed is located at a distance of 68 km away from the Bangalore on Ramanagara-Magadi road, about 18 km from Ramanagara town and 8 km from Kootagal village, the hobli head quarter.

The survey on land use in the ORP watershed revealed that, the 80 per cent of the area is suitable for agriculture and remaining 20 per cent for developing permanent vegetative cover except in the drainage line and it is proposed for establishment of suitable water harvesting structure. About 10 per cent of the total area within the catchment is highly eroded with gully formation and it has to be reclaimed to arrest further deterioration through bio-engineering techniques (Table 11).

Table 11. Land use system in Doddaganganawadi sub-watershed

Prevailing Land use system	Area (ha)	Proposed land use	Area (ha)	Percentage
1. Non-arable	68.00	a. Block plantation	5.00	2.0
a. Community land		b. Silvi pasture	15.00	6.0
b. Govt. land		c. Horti-silvi pasture	15.00	6.0
c. Private land		d. Orchard horticulture	30.00	12.0
d. Water course		e. Water spread area	3.00	1.2
Sub total	**68.00**		**68.00**	**27.2**
2. Arable land				
a. Dry land	157.30	a. Agro-forestry	107.00	42.8
b. Garden land	2.70	b. Agri-horticulture	40.00	16.0
		c. Orchard horticulture	10.00	4.0
Sub total	**160.00**		**157.00**	**62.8**
3. Habitation	**22.00**		**25.00**	**10.0**
Grand total	**250.00**		**250.00**	**100.0**

The total area of the sub-watershed is characterized for different land capability classes (Table 12). The larger proportion of the area was under Class III (42.4%) followed by Class VI (20.0%) and Class IV (14.4%).

Table 12. Land capability classes in Doddaganganawadi sub-watershed

Class	Area (ha)	Percentage	Suitability
Class II	18	7.2	Agri / Horticulture
Class III	106	42.4	Agri / Horti / Agro-forestry, Agri - Horti
Class IV	36	14.4	Agri / Horti, Agri-Horti, Agro-Forestry
Class V	5	2.0	Afforestration and pasture (Water logged)
Class VI	50	20.0	Afforestration / Horti-Pasture / Silvi-Pasture
Class VII	29	11.6	Pasture / Horti on limited scale
Class VIII	6	2.4	Recreation and wild life
Total	**250**		

RAINFALL

The area receives an average of 826.3 mm of rainfall with 48 rainy days in bimodal distribution with the first peak in April-May and second in September to October (Table 13).

Table 13. Rainfall distribution (mm) in Doddaganganawadi sub-watershed

Year/month	1999	2000	2001	2002	Normal
January	0.0	0.0	0.0	0.0	0.0
February	0.0	9.0	0.0	0.0	0.0
March	0.0	0.0	4.2	4.6	4.4
April	95.8	82.5	141.3	19.5	43.2
May	116.0	75.0	25.3	156.4	77.9
June	46.8	56.5	3.2	77.3	84.3
July	30.0	105.4	37.9	63.8	89.9
August	138.1	258.7	102.4	30.2	129.5
September	212.1	242.2	363.7	72.4	169.9
October	466.3	337.6	146.4	89.6	187.9

November	105.5	12.1	115.2	52.0	31.4
December	7.5	1.8	0.0	0.0	7.9
Total	**1218.1**	**1180.8**	**939.6**	**565.8**	**826.3**
No. of rainy days	**68**	**70**	**54**	**42**	**48**

TOPOGRAPHY

The area has undulating topography with slope ranging between 1 to 5 and 5 to 12 per cent in arable and non –arable lands respectively. The area is intercepted with lot of rock out crops. The treatment map has been prepared according to the land capability classes and beneficiaries desire by adopting participatory rural appraisal (PRA) technique.

SOILS

The Soils are red sandy to sandy loam and soil depth ranging from very shallow (<10 cm) in the upper reaches to 30-40 cm in the middle and lower reaches. The soil fertility is poor and has low water holding capacity. The pH of the soils was slightly acidic to neutral, high in organic matter content and medium to low in available nutrients (Table 14).

Table 14. Physico-chemical properties of soils in the study area.

Village	Texture	MWHC (%)	pH (dsm^{-1})	EC (%)	OM ($kg\ ha^{-1}$)	N ($kg\ ha^{-1}$)	P_2O_5 ($kg\ ha^{-1}$)	K_2O
Veeregowdanadoddi	Loamy	30.34	6.53	0.12	0.81	200.31	12.91	82.08
Channegowdanadoddi	Sandy loam	25.73	6.32	0.10	0.73	203.84	13.71	123.58
Adhishakthihalli	Sandy loam	24.53	6.10	0.08	0.53	196.00	18.51	108.34
Doddaganganawadi	Loamy	34.34	6.40	0.11	0.93	244.61	22.61	102.60

NATURAL VEGETATION

The area is sparsely vegetative dominated by shrubs like *Deudinea viscose*, *Cassia* species, agave and trees like neem, *Acasia* species, *Ficus* species in the upper reaches and pongamia, bamboo in the valleys. Economic trees like tamarind, mango and jack are also found in private holdings.

SOCIO-ECONOMIC FEATURES

The socio-economic features of the sub-watershed revealed that the population inhabitation in the sub-watershed of 1855 comprising of 959 males and 896 females. There were 227 farm families and 147 labour families (88-agriculture and 55 non-agriculture respectively). The literacy is about 37 per cent, majority of the farmers are small and marginal.

Animal husbandry particularly dairy and sheep rearing are the important activities. The economic condition was generally poor (Table 15).

Table 15. Socio-economic features of Doddaganganawadi micro-watershed

Particulars	Quantity
Marginal farmers (<1.0 ha)	68 (30%)
Small to medium (1.0 – 2.0 ha)	125 (55%)
Medium to big (>3.0 ha)	34 (15%)
Male	959
Female	968
Literacy	37%
Agricultural labourers	88
Non-agricultural labourers	55
Schedule caste	299
Schedule tribes	9
Primary & middle school	2

Particulars	Quantity
Mahila mandal	1
Dairy	1
Input society	1
Youth club	2
Post office	1
Cattle	180
Sheep	1400
Goat	240
Poultry	2000
Pig	5

Objectives:

a) On-farm research

i. To conserve natural resources like soil, rainwater and vegetation

ii. To impart stability of crop yield through improved crops and cropping systems

iii. To develop alternative land use system through horticulture, forestry and pasture

iv. To ensure the income and employment of individual by alternate enterprises

v. To restore ecological balance

b) Location specific objectives

i. To identify and list out the available technologies in different fields for the development of programme

ii. To take up testing, validation and adoptive trials of proven practices

iii. To identify new practices of crop and varieties and alternative land use systems specific to the watershed area

iv. To diagnose the constraints faced by the farmers in the adoption of recommended farming systems

v. To monitor the changes due to implementation of watershed development programme with bench mark survey and periodical evaluation

Salient findings of trials / demonstrations

A) Soil and moisture conservation

The area needs soil and moisture conservation activities of mechanical, biological and agronomic practices. The practices adopted are fall ploughing, deep ploughing and land smoothing with contour cultivation. Deep[ploughing showed an increase in yield of 540 kg ha^{-1} grain of finger millet and 200 kg ha^{-1} of groundnut over farmers method (Table 16) and ensured the favourable moisture regime in the soil and uniform crop growth.

Table 16. Effect of land treatment and improved practices on yield (kg ha^{-1}) of finger millet and groundnut in watershed area

Treatment	Improved practice				Farmer's practice			
	Finger millet		Groundnut		Finger millet		Groundnut	
	Grain	Straw	Pod	Haulm	Grain	Straw	Pod	Haulm
Deep ploughing	1900	2370	840	1050	1360	1570	640	780
Deep ploughing + land Smoothening + Contour cultn.	2390	2750	1050	1290	1620	1830	760	950

The effect of deep tillage using Kolar mould board iron plough verses wooden plough clearly indicated that deep ploughing could enhance the finger millet yield (Cv. GPU-28) by 18 per cent because of *in-situ* moisture conservation as compared to tillage with wooden plough.

The drill sowing was compared with dibbling and transplanting in pagadi system. The results revealed that the dibbling and transplanting in pagadi system was given 6 and 9 q/ha of increased grain yield of finger millet as compared to drill sowing, respectively (Table 17).

Table 17. Effect of different sowing practices on the yield (kg ha^{-1}) of finger millet

Sl No.	Treatment	Spacing (cm)	Grain (kg ha^{-1})	Straw (kg ha^{-1})	Pl. population / ha (Lakhs)	No. of tillers
1	Drill sowing	30 X 10	1850	2120	3.0	4
2	Dibbling in pagadi system	30 X 30	2450	2760	1.2	9
3	Transplanting in pagadi system	30 X 30	2750	2910	1.2	12

The agronomic practices viz., small section bund and opening of furrow at 2-3 seed drill width were unaccepted initially by the farmers. But in the 2nd and 3rd year due to heavy rains, they acted as disposal system of excess water and saved the crop from water stagnation.

In agri-horti system, the growth and its performance of mango grafts was studied with different mulching and pot irrigation, among the treatments coir pith mulch was found to be better followed by weed and pebble mulch.

Contour V-ditches and planting of forestry species were taken in 3.2 ha land under silvi pasture system and this was compared with the regular planting. The 'V' shaped ditches has helped in conservation of moisture and survival of plants upto 93 per cent compared to 82 per cent in normal practices in silver oak plants (Table 18)

Table 18. Survival per cent of silvi species due to land treatment

Treatment	Silvi species				Mean	Per cent increase
	Silver oak	Teak	Pongamia	Phyllanthus		
Contour trench	82	61	74	70	72	-
V-ditches	93	73	83	81	83	16

B) Rain water management

Intercropping of pigeonpea in finger millet cropping system with conservation furrow recorded higher finger millet equivalent yield (T_5: 2694 kg ha^{-1}) followed by paired row finger millet with two (T_3: 2230 kg ha^{-1}) and one (T_2: 2076 kg ha^{-1}) inter-cultivation and conservation furrow (Fig. 2).

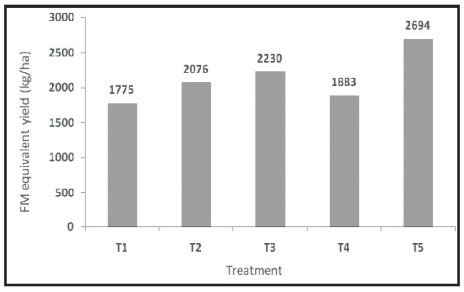


Fig 2. Finger millet equi. yield

C) Intercropping of pigeonpea in finger millet and groundnut

The trials on finger millet + pigeonpea and groundnut + pigeonpea intercropping at Doddagangawadi watershed attracted the farmers in and around the watershed. The farmers in the study area were previously growing finger millet with akkadi crop. About 5 ha area with groundnut + redgram intercropping was brought under oil seed front line demonstration during 2000, which has paved way for the dominance of the system. The trials conducted at Doddagangawadi indicated that the intercropping of finger millet with redgram in 10:2 ratio, finger millet with field bean or soybean in 4:1 ratio has shown 36 per cent higher yield over the farmer practice of finger millet with akkadi crop (Table 19).

Table 19. Yield and economics of finger millet intercropping with different pulses under recommended dryland technologies.

Sl. No.	Treatments	Grain	Seed	Cost of cultivation`	Gross income	Net income	Per cent increase over akkadi
		(kg ha^{-1})		(Rs. ha^{-1})			
1	Finger millet with akkadi	1810	65	3,000	5,755	2,755	-
2	FM + Pigeonpea (10:2)	1710	280	3,500	7,930	4,430	60.8
3	FM + Field bean (4:1)	1840	300	3,500	7,470	3,970	44.1
4	FM + Soybean (4:1)	1890	310	3,500	8,350	4,850	76.0

In another trial, finger millet+ pigeonpea and groundnut+ pigeonpea in 10:2 and 8:2 ratio has given a net return of Rs.4680 and Rs.9300, respectively (Table 20).

Table 20. Yield and economics of intercropping system adopted in Doddagangawadi watershed during 2001.

Treatments	FM Grain	Grout ndnu	Pigeo npea	akka di	Cost of cultn.	Gross income	Net income	Per cent increase over akkadi
	(kg ha^{-1})				(Rs. ha^{-1})			
Finger millet + akkadi	1820	-	-	65	3,000	5,785	2.785	-
FM + pigeonpea (10:2)	1790	-	280	-	3,500	8,170	4,670	67
GN + pigeonpea (8:2)	-	950	290	-	5,000	14,300	9,300	99

Note: Finger millet (FM): Rs. 300 q^{-1} Groundnut (GN): Rs. 1200 q^{-1}
Pigeonpea: Rs. 1000 q^{-1} Akkadi: Rs. 500 q^{-1}
Akkadi: Field bean, castor, pigeonpea, niger, jowar, cowpea in single row

D) Performance of tomato / chilli in watershed

The Pusa rubi variety was compared with Rainfed selections RS-1 and RS-2 released from IIHR, Hesarghatta, Bangalore in 10 farmers field during *Kharif* 2000. The improved varieties yielded higher yield of 16 and 19 per cent under dryland conditions and 28 and 32 per cent with 1-2 protective irrigation compared to Pusa rubi. Similarly the chilly variety Ceylon was also taken in the watershed to assess the yield with protective irrigation and mulching. The results revealed that, protective irrigation gave 30.4 and 43.4 per cent higher yield with mulching compared to dry crop (Table 21). Similar trends were observed during 2001. However, harvesting chillies for vegetable purpose as green chillies was found to be more remunerative than dry chillies because of the chance of exposure to end season moisture stress and severe incidence of fruit rot which require costly plant protection measures.

Table 21. Dry chilli yield and economics as influenced by protective irrigation and mulching

Treatment	Yield (kg ha^{-1})			Net income (Rs ha^{-1})	Per cent increase
	2000-01	2001-02	Mean		
Without irrigation	660	586	623	16,100	-
With irrigation	800	786	793	21,000	30.4
Irrigation + mulching	860	866	863	23,100	43.4

E) Integrated nutrient management

Non-availability of farm yard manure and introduction of high yielding varieties has led to dependence on inorganic fertilizers in the farming system. The research data revealed that, the continuous imbalanced application of fertilizers has deleterious effect on soil physical, chemical and biological activities and affected yield and soil health.

With an intension to create awareness to the farmers, a trial has been laid out in the watershed using organic and inorganic fertilizers in finger millet. After the two year trial it was observed that, application of recommended NPK yielded 1960 kg ha^{-1} followed by 50 per cent substitution with FYM (1830 kg ha^{-1}) and was lower with 50 per cent substitution of RDF with green leaf manure (Table 22).

Table 22. Yield of finger millet (kg ha^{-1}) under different INM practices at Doddagangawadi

Sl No.	Treatment	Yield (kg ha^{-1})
1	50% NPK + 50% FYM	1830
2	50% NPK + 50% green leaf manure	1780
3	50% FYM + 50% Green leaf manure	1520
4	100% NPK	1960
5	Control (Farmers practice)	1460

Fertilizers at farmer's and recommended level was tested under farmers and improved management practices for three years. Recommemded management practices with recommended fertilizer dosage recorded higher grain yield of finger millet (2510 kg ha^{-1}) followed by recommended management practices with farmer's level of fertilizer (2200 kg ha^{-1}), farmers management with recommended fertilizer (2110 kg ha^{-1}) and was lower with farmers management at farmers level of fertilizer. This has clearly indicated that the recommended management practices are key for higher yield followed by recommended fertilizers under dryland situation.

F) Crops and cropping systems

The trials on crops and cropping system revealed in finger millet (Fig.3) that, long duration varieties yielded higher than medium and short duration varieties. Among the long duration varieties, L-5 recorded higher grain yield (2562 kg ha^{-1}) and B:C ratio (2.17). In medium duration varieties, GPU-28 recorded higher grain yield (2126 kg ha^{-1}) and B:C ratio (1.96) compared to HR-911 (2061 kg ha^{-1} & 1.84, respectively). In short duration varieties, PR-202 recorded higher grain yield (1892 kg ha^{-1}) and B:C ratio (1.65) against GPU-26 (1746 kg ha^{-1} & 1.51, respectively) and local (1481 kg ha^{-1} & 0.97, respectively).

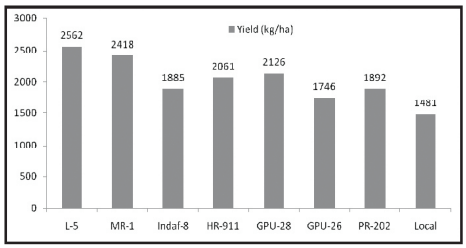
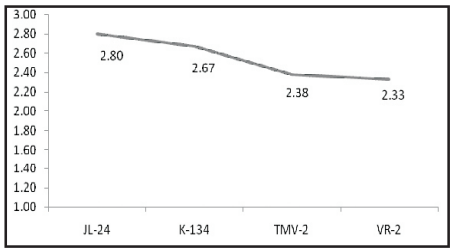


Fig. 3. Performance of finger millet varieties



In case of groundnut, the ruling varieties JL-24 and TMV-2 were tested against K-134 and VR-2 (Fig 4). JL-24 variety performed superior with B:C ratio (2.80) followed by K-134 (2.67) and TMV-2 (2.38). Similar trend was observed with respect to seed yield.

Fig 4. B:C ratio of groundnut varieties

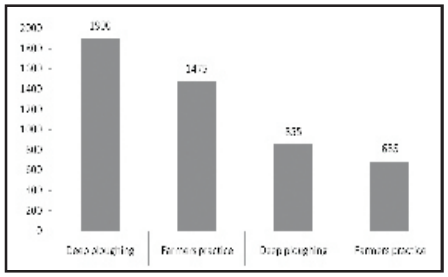
In soybean, the variety KHSB-2 recorded higher seed yield (2126 kg ha^{-1}) followed by MACS-124 (1978 kg ha^{-1}) and MACS-450 (1970 kg ha^{-1}). Hardee recorded lower yield (1850 kg ha^{-1}) among the tested genotypes. However, the farmer's are reluctant towards soybean cultivation in the watershed attributing to the marketing problems.

Three cowpea varieties were compared for their performance for 5 years. The pooled data indicated that, higher seed yield was noticed in KBC-2 (493 kg ha^{-1}) followed by KBC-1 (458 kg ha^{-1}) and TVX-94402-E (329 kg ha^{-1}). Farmers in the site demanded for the rust tolerant varieties in cowpea.

Pigeonpea was evaluated for optimum time of sowing and pest management practices for 3 years. Among the different dates of sowing higher seed yield was observed with sowing during May 2nd fortnight (969 kg ha^{-1}) followed by june 2nd fortnight (800 kg ha^{-1}) and july 2nd fortnight (620 kg ha^{-1}). Under pest management trial, IPM practice composed of two sprays + one dusting + Pheramone trap and bird resting recorded higher yield (1030 kg ha^{-1}) followed by two dusting (965 kg ha^{-1}), two sprays of monocrotophos (765 kg ha^{-1}) and was least with control (550 kg ha^{-1}). A feedback from the farmers that IPM is cumbursome and its components specially pheramone trap is unavailable timely.

In finger millet based cropping systems, higher finger millet equivalent yield and B:C ratio was observed in 10:2 ratio finger millet + pigeonpea system (3190 kg ha^{-1} and 2.42, respectively) followed by finger millet + soybean in 4:1 proportion (2613 kg ha^{-1}). The lower finger millet equivalent yield was observed with farmer's practice (1775 kg ha^{-1} and 1.56, respectively). Among the oilseed based cropping system groundnut + pigeonpea in 8:2 proportion performed better followed by groundnut + castor.

G) Energy management



Trials on energy management comprised of two treatment / demonstrations of deep ploughing and farmers practice of shallow tillage tried for 3-years. The mean values of finger millet grain yield revealed that, deep ploughing once in three years recorded higher yield (1900 kg ha^{-1}) and B:C ratio (1.75) against the farmers practice (1475 kg ha^{-1} and 1.48, respectively). Similar trends were also observed in groundnut as well (Fig 5).

Fig. 5. Yield (kg ha^{-1}) of finger millet and groundnut at Doddagangawadi watershed

H) Alternate land use systems

Mango based agri-horti system was initiated in Doddagangawadi watershed during 1998. Intercropping of pigeonpea with finger millet and field bean in mango orchard was adopted for the system. Finger millet + pigeonpea system performed better than finger millet + field bean system.

Impact of improved practice

A survey was conducted to assess the adoption of improved practices in Doddagangawadi watershed in 1998 and 2000 (Table 23). It was observed that 27 farmers' out of 50 were adopted improved practices during 2000 as against 10-farmers in 1998. A trial was laid out on adoption of improved dryland technology with farmers method of management and farmers level of fertilizers, recommended management practice with recommended dose of fertilizers. Though the recommended management and fertilizers has given a higher grain yield of 2540 kg ha^{-1} followed by recommended management with farmers level of fertilizers (2240 kg ha^{-1}) by adopting resource reallocation (use of straight fertilizers). But least was observed (1680 kg ha^{-1}) in farmers, practice.

Capacity building

Farmers' training:

Beneficiaries under watershed program were trained about the maintenance and multiplication of horticultural plants, compost preparation, use of rock phosphate and integrated pest management.

Table 23. Survey on impact of improved practices and yield of finger millet

Sl. No.	Components	No. of farmers adopted (out of 50)		Yield (kg ha^{-1}) during 2000	
		1998	2000	Grain	Straw
1	FM + FFL	40	13	1680	1730
2	FM + RDF	6	9	2150	2420
3	RM + FFL	2	14	2240	2640
4	RM + RDF	2	4	2540	2830

FM : Farmers' management FFL: Farmers' level of fertilizer
RM: Recommended management RDF: Recommended dose of fertilizer

Community approach

All the beneficiaries coming under the watershed were brought together for discussions about the watershed activities, maintenance of common lands and distribution of fuel plants and fodder saplings. The community approach has created awareness among the beneficiaries and made them feel that community land is their own property and its maintenance is their responsibility. Custom hiring of agri-implements and plant protection equipments were also arranged.

Field visits / field days

The beneficiaries visited the research station in connection with field day programme and Krishi Mela during 1998 held at UAS, GKVK, Bangalore and discussed with the scientists about their problems. A field day was also organized involving the Department of Agriculture, Horticulture and Fodder institute Hesarghatta, scientists of DLAP and NWDPRA on 30th Oct, 1998. About 700 farmers participated in the field day program.

Scientific interventions in the project

i. As it is contemplated to generate location specific, need based and sustainable technology for optimal use of production resources, the information thus evolved will be more relevant to the watershed area and acceptable to the farmers.

ii. Involvement of the university through ORP in the watershed development programme will result in the strong linkages between the research and extension which ultimately helps in achieving the basic objectives of the watershed management.

iii. The ORP of this type will greatly help in scientifically understanding the watershed development programme and also helps in analyzing the impact in terms of resource conservation, improvement in biomass production and ground water recharge.

iv. Provides first hand feed back to the scientists for technology development and refinement.

IV. Malenanayakarandahalli (2003 to 2006)

ORP site at Doddagangawadi, Ramanagara district had completed five years of operation (1998-2003) and with the intension of expanding the technologies horizontally, a new project site viz., Malenanayakarandahalli (MN halli) was selected in Doddaballapur taluk, Bangalore Rural district for its operation for a period of three years from 2003 to 2006.

Location and area

The newly selected project site "Malenanayakarandahalli" is located at an altitude 890M above MSL, 13^0 24' N Latitude and 77^0 30' E Longitude and at a distance of about 35 kms from GKVK campus, Bangalore situated on Bangalore - Gowribidanur road and it is about 12 kms from the taluk head quarter Doddaballapur (Annexure 1).

The geographical area of the village is 817.60 ha. Out of which 126.0 ha under dryland (15.41%), 2.13 ha under garden land (0.26%) and 689 ha is waste land devoid of vegetation comprising exposed earth and hillocks (84.27%). The common property of the village accounted for 45.62 ha. The village is mainly agriculture based, which forms the major income activity.

Rainfall

The average annual rainfall of the location is 830 mm distributed in 49 rainy days. Intermittent dry spells are common during crop growth period. The rainfall is bimodal in nature with one peak in May and another during Sept-Oct. The rainfall during the study period was below normal during 2003 and 2004 and normal during 2005 (Table 24).

Table 24. Mean monthly rainfall (mm) distribution MN. Halli, Doddaballapura taluk

Months	Rainfall (mm)			
	2003	2004	2005	Normal
Jan	0.0	0.0	0.0	8.3
Feb	0.0	0.0	0.0	7.3
Mar	6.4	3.0	0.0	4.8
Apr	34.8	15.6	33.0	34.5
May	8.4	155.4	120.0	68.0
June	58.2	73.0	50.0	75.7
July	59.8	150.0	80.0	98.6
Aug	123.5	6.0	185.0	126.4
Sep	45.8	119.5	121.0	159.9
Oct	69.6	107.0	264.0	166.9
Nov	0.0	22.0	60.0	65.5
Dec	0.0	0.0	10.0	14.1
Total	**406.2**	**651.5**	**923.0**	**830**
No. of Rainy days	**29**	**32**	**37**	**49**

Soils, Topography and Natural vegetation

The soils are red sandy to gravelly in texture and shallow in depth, poor fertility and low water holding capacity. The soils are acidic in reaction (pH: 5.6–6.8) with low to medium in organic carbon, available phosphorous and potassium and low in available nitrogen (Table 25).

The area has undulating terrain with slope ranging from 2 per cent in arable land and 5-20 per cent in non-arable land. The area had sparse shrub vegetation with lantana, agave, eucalyptus, neem, pongamia etc. The economic tree species like jack and tamarind were also found in private holdings.

Table 25. Chemical properties of soil at ORP site

Parameter	Maximum	Minimum	Avg. of 9 location
pH	6.80	5.65	6.19
EC (dsm^{-1})	0.13	0.06	0.08
OC (%)	0.65	0.39	0.52
Av. Nitrogen (kg ha^{-1})	220	178	198.8
Av. Phosphorous (kg ha^{-1})	58	18	34.3
Av. Nitrogen (kg ha^{-1})	244	80	128.2

Socio-economic features

The village consists of about 119 families with a population of 627 comprising 332-males and 295-females. The marginal farmers' are the major category (72.2%) in the village. There is one anganawadi center, Government primary and secondary school, milk society and 20 adults educated up to Pre-University level. There were 131 cross breed cows, 30 bullock pairs, 122 sheep, 104 goats, 130 poultry birds in the village.

Bench mark survey report of MN halli.

1. No. of families: 119

2. Land holding size
   - a. Landless : 11
   - b. Marginal farmers (<1 ha) : 78
   - c. Small farmers (1-2 ha) : 27
   - d. Semi medium farmers (2-4 ha): 03

3. Human population : 627
   - a. Adults
     - Male: 216
     - Female: 208
   - b. Childrens
     - Male: 116
     - Female: 87

4. Educational status
   - a. Literate
     - Male: 112
     - Female: 50
     - Children: 156
   - b. Illitarate
     - Male: 104
     - Fenale: 158
     - Children: 47

5. Occupation
   a. Farming: 31
   b. Farming + Labour: 77
   c. Labour only: 11

6. Caste
   General: Nil SC: 18 ST: 22 Backward class: 79

7. Medical and other facilities
   School: up to Middle School Hospital: Nil
   Co-operative society: Nil Post office: Nil
   Bus service; Available Milk collection center: Available

8. Animal population
   Bullock:30 Pairs Cows: 131 Goats: 104
   Sheep: 122 Poultry birds: 130

9. Farm equipments
   Seed drill: 10 Iron plough: 10
   Cultivator: 13 Sprayer: 01
   Bullock carts: 02

10. House holdings
   Two wheeler: 07 Bicycle: 13
   Radio: 21 Television: 16
   Telephone: 04 Sewing machine: 01
   Refrigerator: 01 Gas connection:01

11. Major crops, input used and yield level
   a. Main Crops : Finger millet + Fodder jowar
   b. Crop variety : Indaf 5 / Local
   c. FYM : 3.7 MT ha^{-1}
   d. Fertilizer (NPK) : 63.0:22.3:11.6 kg ha^{-1}
   e. Seed rate : 18.7 kg ha^{-1}
   f. Yield : 1297 kg ha^{-1}

Crops and cropping system

Traditionally, mono-cropping of finger millet is the major crop grown, with local variety and Indaf-5 in some cases, farmers were also growing fodder jowar, field bean, niger and mustard in akkadi rows of finger millet. Dryland horticulture, crop diversification and double cropping wasn't possible because of wild boar, monkey, cattle, sheep and goat menace besides acute scarcity of water during summer months. The average yield level of finger millet in the village is 1297 kg ha^{-1}.

The farming activity in the village is restricted to six months (July-Dec), while the major activities are concentrated during Aug-Oct. Labour availability is good in the village.

Production constraints

Production constraints were identified through PRA technique during June, 2003 and the constraints observed were;

- Non-use of improved varieties
- Low soil fertility and organic matter status
- Cultivation of marginal and sub marginal lands
- Non-adoption of improved soil and moisture conservation practices
- Non-adoption of improved dryland technologies due to economic backwardness
- Inadequate and imbalanced fertilizer use
- Mono cropping of finger millet
- Wild boar, monkey and cattle menace

Farmer needs: The PRA technique indicated the need for high yielding varieties, crop diversification, cropping systems, *in-situ* soil and moisture conservation practices, balanced fertilizer application for increasing productivity and value addition to agriculture produce.

Salient findings

Soil moisture conservation

In-situ soil and moisture conservation measures in finger millet based cropping system consisting finger millet + red gram in 10:2 ratio sown across the slope was implemented during 2003 (Table 26). Higher soil moisture was observed in intercropped areas compared to control (finger millet with farmer's practices). Similar trends were also observed during 2005-06 (Table 27 & 28).

Table 26. Soil moisture regimes under finger millet and pigeonpea intercropping

Soil depth (cm)	Per cent soil moisture (Avg. of 3 locations)				Remarks
	23.09.2003		09.11.2003		
	Intercropping	Control	Intercropping	Control	
0-15	4.82	4.80	3.00	3.00	Latest rain before
15-30	6.30	6.20	5.51	5.10	23.09.2003 was on 25th
30-45	7.62	7.00	10.10	9.00	(14 mm), 26th (3 mm) &
45-60	4.72	7.00	10.50	9.10	27th (20 mm) August.
60-75	Dry	Dry	10.85	8.00	
75-90	-	-	14.67	7.00	Latest rain before
90-100	-	-	8.60	Dry	09.11.2003 was on 20th
100-115	-	-	6.50	-	(22 mm), 21st (10 mm) and
Crop stage	Flag leaf		Harvesting		22nd (86 mm) October.
Total RF	**296.7 mm**		**406.7 mm**		

Table 27. Soil moisture regimes under finger millet + pigeonpea intercropping

Depth of soil (cm)	Soil moisture (%)	
	Intercropping	Akkadi method
0-15	6.44	4.86
15-30	9.52	5.93
30-45	10.63	7.46
45-60	11.97	8.13

Table 28. Influence of soil moisture conservation practices on crop yields (kg ha^{-1}).

Treatment	Finger millet		Redgram	Fodder jowar
	Grain	Straw		
Contour cultivation and contour sowing	2118	5430	-	-
Cultivation & sowing along the slope (Control)	1783	4417	-	-
Intercropping finger millet + redgram (10:2)	2095	5138	297	-
Finger millet + Jowar (10:1)	1392	3481	-	937

During 2005-06, higher gross returns (Rs.20330 ha^{-1}) and B.C ratio (1.78) were obtained from finger millet + pigeonpea intercropping system (Table 29).

Table 29. Influence of soil and moisture conservation practices on the crop yields

Treatments	Finger millet(kg ha^{-1})		Pigeonpea (kg ha^{-1})	Fodder Jowar/ fuel wood yield (kg ha^{-1})	Gross returns (Rs ha^{-1})	BC ratio
	Grain	Straw				
Cultivation and sowing along the slope (Control)	1450 (7250)	2560 (1920)	-	-	9170	1.16
Contour cultivation and contour sowing	2315 (11575)	3450 (2587)	-	-	14162	1.25
Intercropping of finger millet + pigeonpea(10: 2)	2550 (12750)	3840 (4550)	350 (4550)	850 (fuel) (150)	20330	1.78
Finger millet + Jowar (10:1)(farmers practice)	1900 (9500)	2860 (2146)	-	856 (fodder) (642)	12258	1.48

Note: Values are average of five locations. Figures in parenthesis are values in rupees. Produce Price (kg^{-1}): Finger millet: Rs.5, Pigeonpea: Rs.13, Fodder: Rs.0.75.

Crops and cropping systems

Performance of finger millet varieties

In finger millet many short, medium and long duration varieties suitable for different sowing time and rainfall pattern are available. The varieties released by UAS, Bangalore in the

last few years were tested and evaluated for further performance at ORP center. The finger millet varieties were compared with the local variety in the region. Among the tested varieties, long duration varieties recorded higher grain yield in all the three years. Among medium duration varieties HR-911 recorded higher grain yield in two years and GPU-28 recorded higher grain yield in one year (Table 30).

Table 30. Performance of finger millet varieties

				Yield (kg ha^{-1})			
Sl.	**Variety**	**2003-04**		**2004-05**		**2005-06**	
No.		**Grain**	**Straw**	**Grain**	**Straw**	**Grain**	**Straw**
1	L-5	-	-	3336	4649	3127	4200
2	MR-1	-	-	3044	5227	3018	5360
3	GPU-28	2080	-	2454	2982	2508	3240
4	HR-911	1735	-	2828	5096	2630	4500
5	GPU-26	1771	-	1720	2867	1820	2490
6	PR-202	-	-	2095	3009	1935	3030
7	Local	-	-	1481	2283	1350	2025

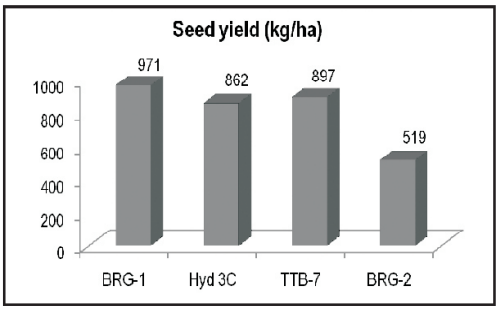


Fig. 6 Performance of pigeonpea varieties

Performance of pigeonpea varieties

Four pigeonpea varieties were tested (Fig. 6) for their performance the mean of two years revealed that higher grain yield was recorded in BRG-1(971 kg/ha).

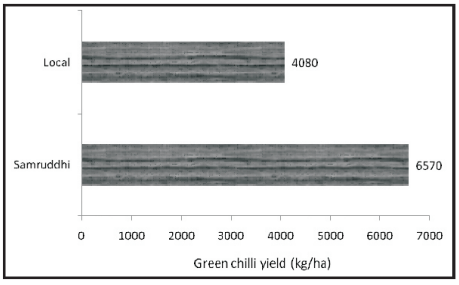


Fig 7. Performance of chiili varieties

Performance of Samruddhi chilli for green pods

Chilli variety Samruddhi recorded higher green chilli yield (6570 kg ha^{-1}) as compared to local (4080 kg ha^{-1}) and found to be promising for dryland condition. The farmers accepted this variety as it provides intermediary income (Fig. 7)

Performance of cowpea varieties

Cowpea being important short duration crop for drylands, intensive work was carried out right from inception of this center and many varieties were released in the university. TVX-

944 02E, KBC-1 KBC-2 and IT-38956-1 are the important ones. Among these varieties, KBC-2 recorded higher yield (485 and 605 kg ha^{-1}, respectively) during 2003 and 2004 subsequently in 2005-06, IT-38956-1 (815 kg ha^{-1}) as compared to other varieties (Table 31).

Table 31. Performance of cowpea varieties at MN halli

Sl. No.	Variety	Grain Yield (kg ha^{-1})		
		2003-04	2004-05	2005-06
1	TVX-944 02E	294	360	495
2	KBC-1	365	485	535
3	KBC-2	485	605	785
4	IT-38956-1	-	-	815

Performance of Horsegram varieties

Horsegram is a very important crop in dryland agriculture because of its drought resistance. When the onset of monsoon gets delayed upto the end of August, horsegram serves as best crop that can be sown up to October 15th to produce substantial grain and fodder yield. Two improved varieties PHG-9, KBH-1 and local varieties were tried in the area and higher yield was recorded with PHG-9 (609 kg ha^{-1}) and KBH-1 (481 kg ha^{-1}) over local variety (307 kg ha^{-1}) (Fig.8). The farmers' desire to cultivate these verities.

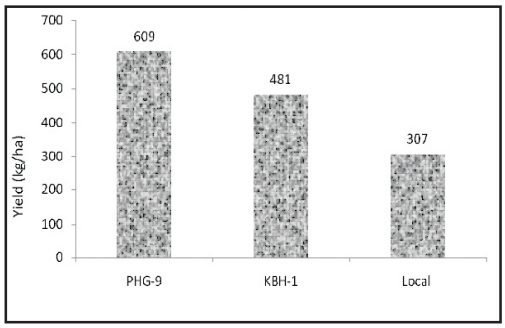


Fig 8. Performance of Horsegram varieties

Performance of fodder varieties

Among three fodder crop varieties tested, fodder maize recorded higher fodder yield of 23.25 t/ha during 2003-04. Giant Bajra recorded higher fodder yield of 40.50 t ha^{-1} during 2004-05 (Table 32).

Table 32. Performance of fodder crop varieties at MN halli

Sl. No.	Variety	Fodder Yield (t ha^{-1})		
		2003-04	2004-05	2005-06
1	Fodder maize (S. African tall)	23.25	37.25	28.60
2	Fodder jowar (SSV474)	11.09	18.15	16.30
3	Bajra (Giant Bajra)	-	40.05	33.85

Integrated cropping systems

The area is traditionally monocropped with finger millet + local fodder jowar as akkadi crop. Continuous mono-cropping had deleterious effect on soil health and crop yield.

To improve soil health and productivity and to overcome risk of failure of crops due to weather aberrations, besides employment generation, efforts were made to assess the performance of five different cropping system against the farmer practice at MN halli. Results (Table 33 & 34) indicated that higher net return and B:C ratio was observed with integrated cropping system as compared to farmers' practice.

Table 33. Performance of Integrated cropping systems at MN halli

Sl. No.	Cropping system	Area (ha)	Gross returns (Rs)	Net returns (Rs)	B:C ratio
1	Finger millet + Pigeonpea (10:2)	0.2	6053	3461	2.34
	Finger millet + Soybean (4: 1)	0.2	3723	1065	1.40
	Groundnut + Castor (8:1)	0.2	5145	2071	1.67
	Fieldbean sole crop	0.2	2678	956	1.56
	Maize + fodder Cowpea (3:1)	0.2	5290	2848	2.17
	Total	**1.0**	**22889**	**10401**	**1.83**
2	Farmers practice (FM +Akkadi)	1.0	13905	1975	1.17

Produce price (kg^{-1}): Red gram & Field bean Rs.13, Finger millet Rs. 6, Castor Rs.12, Soybean Rs.11, Groundnut pod Rs. 15, Finger millet dry straw Rs.0.75 and Green Fodder Rs. 0.75.

Table 34. Performance of Integrated cropping systems at MN halli

Sl. No.	Cropping system	Area (ha)	Total returns (Rs)	Net returns (Rs)	BC ratio
1	Finger millet + Pigeonpea (10:2)	0.2	4422	2124	1.93
	Finger millet + Soybean (4: 1)	0.2	3127	724	1.30
	Field bean sole crop	0.2	2496	774	1.45
	Maize + fodder Cowpea (3:1)	0.2	5280	2830	2.13
	Pigeonpea + cowpea (1:1)	0.2	3375	1170	1.53
	Total	**1.0**	**18700**	**7622**	**1.68**
2	Farmers'practice (FM +Akkadi)	1.0	11662	2455	1.27

Produce price (kg^{-1}): Finger millet: Rs.5, Soybean: Rs.11, Pigeonpea: Rs.13, Field bean Rs. 13, Cowpea: Rs. 13, Fodder Maize Rs. 0.75, FM dry fodder: Rs. 0.75, Soybean: Rs. 11.

Finger millet based production system

Among the different finger millet intercropping systems, growing of pigeonpea with paired row planting at 10:2 row proportion found beneficial. A furrow was opened between pigeonpea rows to achieve effective soil and moisture conservation as an inter-terrace management in the field. Thus, the systems served as combination of inter- cropping and inter terrace management. Yield and economics were superior with intercropping systems compared to control (Table 35).

Table 35. Yield & economics of finger millet based cropping system (Avg. of 2 years).

Sl. No.	Intercropping system	Yield (kg ha^{-1})					Returns (Rs ha^{-1})		BC ratio
		RG		RJ	SB	FJ	Gross	Net	
		Grain	Straw						
1	FM + RG (10:2)	2323	5112	764	-	-	26580	14490	2.29
2	FM + SB (4: 1)	2365	5529	-	102	-	18309	6294	1.52
3	FM + FJ (Control)	1406	3400	-	-	1350	11264	2557	1.29

FM: Finger millet (GPU 28), RG: Redgram (TTB-7), SB: Soybean (Hardee), FJ: Fodder Jowar (Local)

Groundnut based production system

Crop rotation with legumes is necessary for maintenance of soil fertility and productivity. However, rotation through double cropping isn't possible in the watershed attributing to the rainfall. Hence, introduction of new intercropping system with leguminous crops to increase the fertility status of the soil and also to harvest better monitory returns were attempted in the project area. Pigeonpea variety TTB-7 + groundnut variety TMV-2 (8:2) cropping system is introduced in a row proportion with a moisture conservation furrow between paired rows of pigeonpea, resulted in 685 kg ha^{-1} of groundnut pods and 624 kg ha^{-1} of pigeonpea grain with a B:C ratio of 1.19 (Table 36).

Table 36. Yield and economics Groundnut based intercropping system (2004-05 to 2005-06)

Cropping system	Yield (kg ha^{-1})		Returns ((Rs. ha^{-1})		B:C ratio
	Groundnut	Pigeonpea	Gross	Net	
Groundnut + Pigeonpea (8:2)	685	624	18379	3009	1.19

Pulse based production system

The new cropping system is taken up in the farmer's field to avoid mono cropping of finger millet. The farmers in red soil area, in view of its wide spacing and initial slow growth, generally do not grow pigeonpea as a pure crop. The short duration pulse crop, cowpea as intercrop was introduced with pigeonpea to generate intermediate income to take up plant protection for main crop, besides promoting efficient utilization of resources. The results indicated

that growing of pigeonpea variety TTB-7 and cowpea variety TVX-944 (1:1) resulted in 814 kg pigeonpea and 295 kg of cowpea per ha with a net returns of Rs.3409 ha^{-1} (Table 37).

Table 37. Yield of crops under pulse based inter- cropping system (2004-05 to 2005-06)

Cropping system	Yield (kg ha^{-1})		Returns (Rs ha^{-1})		B:C ratio
	Pigeonpea	Cowpea	Gross	Net	
Pigeonpea + Cowpea (1:1)	814	295	14430	3409	1.31

Integrated nutrient management

Red soils are generally low in organic matter, low water holding capacity and poor to low in soil fertility status. Addition of organic matter along with fertilizer was found to improve soil health and productivity. Further, the availability of FYM is limited for large dryland area because of diminishing cattle population. In addition, use of bio- fertilizer is gaining importance in agriculture as they fix atmospheric nitrogen up to 50- 55 kg/ha in legumes leading to improved soil fertility, enhance the crop yield by 10-15 per cent and reduce cost of production. Hence, demonstrations were conducted at project site.

A trial was conducted using organic and inorganic fertilizer on finger millet crop. The results indicated that application of 50% NPK + 50% N through FYM recorded higher grain yield (2358 kg ha^{-1}) of finger millet followed by 100% NPK (2283 kg ha^{-1}). On the contrary farmers' practice have recorded lower grain (1419 kg/ha) yield (Table 38).

Table 38. Yield of finger millet in integrated nutrient management (2004-05 to 2005-06)

Sl. No.	Treatments	Grain yield (kg ha^{-1})	% increase over farmer practice
1	50% NPK + 50% N through FYM	2358	66.20
2	100% NPK	2283	61.85
3	Farmers' practice	1419	-

Use of bio-fertilizer in groundnut and pigeonpea

Seed treatment of bio-fertilizer for both groundnut and pigeonpea crops was conducted using the respective strains. The groundnut (TMV-2) and pigeonpea (TTB-7) recorded 12.94 and 16.26 per cent improvement in the yield over untreated (Table 39).

Table 39. Yield of groundnut and pigeonpea with bio-fertilizer seed treatment (2 year Avg.)

Sl. No.	Crop	Yield (kg ha^{-1})		% increase
		Treated	Untreated	
1	Groundnut	765	678	12.94
2	Pigeonpea	927	911	16.26

Value addition to agriculture produce

Majority of the farmers were marginal and small and under the clutches of local petty traders. They sell their marketable produces in the local market for lower price. In order to improve the value of the produce, trial was initiated to make pigeonpea into dhal for marketing at higher prices. The results indicated that by conversion of pigeonpea into dhal, the individual farmers obtained additional income of Rs. 263.12 q^{-1} of grain with 20.63 per cent value addition (Table 40).

Table 40. Economic benefit obtained by making pigeonpea into dhal (Avg. of 2 years)

Material	Quantity (kg)	Value (Rs)
Whole grain	100	1275
Total dhal recovery	71.5	1511.25
Bran	21.5	26.87 (@ Rs.1.25/kg)
Milling charges	-	60/- (@ Rs.0.60/-kg.)
By value addition	-	263.12 (20.63 %)

V. Chikkamaranahalli (2006-2010)

The ORP was in operation at Malenanayakarandahalli (M.N.Halli), Doddaballapur taluk during 2003-04 to 2005-06. Subsequently the ORP site was shifted to Chikkamaranahalli (C.M.Halli), Nelamangala taluk and worked for four years from 2006-07 to 2009-10.

ORP Site : Chikkamaranahalli cluster, comprises Chikkamaranahalli, Chikkamaranahalli Colony, Chikkaputtayyana Palya, Mudlupalya.

Location : Located at 13 ^{0}6' N Latitude, 77^{0}19' E Longitude and 896 to 970 m above MSL Altitude and at a distance of 50 km from GKVK campus.

Area : 137.0 ha

Cultivated Area : 117.0 ha

Waste land : 20.0 ha

Soil Type : Sandy Loam to sandy clay loam, acidic in reaction (pH 4.3 -6.5), low to medium soil fertility and deficit in Zn and B.

Socio Economic Features

Farm Families : 143

Population

Male : 323

Female : 282

Land holdings

Land Less Families	:	18
Marginal Farmers (< 1 ha)	:	84
Small Farmers (1-2ha)	:	36
Semi Medium Farmers (2-4 ha)	:	03
Medium Farmers (4-10 ha)	:	01
Large Farmers (> 10 ha)	:	01

Existing Crops and cropping systems

1. Finger millet with akkadi crops (fodder jowar, cowpea, field bean, niger, mustard) in 7:1 row proportion-major cropping system.
2. Groundnut + pigeonpea during early *Kharif* in 16:1 row proportion in limited area

Fertilizer dosage : 65: 48: 0 kg NPK ha^{-1} for finger millet

Seed Rate (kg/ha) : 25 kg

Yield (kg/ha) : 1250

Production constraints

- Mono-cropping of finger millet with *akkadi* crops
- Lack of awareness about improved varieties and production practices
- Imbalanced fertilizer use
- Low to medium soil fertility
- Soil crusting
- Influence of semi urban and urban population
- Poor quality drinking water
- Undulating topography
- Poor animal population and malnutrition
- Severe wild boar menace
- Attraction of farmers towards stone quarrying

Farmer needs

- Human resource development (capacity building)
- Improved crops and cropping system to increase productivity and sustainable income
- Soil and water conservation technologies
- Nutrient management (INM / SSNM)
- Post-harvest technology including value addition
- Maintaining soil health for sustainable productivity
- Improvement of local animal population (cattle, sheep, poultry etc.,)
- Animal health camps

Rainfall:

The watershed receives a normal rainfall of 751.9 mm, of which about 572.9 mm is received during *Kharif* season (June-Oct). During 2006-07, total rainfall of 214.4 mm (71.5 per cent deficit) was received. The deficit rainfall during August and September months and no rainfall during October month severely affected the crops performance and it was a drought year. During 2007-08, although it received 45.7 per cent excess rainfall (1095.4 mm), there were four dry spells of two weeks duration during July, August, September and October months. Heavy rains during early *Kharif* affected cowpea varietal trial.

During 2008-09, an amount of 906.6 mm (+20.6%) of rainfall was received. Non receipt of rainfall during April, May and June months affected land preparation. Rainfall of 152 mm received on 7th October caused severe soil erosion, besides affecting standing crops. There was a long dry spell of 24 days during September month. An amount of 782.2 mm (4 per cent more) rainfall was received during 2009-10. There were 2 dry spells of 13 days duration during July and 2 dry spells of 10 days duration during August. There was no rainfall from 1st Oct to 15th Nov (46 days) which has affected the performance of standing crops (Table 41).

Table 41. Rainfall (mm) during last four years period from 2006-2010 (CM Halli)

Sl. No.	Period	Normal rainfall (mm)	Actual Rainfall (Rainy days)			
			2006-07	2007-08	2008-09	2009-10
1	Summer(April-May)	119.1	42.4(3)	196.0(9)	0.0(0)	213.8(11)
2	*Kharif* (June-October)	572.9	172.0(11)	696.0(31)	882.6(31)	519.4(29)
3	Rabi(November-March)	59.9	0.0(0)	203.4(5)	24.0(3)	49.0(2)
4	**Total**	**751.9**	**214.4(14) (14)**	**1059.4(45) (45)**	**906.6(34) (34)**	**782.2(42) (42)**
5	% deviation from normal RF	-71.5%	+45.7%	+20.6%	+4.0%	

Salient findings

Rainwater management

Uncertainty of rainfall and lack of knowledge on soil and moisture conservation practices are the two major problems in dryland Agriculture. Cultivation along the slope results in increased runoff, leading to soil erosion and loss of plant nutrients. Therefore, rainwater management plays a fundamental and pivotal role in dryland agriculture.

In soil and moisture conservation trials with finger millet variety MR-1+ pigeonpea variety TTB-7 (10:2), higher finger millet grain (2277 kg/ha), straw (5578 kg/ha) yield and pigeonpea grain yield (252 kg/ha) were attained by staggered moisture conservation furrow, while in the farmers practice (finger millet + fodder sorghum), finger millet grain yield of 1255 kg/ha and 2885 kg/ha straw yield and 884 kg/ha of fodder yield of sorghum were recorded. The improved system recorded a benefit cost ratio of 2.26 against the farmers' practice of 1.32 (Table 42).

Table 42. Yield and economics of finger millet based cropping system as influenced by soil and moisture conservation practices (2006-2010)

Sl. No.	Treatments	Yield (kg ha^{-1})				B:C ratio
		Finger millet		Pigeon pea	Fodder Jowar	
		Grain	Straw			
1	Finger millet + pigeonpea (10:2) With staggered moisture conservation furrow	2277	5578	252	-	2.26
2	Farmers' Practice (Finger millet + *Akkadi*)	1255	2885	-	884	1.32

Evaluation of finger millet varieties

All improved varieties produced higher grain yield compared to local. Among the long duration varieties, L-5 recorded higher grain yield of 3954 kg ha. Among the medium duration varieties ML-365 recorded higher grain yield of 3042 kg/ha. Short duration variety GPU-48 recorded higher grain yield of 2498 kg/ha as compared to local variety (Fig. 9).

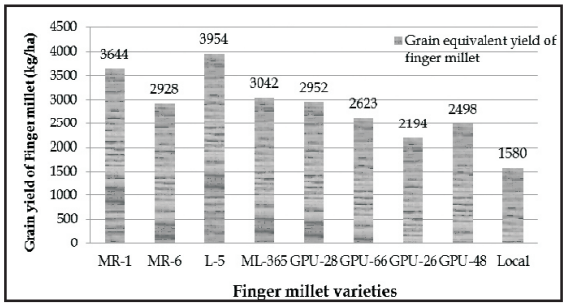
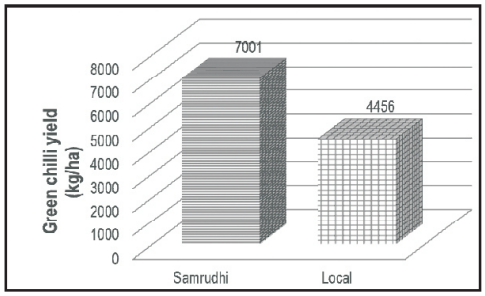


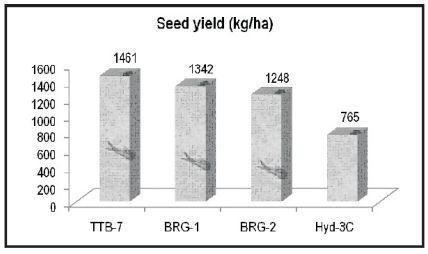
Fig 9. Performance of finger millet varieties



Performance of Samrudhi chilli

Samrudhi chilli recorded higher green chilli yield of 7001 kg/ha with B:C ratio 2.87 as compared to local variety (4456 kg/ha with B:C ratio 2.03) (Fig. 10). Farmers prefer Samrudhi chilli for green purpose and found to be promising for dryland condition.

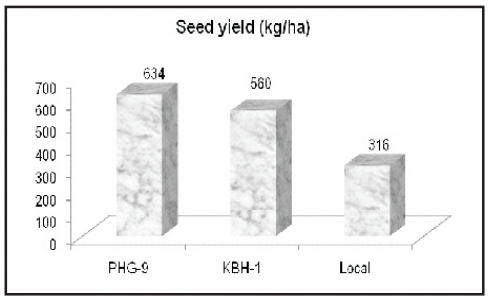
Fig 10. Performance of samrudhi chilli



Evaluation of Pigeonpea varieties

Among the four pigeonpea varieties tested, TTB-7 produced higher grain yield (1461 kg ha^{-1}) followed by BRG-1, BRG-2 and Hyd-3C (Fig 11). Farmers prefer TTB-7 for dhal making and BRG-1 for vegetable purpose.

Fig 11. Performance of pigeonpea varieties



Evaluation of horsegram varieties

Among three horse gram varieties, PHG-9 produced higher grain yield of 634 kg/ha and better option for delayed sowing as compared to local variety (Fig. 12).

Fig 12. Performance of horsegram varieties

Cropping systems

Evaluation of finger millet based production system

Finger millet + Akkadi crop is the predominant mono-cropping system. Growing of finger millet + pigeonpea in 8:2 row proportion with opening of moisture conservation furrow between paired rows of pigeonpea to achieve effective soil moisture conservation as interterrace management practice in the field was found to be beneficial.

Among different finger millet based production system, growing of finger millet and pigeonpea in 10:2 ratio recorded higher finger millet grain yield of 2081 kg/ha and pigeonpea yield of 271 kg/ha with higher B:C ratio of 2.02 as compared to finger millet + soybean and farmers' practice (Table 43).

Table 43. Yield and economics of finger millet based production system

Treatments	Yield (kg ha^{-1})					B:C ratio
	Finger millet		Pigeon pea	Soy bean	Fodder Jowar	
	Grain	Straw				
Finger millet + Pigeonpea (10:2) (MR-1 + TTB-7)	2081	4370	271	-	-	2.02
Finger millet + Soybean (4:1) (MR-1 + MAUS-2)	2133	4272	-	124	-	1.85
Finger millet + *Akkadi* (Farmers' practice)	1222	2410	-	-	1120	1.07

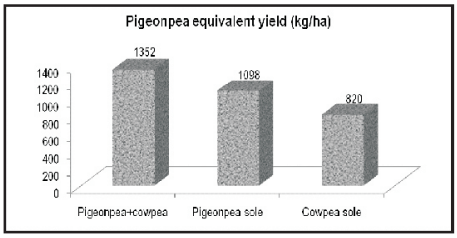
Monocropping of finger millet and fodder Jowar as akkadi crop was commonly practiced in ORP site, resulting in reduced soil fertility and productivity. Introduction of intercropping system with leguminous crop will help in increasing the fertility status of soil and better monitory returns.

Groundnut based Production system:

Among different groundnut based cropping systems growing of groundnut variety TMV-2 + pigeonpea variety TTB-7 in 8:2 row proportion with opening of moisture conservation furrow between paired rows of pigeonpea recorded 626 kg/ha of groundnut pod yield and 605 kg/ha pigeonpea grain yield and higher B:C ratio of 1.98 followed by groundnut + castor (8:1) as compared to farmers' practice (Table 44). Technology of growing groundnut + pigeonpea in 8:2 row proportions with moisture conservation furrow was accepted by the farming community.

Table 44. Yield and economics of groundnut based production systems

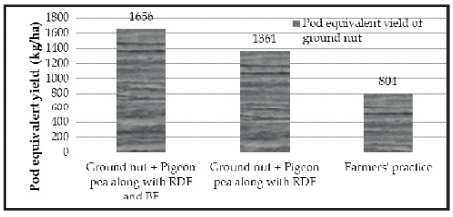
Treatments	Yield (kg ha^{-1})				Returns (Rs/ha)		B:C ratio
	Groundnut		Pigeon pea	Castor	Gross	Net	
	Pod	Haulm					
Groundnut + Pigeonpea (8 :2)	626	3300	605	-	27546	12265	1.98
Groundnut + Castor (8:1)	696	4102	-	342	20793	7649	1.58
Groundnut + pigeonpea (15:1) Farmers practice	421	3056	246	-	13848	5396	1.39



Pulse based production system

Pigeonpea + cowpea cropping system has produced higher pigeonpea equivalent yield (1352 kg/ha) as compared to sole crops of pigeonpea and cowpea (Fig. 13).

Fig 13. Performance of pulse based intercropping system

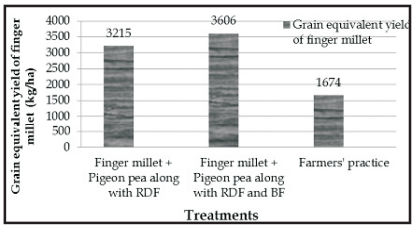


Site specific nutrient management in groundnut + pigeonpea cropping system

Application of recommended dose of fertilizers along with micronutrients and bio-fertilizer treatment in groundnut + pigeonpea cropping system produced higher pod equivalent yield (1656 kg/ha) with B:C ratio 2.26 as compared RDF and farmers' practice (Fig. 14).

Fig 14. Performance of site specific nutrient management

Integrated nutrient management for sustainable productivity of finger millet + pigeonpea cropping System



Combined application of organic and inorganic manures along with micronutrients and bio-fertilizers produced higher yield in finger millet + pigeonpea cropping system with B:C ratio 2.09 as compared to other treatments (Fig.15).

Fig 15.Grain equivalent yield of finger millet

Integrated farming systems

During 2006-07, though it was a drought year, integration of crops and cropping system along with livestock component resulted in higher benefit cost ratio of 1.46 as compared to negative returns in farmers' practice (Table 45).

During 2007-08, Integration of crops and cropping systems along with livestock component (Table 46) resulted in increased returns (B:C ratio 2.01) as compared to farmers' practice (B:C ratio 1.14).

Table 45. Returns from different components of IFS during 2006-07

Sl. No.	Cropping system	Area (ha)	Grain equivalent yield kg/plot	B:C ratio
1	Groundnut + Pigeonpea (8:2)	0.15	180	1.41
2	Groundnut + Castor (8:1)	0.15	149	1.26
3	Pigeonpea + Cowpea (1:1)	0.15	149	1.51
4	Field bean followed by Horse gram	0.15	163	1.37
5	Maize + Cowpea (Green fodder) (3:1)	0.10	2150	1.44
6	Finger millet + Pigeonpea (10:2) + Mango	0.10	175	1.18
7	Finger millet + Soybean (4:1) + Mango	0.10	106	0.88
8	Pigeonpea sole crop + Mango	0.10	98	1.83
9	Dairy	-	-	1.51
	Total	**1.00**	**-**	**1.46**
	Farmers' practice Finger millet + Akkadi	1.00	-	0.91

Table 46. Returns from different components of IFS during 2007-08

Sl. No.	Cropping system	Area (ha)	Grain equivalent yield kg/plot	B:C ratio
1	Pigeonpea + Cowpea (1:1)	0.20	392	3.04
2	Groundnut + Pigeonpea (8:2)	0.08	52	1.82
3	Groundnut + Castor (8:1)	0.07	105	2.23
4	Finger millet varieties (MR-1, GPU-28, GPU-48)	0.15	493	2.24
5	Fodder maize + Mango followed by Chilli, Fodder bajra and Horse gram	0.10	10160	2.31
6	Castor + Field bean + Mango	0.10	136	1.86
7	Finger millet + Soybean (4:1)	0.15	542	2.35
8	Finger millet + Pigeonpea (10:2)	0.15	560	2.33
9	Dairy	-	-	1.82
	Total	**1.00**	**-**	**2.01**
	Farmers' practice	1.00	-	1.14

During 2008-09 (Table 47), Integration of crops and cropping systems along with livestock component resulted in increased returns (B:C ratio 2.23) as compared to farmers' practice (B:C ratio 1.37).

Table 47: Returns from different components of IFS during 2008-09

Sl. No.	Cropping system	Area (ha)	B:C ratio
1	Groundnut + Castor (8:1)	0.07	1.90
2	Groundnut + Pigeonpea (8:2)	0.08	1.58
3	Pigeonpea + Field bean (1:1)	0.08	2.91
4	Pigeonpea + Cowpea (1:1)	0.07	2.89
5	Fodder maize + Cowpea (3:1) – followed by cowpea grain and Fodder bajra	0.12	2.89
6	Samrudhi chilli (green)	0.03	2.26
7	Field bean	0.15	3.16
8	Finger millet + Pigeonpea (10:2) + Mango	0.40	2.88
9	Dairy	-	2.02
	Total	**1.00**	**2.23**
	Farmers' practice	1.00	1.37

During 2009-10 (Table 48), Integration of crops and cropping systems along with livestock component resulted in increased returns (B:C ratio 2.21) as compared to farmers' practice (B:C ratio 1.57).

Table 48: Returns from different components of IFS during 2009-10

Sl. No.	Cropping system	Area (ha)	B:C ratio
1	Groundnut + Castor (8:1) (TMV-2 + DCS-9)	0.07	1.80
2	Groundnut + Pigeonpea (8:2) (TMV-2 + TTB-7)	0.08	2.23
3	Pigeonpea + field bean (1:1) (BRG-1 + HA-4)	0.12	4.72
4	Finger millet + Pigeonpea (10:2) (MR-1 + TTB-7)	0.15	2.28
5	Finger millet + Soybean (4:1) (MR- 6 + Hardee)	0.15	2.13
6	Finger millet Varieties + mango (GPU-28, ML-365, GPU-66 and GPU-48)	0.20	2.10
7	Samruddhi chilli (green)	0.02	1.95
8	Field bean – I crop (HA-4) Cowpea grain – II crop (IT-38956-1)	0.16	2.35
9	Fodder maize + cowpea (3:1)-I crop (SAT + KBC-2) Horse gram– II crop (Local)	0.03	1.86
10	Farm Pond	0.02	-
11	Dairy	-	2.10
	Total	**1.00**	**2.21**
	Farmers' practice	1.00	1.57

Pulse storage technique

Cleaned and well dried pigeonpea and cowpea produce was stored in plastic container and 5 cm thick well dried sieved fine sand was uniformly spread on it and covered with lid to make it airtight. By adopting this safe and improved non chemical method, pulse could be stored safely free from bruchids and storage pest incidence up to six months.

Value addition

Pigeonpea dhal making resulted in value addition to the extent of 25.7 per cent, as compared to pigeonpea whole grain selling. Farmers can earn more money by converting pigeonpea in to dhal (Table 49).

Table 49. Value addition in pigeonpea

Material	Quantity (kg ha^{-1})	Value (Rs)
Whole grain	100	2138
Total dhal recovery	70	2783
Milling charges (Rs/q)	-	36
Transportation charges	-	59
By value addition (Rs)	-	550 (25.7%)

Capacity building

Field days, ORP farmers visit to krishimela at GKVK campus, Scientists-farmers interaction meeting, training on seed treatment with bio-fertilizers and different aspects of dryland production technologies for sustainable production have been organized during the period under study. The farmers were benefitted by these programmes and resulted in knowledge empowerment of farmers.

Technologies modified / refined

***In-situ* moisture conservation through furrow for improving productivity**	Simultaneous sowing of finger millet + pigeonpea 10:2 row proportions across the slope. Pigeonpea will be sown at 2 feet apart. A furrow will be opened between paired rows of pigeonpea to achieve effective *in-situ* soil and moisture conservation, as inter-terrace management practice in the field.
Integrated farming system	Different crops and cropping systems were integrated with horticulture, forestry and livestock for sustainable income and higher production.
Performance of finger millet varieties	Growing different duration finger millet varieties with package of practice for higher yield. Selecting right variety for the right time of sowing.
Spacing for pigeonpea	Sowing of pigeonpea in 90 X 22.5 cm during May-June month and 60 X 22.5 cm during July month.
Groundnut based production system	Simultaneous sowing of groundnut + pigeonpea in 8:2 row proportion and groundnut + castor in 8:1 row proportion across the slope. Sowing paired row of pigeonpea at 2 feet apart and opening moisture conservation furrow in groundnut + pigeonpea (8:2) intercropping.
INM for sustainable productivity of finger millet + pigeonpea cropping system	Application of micronutrients based on soil test and 50 per cent of recommended N through organic and 50 per cent N through inorganic along with recommended PK, seed treatment with bio-fertilizers.
Pulse based production system	Simultaneous sowing of pigeonpea and cowpea in 1:1 row ratio.

VI. ALANATHA (2010-11 to 2011-12)

After having completed 4 years (2006 -2010) of operation at Chikkamaranahalli, the ORP site has been shifted to a new location, Alanatha cluster, Kanakapura taluk, Ramanagara district from *Kharif* 2010. The new location lies in the area where watershed programme has already been completed by the Watershed Development Department, Government of Karnataka during 2003-2008. The new location comprises Alanatha, Mahadevapura, Arjunahalli, Arjunahalli thandya and Eregowdana Doddi villages.

The Alanatha village in Kanakapura taluk of Ramanagara district, Karnataka comes under Zone-5 (Eastern dry zone) of Karnataka (Annexure 1). Gram panchayat is located at a distance of 6 kms and Kanakapura taluk HQ at a distance of 23 kms from the village and 120 kms from the UAS, GKVK main campus. The cluster is lying at 12^0 23` N Latitude, $77^0$ 31` East Longitude and 968 m Altitude.

Rainfall and seasonal condition

The normal rainfall in the area is 756 mm in 48 rainy days distributed in 2 peaks (May & Sept-Oct). During 2010, 882.0 mm rainfall was received in 41 rainy days, with two dry spells of 18-19 days during July-August coinciding with gynophore and peg formation stage in groundnut and September coinciding with flowering and milky stage in long duration finger millet and affected the crops.

Table 50. Rainfall at Alanatha watershed

Months	2010	2011	2012	2013
Jan	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0
Mar	0.0	0.0	0.0	0.0
Apr	225.0	137.4	44.0	47.0
May	136.0	85.6	69.0	88.6
June	0.0	55.4	19.0	153.8
July	49.4	90.4	39.8	87.8
Aug	107.6	139.4	43.4	202.2
Sep	49.0	78.8	34.8	106.8
Oct	184.0	115.8	111.0	124.0
Nov	131.0	155.4	116.0	38.2
Dec	0.0	0.0	16.6	0.0
Total	**882.0**	**858.2**	**493.6**	848.4

During 2011, highly erratic and uneven rainfall of 858.2 mm was received in 37 rainy days. Non receipt of rainfall during June delayed sowing of crops and inadequate up to 1st fortnight of August and in September didn't support the good establishment of crops. Hence, the taluk is declared as drought affected area (Table 50).

Socio-economic features

Land use details

Land use	Area in ha
Cultivated area	362.09
Irrigated	22.26
Rainfed	339.83
Grazing land	18.86
Uncultivable land	600.89
Forest area	208.42
Total area	1190.26

Soil: Soils are sandy loam, acidic in nature and low to medium in soil fertility

Land holding pattern

Majority of the farmers are marginal and small (80%) and are resource poor. There are 34 landless families in these villages and mainly engaged in wages for employment under NREGA, agricultural labour, building and road works for their livelihood.

Category of farmer	Rainfed area		Irrigated area		Total holding size	
	No.	Area	No.	Area	No.	Area
Marginal (< 1ha)	128	122.44	-	-	-	122.24
Small (1-2 ha)	73	160.99	-	19.26	-	180.25
Medium (2-10 ha)	16	56.40	-	3.00	-	59.40
Large (> 10 ha)	-	-	-	-	-	-
overall	217	339.83	-	22.26	-	362.09

Demographical pattern

a.	Total population	1094
b.	Gender distribution	
	No. of males	610
	No. of females	484
	Male: Female	1 : 0.79

House hold distribution

a.	Total no. households	251
b.	No. of joint families	3
c.	Average house hold strength	4.36

Caste categorization

Caste	Caste	No. of families
General	Vokkaliga and Lingayat	116
Backward class	Madivala, Vishwakarma	13
SC/ST	Adikarnataka, Lambhani, Bhovi and Bedaru	122

The ORP cluster village comprises diversified farming communities. The major group of the farmers belongs to SC/ST community followed by general group.

Educational status

Primary education	29
Secondary education	85
Higher secondary education	177
Graduation	20
Post graduation	5

Irrigation sources

Sources	Status	No
Open wells	Functional	4
	Non functional	2
Bore wells	Functional	15
	Non functional	5

Agricultural scenario : Crop husbandry

Season	Crops	Rainfed	Irregated
Kharif	Field	Sesame, finger millet, groundnut	Paddy
	Horticultural crop	Coconut, Mango	-
	Cash crops	-	Bannana, Mulberry
	Others (if any)	-	

Animal husbandry:

i. Population of the species		
Animal		
Cross breed	Cows	126
Calves (Female)	20	
Calves (Male)	-	
Cattle	Female	162
Bullock	8	
Calves	30	
Buffalo		17
Goat		537
Sheep		352
Rabbit		2
Pig		2
Indigenous poultry		174
ii. Animal production		
Milk		1000 liters
Egg (nos.)		-

Infrastructure facilities:

Drinking water	Over head tank at Arjunahalli meets the drinking water requirement of Arjunahalli, Arjunahalli thanda and Eregowdana Doddi villages. Similarly, Bore wells meets drinking water requirement of Alanatha and Mahadevapura villages.
Milk collection center	One at Alanatha serving all the 5 villages
Village service cooperative society and veterinary hospital	At Kodihalli about 7 km from the village catering to the needs of all the villages
Gram panchayat head quarter	At Bannimukodlu about 6 km from the village
Health care	Primary health unit at Alanatha village and primary health center at Kodihalli
School	The villages have government Anganawadi, primary school and high school
Post office	One at Alanatha
Public distribution system	At Alanatha meets the requirement of the villages.

The cluster village is having good number of livestock population including milch animals, draught animals and other large and small ruminants. The major source of supplementary income is from livestock activity.

Existing crops and cropping systems:

The area is mainly agricultural based which forms the major income activity and some of the farmers are getting staggered income from livestock activity. The major crops and cropping systems in the area

1. Finger millet with *akkadi* crops: 8 to 10 rows of finger millet and 1 row of *akkadi* crops (sorghum, castor, pigeonpea, fieldbean/cowpea, nizer)
2. Groundnut + *akkadi* crops: 15 to 20 rows groundnut and 1 row of akkadi crops (sorghum, castor, pigeonpea, fieldbean/cowpea, nizer)
3. Double cropping system: first crop of sesame during April-May followed by second crop of finger millet/horsegram, if pre-monsoon showers are favourable.

Benchmark survey

The farmers are not using the recommended dose of NP and not applying potassium fertilizer to finger millet crop. Similarly, in case of groundnut, seed rate used is less than the recommended quantity besides, lower dose of fertilizer and non application of potassium and in some cases chemical fertilizer are not applied to groundnut crop. Majority of the farmers apply 2-4 MT FYM per ha which is again less than the recommended quantity (7.5 MT ha^{-1}).

	As per benchmark survey	As per POP
Finger millet		
Fertilizer	35:12:0 kg ha^{-1} $N:P_2O_5:K_2O$	50:40:25 kg ha^{-1} $N:P_2O_5:K_2O$
Seed	20 kg ha^{-1}	10 -12 kg ha^{-1}
Yield	1250 kg ha^{-1}	1500 – 2000 kg ha^{-1}
Groundnut		
Fertilizer	10:25:0 kg ha^{-1} $N:P_2O_5:K_2O$	25:50:25 kg ha^{-1} $N:P_2O_5:K_2O$
Seed	75 kg ha^{-1}	130 kg ha^{-1}
Yield	750 kg ha^{-1}	800 – 1000 kg ha^{-1}

Production constraints:

1. Imbalanced fertilizer use
2. Lack of awareness about improved varieties, dryland production practices and cropping systems.

3. Wild boars and elephants menace.
4. Weed menace.
5. Labours scarcity during peak season.
6. Fragmentation of land holdings.
7. Timely non-availability of inputs.

Farmers' needs:

1. Improved crop varieties and cropping systems for sustainable production.
2. Capacity building about dryland production practices for sustainable production.
3. Integrated farming system approach for sustainable income and production.
4. Integrated nutrient management for higher yield and maintaining soil health.
5. Soil and moisture conservation for higher yield.
6. Weed management practices to reduce cost of cultivation.
7. Value addition to agriculture produce.
8. Post harvest technology.
9. Improving livestock health condition and production efficiency and upgradation of local sheep.

Salient findings

Rain water management

Opening of moisture conservation furrow between paired rows of pigeonpea in finger millet + pigeonpea cropping system produced higher finger millet grain equivalent yield, net returns (Rs. 32632/ha) and B:C ratio (3.22) as compared to farmers, practice (Table 51).

Table 51. Yield & economics of finger millet based cropping system as influenced by soil and moisture conservation practices (Mean of 2010-11 & 2011-12)

Treatments	Yield (kg ha^{-1})			Returns (Rs ha^{-1})		B:C ratio
	Finger millet		Intercrops	Gross	Net	
	Grain	Straw				
Finger millet+ pigeonpea (10:2) with moisture conservation furrow	2683	6947	Pigeonpea:407	47382	32632	3.22
Farmer's Practice (Finger millet + *akkadi*)	1320	2797	Pigeonpea: 54kg Castor: 28kgJ owar: 9kg Field bean: 34kg	19234	8774	1.73

Nutrient Management

In the integrated nutrient management trial for sustainable productivity of finger millet + pigeonpea intercropping system (Table 52), 50% N through organic source +50% N and 100% PK + 12.5 kg ha^{-1} zinc sulphate +10 kg ha^{-1} borax recorded higher net returns (Rs 25,707 /ha) and B: C ratio (2.64) compared to the farmer practice of finger millet +*akkadi* (Rs. 7,318 /ha and 1.69, respectively).

Table 52. Yield and Economics of Finger millet+Pigeonpea cropping system under integrated nutrient management

Treatments	Finger millet yield (kg ha^{-1})		Intercrops yield (kg ha^{-1})	Grain equi. yield (kg ha^{-1})	Returns (Rs ha^{-1})		B:C ratio
	Grain	Straw			Gross	Net	
RDF (50:40:25 kg/ha NPK)	2120	5300	Pigeonpea: 230	2851	35345	20345	2.35
50%N through FYM +50% N and 100% PK through inorganic source + Zinc sulphate (12.5 kg/ha) + borax (10kg/ha)+ bio fertilizer treatment	2420	6050	Pigeonpea: 290	3342	41307	25707	2.64
Farmers' practice (finger millet +*akkadi* crops)	1210	3025	Pigeonpea: 25 Fieldbean: 20 Jowar: 15 Castor: 15	1413	17818	7318	1.69

Site specific nutrient management

Site specific nutrient management is a site based approach for managing nutrients need of crop in intensive production system. The yield of groundnut was lower due to imbalanced nutrition coupled with moisture stress. Continuous use of only NPK fertilizers without secondary and micronutrients has resulted in mining of secondary and micronutrients. Studies were reported earlier on the response of Zinc sulphate and Borax to groundnut crop. Therefore the trial was conducted in groundnut with combined application of Zinc sulphate and Borax

Application of nutrients through SSNM along with zinc sulphate (12 kg ha^{-1}), borax (10 kg ha^{-1}) and bio-fertilizer recorded higher yield, net returns (Rs. 32743 ha^{-1}) and B:C ratio (2.80) compared to farmers practices in groundnut based cropping system (Table 53).

Table 53. Yield and economics of groundnut + pigeonpea cropping system under site specific nutrient management (Mean yield of 2010-11 and 2011-12)

Treatments	Groundnut yield (kg ha^{-1})		Intercrops Yield (kg ha^{-1})	Returns (Rs ha^{-1})		B:C ratio
	Pod	Haulm		Gross	Net	
RDF (25:50:25 NPK kg/ha)	854	3648	Pigeonpea: 615	47247	30577	2.63
SSNM + zinc sulphate (12.5 kg/ha + borax (10kg/ha) + biofertilizer	892	3785	Pigeonpea: 660	49969	32743	2.80
Foliar application of micronutrients (borax)	788	3259	Pigeonpea: 590	44329	27029	2.56
Farmers' practice (Groundnut + *Akkadi* crops)	335	2318	Pigeonpea: 104 Fieldbean: 56 Jowar: 28 Castor-53	25652	11152	1.76

Cropping systems

Finger millet and groundnut with Akkadi crops are the predominant cropping system. Growing of finger millet and groundnut with pigeonpea as an intercrop in 8:2 row proportion with opening of moisture conservation furrow between paired rows of pigeonpea to achieve effective soil moisture conservation as inter-terrace management practice in the field was found to be beneficial.

Finger Millet based cropping system

Among different finger millet based production systems, growing of finger millet and pigeonpea (8:2 ratio) recorded higher finger millet grain equivalent yield with a benefit cost ratio of 3.08 as compared to farmers practice (Table 54).

Table 54. Yield and economics of finger millet based production systems

Treatments	Finger millet yield (kg ha^{-1})		Intercrops yield (kg ha^{-1})	Returns (Rs ha^{-1})		B:C ratio
	Grain	Straw		Gross	Net	
Finger millet+Pigeonpea (8:2) (MR-1 + TTB-7)	2600	6744	Pigeonpea: 375	45258	30508	3.08
Finger millet + soybean(4:1) (MR-1+ Hardee)	2625	6823	Soybean: 185	35592	22642	2.75
Finger millet + *akkadi* (Farmers' practice)	1390	2993	Pigeonpea: 60 Fieldbean:34 Jowar: 20 Castor-33	21087	10087	1.91

Groundnut based cropping system

Among different groundnut based production systems, growing of groundnut + pigeonpea in 8:2 row proportion and opening moisture conservation furrow between paired rows of pigeonpea recorded higher pod equivalent yield with higher benefit cost ratio as compared to farmers' practice (Table 55).

Table 55. Yield and Economics of groundnut based production systems.

Treatments	Groundnut Yield (kg ha^{-1})		Intercrop Yield (kg ha^{-1})	Returns (Rs ha^{-1})		B:C ratio
	Pod	Haulm		Gross	Net	
Groundnut + pigeonpea (8:2)	785	3095	Pigeonpea: 613	44965	27715	2.61
Groundnut + castor (8:1)	798	3120	Castor: 483	40778	23978	2.42
Farmers practice (Groundnut +*akkadi*)	578	2345	Pigeonpea:104 Fieldbean: 76 Sorghum: 26 Castor: 58	25955	11705	1.83

Pulse based cropping system

Pulse based cropping was introduced newly to build up soil fertility and also to enhance the farmers income. The farmers do not grow pigeonpea as a pure crop in view of its wider row spacing. A short duration pulse crop cowpea / field bean was introduced between two rows of pigeonpea as intercrop to generate intermediary income to take up plant protection for the main crop besides promoting efficient utilization of natural resources.

Introduction of pigeonpea + field bean cropping system (1:1 row ratio) resulted in higher net returns of Rs.39,030 (Table 56) with benefit cost ratio of 4.12 as compared to sole crop of pigeonpea (B:C ratio 3.15) and field bean(B:C ratio 2.96).

Table 56. Yield and economics of pulse based production system

Treatments	Yield (kg ha^{-1})		Haulmyield (kg ha^{-1})	Gross income (Rs ha^{-1})	Net Income (Rs ha^{-1})	B:C ratio
	Pigeonpea	Field bean				
Pigeonpea + field bean (1:1) (TTB-7 + HA-4)	970	460	PP: 3880 FB: 3680	51530	39030	4.12
Pigeonpea sole crop	1050	-	4200	38850	26500	3.15
Field-bean sole crop	-	980	7840	33320	22070	2.96

Finger millet based double cropping system

In finger millet based double cropping system, higher returns with B:C ratio of 4.00 in 1st crop of sesame and 1.76 in 2nd crop of finger millet was obtained with adoption of package of practices for higher yields as compared to farmers practice (B:C ratio 3.50 & 1.45 respectively).

Table 57. Yield and economics of sesame - finger millet under double cropping system

Treatment	Yield (kg ha^{-1})		Returns (kg ha^{-1})		B:C ratio
	Grain	Straw	Gross	Net	
I Crop- sesame (RT-46)					
1. POP for higher yield	320	-	11200	8400	4.00
2. Farmers practice	150	-	5250	3750	3.50
II Crop- finger millet (GPU-48)					
1. POP for higher yields	1915	3255	23506	10206	1.76
2. Farmers practice	1210	2057	14852	4652	1.45

Nipping in castor

In a trial with nipping in castor, higher castor bean equivalent yield of 1152 kgha^{-1} was obtained in nipped castor + field bean with B: C ratio 2.98 as compared to non nipped castor + field bean (892 kg ha^{-1}) with B:C ratio 2.53 (Table 58).

Table 58. Yield and economics of nipping technique in Castor

Treatments (Castor +field bean)	Castor bean Yield(kg ha^{-1})	Fieldbean Yield(kg ha^{-1})	Bean equivalent yield (kg ha^{-1})	Returns(Rs ha^{-1})		B:C ratio
				Gross	Net	
1. Nipped	797	415	1152	40345	26845	2.98
2. Non nipped	592	350	892	31220	18920	2.53

Participatory varietal selection

Evaluation of finger millet varieties: All the improved varieties produced higher yield (1915 to 3040 kg ha^{-1}) compared to local variety (1410 kg ha^{-1}). Among the long duration varieties MR-1recorded higher grain yield of 3040 kg/ha as compared to other two verities. ML-365 recorded grain yield (2922 kg ha^{-1}) as compared to GPU-66 and GPU-28 among medium duration varieties. The short duration variety GPU-48 performed better (Table 59).

Table 59. Performance of different finger millet varieties

Variety	Yield (kg ha^{-1})		Returns (Rs ha^{-1})		B:C ratio
	Grain	Straw	Gross	Net	
Long duration varieties					
1. MR-1	3040	7904	37468	24318	2.85
2. L-5	3053	4376	34837	21687	2.65
3. Local	1410	2522	16576	4676	1.43
Medium duration varieties					
4. GPU-28	2507	4353	29396	16247	2.23
5. ML-365	2922	5503	34648	21498	2.63
6. GPU-66	2858	5025	33551	20401	2.55
Short duration variety					
7. GPU-48	1915	4007	26757.5	13608	2.03

Evaluation of green chilli varieties: Chilli variety, Samruddhi recorded higher green chilli yield (6494 kg ha^{-1}) and B: C ratio (4.19) as compared to local variety (Table 60).

Table 60. Yield and economics of green chilli (Mean yield of 2010-11 and 2011-12)

Variety	Green chilli (kg ha^{-1})	Returns (Rs ha^{-1})		B:C ratio
		Gross	Net	
1. Samruddhi	6494	64940	49440	4.19
2. Local	3882	38820	24070	2.66

Evaluation of pigeonpea varieties: Among four pigeonpea varieties TTB-7 recorded higher grain yield (1003 kg/ha) & B:C ratio (2.53) followed BRG-1 and BRG-2. Higher stalk yield was recorded in BRG-1 followed by TTB-7 (Table 61).

Table 61. Yield and economics of different pigeonpea varieties

Variety	Grain yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Returns (Rs ha^{-1})		B:C ratio
			Gross	Net	
1. TTB-7	1003	3795	36985	24785	3.04
2. BRG-1	915	3885	33968	21768	2.79
3. BRG-2	868	2923	31824	19624	2.61

Integrated farming system

Manocropping of finger millet with *akkadi* crops was the predominant practice followed by the farmers. Integration of different cropping systems with forestry, horticulture, live stock helps to overcome the risk of failure of crops due to weather aberration and tool for sustainable income and increased production. Besides it helps to improve the soil health.

Hence, a trial on integrated farming was taken over an area of 1.2 ha with the objective of efficient use of stored water to increase water productivity and sustainable staggered income with increased production per unit area besides overcoming risk of failure of crops due to weather aberrations and to improve soil health. The results revealed that, Integration of different cropping systems resulted in higher returns Rs. 20704 with B: C ratio 2.53 (Table 62).

Table 62. Yield and economics of integrated farming system

Treatments	Area (ha)	Yield (kg ha^{-1})				Finger millet Yield (kg ha^{-1})		Returns (Rs ha^{-1})		B:C ratio
		Castor bean	Cow pea	Pigeonpea	Field bean	Grain	Straw	Gross	Net	
Castor + cowpea (1:1)	0.15	530	280	-	-	-	-	26950	14650	2.19
Pigeonpea + (1:1) field bean	0.15	-	-	720	326	-	-	34980	22180	2.73
Finger millet + (8:2) pigeonpea	0.90	-	-	360	-	2150	5375	40281	25281	2.68
Total	1.20	530	280	1080	326	2150	5375	-	-	-

VII. IMPACTS OF OPERATIONAL RESEARCH PROJECT

A. Reduction in yield gap: The activity of ORP has resulted in 29.15 to 123.53 per cent improvement in yield of crops against the non-adopters (Table 63).

Table 63. Impact of ORP on bridging the yield gap (Mean of Villages)

Crop	Adopters	Non-adopters	Overall yield increase (%)
Finger millet	2593	1437	+ 80.39
Groundnut	956	638	+ 49.92
Pigeonpea	1066	679	+ 57.03
Castor	1152	892	+ 29.15
Sesame	190	85	+ 123.53
Chilli	5883	3468	+ 69.65
Horsegram	622	312	+ 99.52
Cowpea	654	356	+ 83.71
Soybean	2126	1850	+ 14.92
Fodder	36950	15180	+ 143.41

B. Performance of individual or package of technologies:

The technologies performed better as a package rather than in isolation. Some of the successfully performing technologies are documented below

1. Contour cultivation proved better than cultivation along the slope
2. Improved finger millet varieties performed better over local variety with an yield increase of more than 100 per cent and fitting to different sowing window
3. Drill sowing of finger millet recorded higher grain and straw yield over broadcasting
4. Transplanting in finger millet served as real time contingency against early season drought
5. Intercropping of pegionpea in paired rows in finger millet (8:2 or 10:2) with moisture conservation furrow between paired rows was found superior specially in drought years
6. Recommended dose of fertilizer recorded higher grain yield of finger millet over farmers practice
7. Recommended management practices (Drill sowing & gap filling) in finger millet recorded 24 per cent higher grain yield than farmers practice (Broadcasting in plough furrow and heavy thinning with cross cultivation)

8. Graded border strips recorded higher yield advantage (41%) in finger millet over control
9. In Preparatory tillage, fall ploughing with iron (MB) plough recorded higher grain (37%) and straw (32%) yield than ploughing with wooden plough
10. Farm pond technology for *ex-situ* rain water harvesting and multiple use of water is a boon for dryland farmers
11. Deep ploughing with KM plough enhanced the finger millet and groundnut productivity by 18-20 per cent than wooden plough
12. Maize hybrid Deccan-101 recorded 11 per cent higher grain yield over local variety
13. Balanced fertilization (3:2:1) in maize resulted in 28 per cent higher yield over control and the response varies with genotypes (24 to 32%)
14. Integrated nutrient management with 50% each through organic and inorganic sources enhanced the finger millet productivity.
15. SSNM in groundnut + pigeonpea intercropping proved better
16. Pigeonpea and castor fits well for intercropping in groundnut
17. Field bean and cowpea suits for intercropping in pigeonpea at 1:1 ratio for best management of natural resources with flow of income
18. Pigeonpea could be successfully grown with adequate plant protection measures
19. Chilli tried as an alternate crop and observed harvesting green chilli is more useful to the farmers than dry chilli because of early harvesting and proximity to the market. Samrudhi green chilli variety was found promising considering medium pungency, higher yield and attractive colour
20. Double cropping of sesame followed by short duration finger millet can be successfully cultivated with bi-modal rainfall distribution
21. IT-38956-1, a promising short duration white seeded cowpea variety suits for both early and late sowing in double cropping system
22. Value addition in pulses comprising dhal making in pigeonpea enhanced income to the farmer
23. Nipping in castor served as a simple strategy to enhance yield and income to the farmer besides reducing botrytis disease
24. Alternate land use systems considering agri-horti, horti-silvi-pasture system depending on the land capability served as a drought proof strategy for low rainfall areas
25. Integrated farming system approach was superior to mono cropping approach and is an insulation for aberrations and uncertainties

26. Capacity building of farmers through trainings and exposure visits will empower and convince the technologies

27. Crop diversification with fodder and animal health camps will improve the livelihood security

C. Livelihood improvement: The livelihood of the domain villages was improved because of diversified cropping and increased net income which made them access to diversified commodities. The livestock status in the village is not assessed after the ORP. However, the population of cross breed cows were improved due to the good development of milk co-operatives while, the draught animals and local cows were reduced because of the reduced community land which is diversified for commercial use.

D. Employment generation: Quantitative data on employment generation in terms of man days are not available. However, the farmers in the domain villages feels that the interventions viz., cropping systems, IFS, alternate land use systems, nipping in castor have generated additional employment while, the interventions viz., rain water management, weed management have reduced the labour requirement. Overall, the migration towards towns / cities was reduced because of the overall improved employment and sustainable income after the ORP.

E. Environmental services (Soil fertility improvement): The fertility status of the soil is improved through the activities viz., leguminous crops in cropping system, encouragement for green manuring, organic sources of nutrient, balanced nutrition etc (Table 64)

Table 63. Mean soil fertility status of ORP villages

Village	No. of farmers field	SOC		SN		SP		SK	
		Initial Year	End Year	Initial Year	Endr Year	Initial Year	End Year	Initial Year	End Year
Alanatha	113	0.40	0.41	153.3	165.2	19.8	20.5	158.5	163.7
CM Halli	92	0.35	0.40	168.0	186.4	21.3	33.5	145.3	158.2
MN Halli	102	0.52	0.53	198.8	210.6	34.3	35.8	128.2	150.7
Doddagangawadi	85	0.75	0.78	160.0	180.4	14.5	17.1	196.3	204.8
Rajanukunte	-	0.41	0.46	172.4	191.3	13.2	17.6	211.6	234.2

Farmer's views:

- Farmers prefer MR-1, GPU-28 and GPU-48 finger millet varieties for early, mid and late sowing respectively.
- Farmers were convinced about finger millet, groundnut and pulse based production systems. The farmers need animal drawn implements for sowing and intercultural operations.
- Farmers expressed difficulty to establish mango in Agri-Horti system due to scarcity of water during summer months besides livestock menace.

- Farmers were though convinced about the profitability of the IFS approach, improvement in soil health and overcoming risk of failure of crops due to weather aberrations, the spread of the technology is slow because of the fact that there are no adequate labour force and animal power to carry out timely operations.
- Farmers were convinced about opening of soil and moisture conservation furrow between paired rows of pigeonpea. They need animal drawn implement for opening the furrow.
- Field day and training programs resulted in knowledge empowerment of farmers regarding dryland production practices for sustainable production.
- Animal health camps improved health condition and production efficiency of livestock and prevented distress sale of infertility animals.
- The seed cum fertilizer drill for sowing finger millet + pigeonpea, finger millet + soybean is not farmer friendly, as it requires more number of laboures for dropping seed and fertilizer separately. Besides, it is heavier and drudgery. It needs refinement.
- Farmers were convinced about the performance of high yielding pigeonpea varieties and prefer to take up as intercrop since it is difficult to take up plant protection measures because of tall and wider canopy, when the crop is sown during (May and June months.
- The farmers realize higher returns by converting pigeonpea into dhal as compared to whole grain selling. However, there is no equipment available locally for dhal purpose. Therefore, farmers need low cost portable dhal making equipment for value addition to pigeonpea.
- Samruddhi chilli was found promising for dryland conditions. Suitable control measures for fruit rot to be developed.
- By growing glyricidia on bunds (about 400 plants/ha) green biomass can be generated for soil incorporation. However, glyricidia on internal bunds is not accepted by the farmers, as it affects movement of animals from plot to plot during sowing, intercultural operations because of small plot size. Therefore farmers prefer to take it up on farm boundary.

VIII. POST PROJECT SUSTAINABILITY

Post-project adoption and reasons for such gaps in technologies usage

Theme	Technology	% Adoption	Reasons
	a).Ravine reclamation (Vegetation, boulder check dams and shunken ponds	-	Higher initial cost
RWM	b) Contour cultivation	80-85%	Adopted largely
	c) Opening of staggered moisture conservation furrow	35-40%	Farmers practice crop mixture as akkadi and are reluctant to switch over in short periodPoor economyLivestock menace after the harvest of base crop
CS	Finger millet + Pigeonpea (8:2)Groundnut+Pigeonpea (8:2)Pigeonpea+cowpea(1:1) Finger millet+soybean (4:1)	35-40% 10-15% 20-25% 3-5%	Socio-economic conditionLivestock menace after the harvest of base cropLow yield of groundnut due to eratic rainfall.Wild bore menace for groundnut
INM	Use of organic and inorganic manures	50-60%	Non-availabilty of sufficient organic manures
IV	Finger millet varieties	80-90%	Availability of seeds
	Pigeonpea and cowpea varieties	10-15%	Need for fodder for livestock and the risk of plant protection
EM	Deep ploughing, land smoothening	15-20%	Poor economy statusNon-availability of draught power
ALU	Agri-silvi	5-8%	Poor establishment due to erratic rainfall. Non-availability of water during summer to give protective irrigation
	Agri-Horti (Finger millet + Mango)	15-20%	Poor economic conditionNon-availability of water during summer to give protective irrigationPoor establishment due to grazing by sheep during off-season
	Silvi pasture	5-10%	Poor establishment due to moisture stressWater scarcity for pot watering during summer monthsUncontrolled & overgrazing by livestock

IX. LESSONS LEARNT

Though Operational Research Project (ORP) could convincingly demonstrate the beneficial effect of improved technologies on increasing productivity, the adoption level continues to be low many a times. It could be observed that apart from technical feasibility and economic viability, other constraints such as social acceptability and institutional support played a major role in the adoption of technology. In this context, ORP could identify some of the adoption constraints listed hereunder:

- Establishment of good rapport in the beginning and building confidence with farmers about the importance and activities of the project
- Implementation of soil and moisture conservation measures in small and marginal farmers' field needs the identification of suitable practices
- Operational inconveniences restricted the acceptance of bunds / vegetative live hedges on the contour, which needs intensified training programmes
- Timely supply of critical inputs at affordable cost needs to be taken care for implementation of technologies
- Trainings for no-cost / low cost technologies for generation of organic biomass on the farm for maintenance of soil health
- Maintenance of optimum plant population, encouragement for inter-cultivation for aeration and weed suppression demands the popularization of seed drill
- Lack of plant protection equipments restricts the adoption of timely plant protection measures by resource poor farmers. This calls for the establishment of custom hiring center at hobli or RSK level for easy access at affordable cost.
- Lack of watch and ward and stray cattle menace restricts the cultivation of promising pre-monsoon / long duration crops
- Organizing raita sanga's to assist among themselves could address timely operation under inadequate draught power and labour force in dryland situation
- Seed villages & seed bank concept needs to be encouraged in villages through raita sanga / self help groups (SHG's)
- Absence of assured market restrict the large scale adoption of remunerative cash crops like chilli, groundnut, sunflower, soybean etc through farmers' sandy

- Planning alternate land use systems viz., horti, silvi or pasture systems in marginal lands instead of food and fodder by providing alternative employment and fulfilling food demand through public distribution system (PDS)
- Horizontal spread of dryland technologies through ORP depends on dedicated efforts of scientists intervention in farmers fields
- Alternate enterprises like dairy, sericulture, bee keeping, sheep rearing, back yard poultry, vermi-composting and cottage industries to landless labourers and rural artisans needs to be encouraged and strengthened
- Farmers prefer to plant green manuring /fodder crops around the field and not in the inter bunds.

X CAPACITY BUILDING (For farmers)

In collaboration with line departments, organized field days, training programmes on dryland production technologies and demonstration of hand tools to reduce drudgery at ORP site, also arranged visit of ORP farmers to Krishimela at GKVK campus for wider exposure to dryland production technologies and sustainable production. Further, free animal health camp and infertility camps to improve the health and production efficiency of livestock and micro-enterprises for livelihood improvement of farmers were organized in collaboration with department of animal husbandry and veterinary services.

Title	No. of farmers	Venue	Date	Department involved
Field visit to On station	50	Krishimela, UAS, GKVK	18-11-2005	Farmers from ORP area brought to GKVK, Krishimela
Farmers'-Scientists' interaction meeting	80	ORP Doddaballapur	03-11-2005	Director of Research inaugurated the meeting
Field day	180	ORP, Nelamangala	16.10.2006	Dept. of Agriculture
Field day	115	ORP, Nelamangala	27.08.2007	Dept. of Agriculture
Field day	150	ORP, Nelamangala	15.10.2008	Dept. of Agriculture Dept. of Animal husbandry and veterinary Science
Field visit to On-station	46	Krishimela, UAS, GKVK	22-11-2009	Farmers from ORP area brought to GKVK, Krishimela

TrainingsOrganized seven training programmes on different aspects of dryland production practices for sustainable production.

○ Animal Health camps

Title	No. of animals treated	Venue	Date	Dept. involved
Animal health camp and training	500	ORP, Nelamangala	05.03.2007	Dept. of Animal husbandry & Science veterinary
Animal health camp and training	550		18.12.2007	
Animal health camp & infertility camp	910		05.02.2009	
Animal health camp & infertility camp	820		04.11.2009	

XI. SUCCESS STORIES

A. Cultivation of improved finger millet varieties for higher yield.

Sri. Rajanna C.P. son of Puttaswamaiah of Chickmaranahalli village, Mahadeavpura post, Nelamangala taluk, Bangalore Rural district was having 0.8 ha rainfed and 0.1 ha irrigated land. He was cultivating local Finger millet variety and harvesting 1244 kg ha^{-1} grain and 2861 kg ha^{-1} straw. He has to support his family only with agriculture and livestock.

Operational Research project on dryland agriculture with its main focus on participatory technology demonstration motivated the farmer to grow long duration varieties of finger millet *viz*., MR-1, MR-6 for early sowing, medium duration varieties such as GPU-28, ML-365 and GPU-66 for mid sowing, while short duration variety GPU-48 for late sowing, in his land along with local variety for comparison.

The required inputs like seeds of improved varieties and fertilizer based on soil test were given under ORP. Timely sowing, maintenance of optimum spacing and plant population on thinning, timely weeding and intercultural operations were attended as per the instructions of ORP Scientists.

A rainfall of 363.4 mm was received during the cropping season with 4 dry spells of 10-15 days duration. Among the long duration varieties, the farmer has harvested 2378 kg ha^{-1} grain and 5588 kg ha^{-1} straw in respect of MR-1 with 2.24 B:C ratio as against 1244 kg grain and 2861 kg straw ha^{-1} with B:C ratio of 1.42 in case of local variety. Among the medium duration varieties ML-365 registered 2749 kg grain and 5499 kg straw ha^{-1} with B:C ratio 2.53 as compared to 1.79 and 2.01 in GPU-28 and GPU-66, respectively. Short duration variety GPU-48 recorded 1895 kg grain and 3505 kg straw ha^{-1} with B:C ratio of 1.73 compared to local variety under late sown condition.

The farmer was very happy with the performance of MR-1, ML-365 and GPU-66 and GPU-48 during early, mid and late sowing conditions and convinced about right variety for the right time of sowing. Surrounding farmers were also convinced about success of early, mid and late varieties and adopted these varieties in the next season. The seeds of these varieties were distributed by the farmer to the interested farmers for the further spread on cost basis.

B. Cultivation of improved pigeonpea varieties for higher yield

Sri. Gurumurthy, son of Siddaiah of Chickmaranahalli village, Mahadeavpura post, Nelamangala taluk, Bangalore rural district was having 1.20 ha rainfed land. His major source of income is from agriculture and livestock.

Operational Research project on dryland agriculture with its main focus on participatory technology demonstration motivated the farmer to grow improved varieties of pigeonpea *viz.,* BRG-1, TTB-7 and BRG-2 and it is new introduction.

The required inputs like seeds of improved high yielding varieties and fertilizer based on soil test were given under ORP. Timely sowing, maintenance of required spacing and plant population on thinning, timely weeding, intercultural operations and plant protection measures were attended as per the instructions of ORP Scientists.

Total of 516.4 mm rainfall was received during the cropping season with 6 dry spells of 10-15 days duration. The farmer obtained higher grain yield of 1825 kg ha^{-1} with B:C ratio of 5.73 in respect of BRG-1 followed by TTB-7 (1694 kg ha^{-1}) and BRG-2 (1435 kg ha^{-1}). The farmers prefer BRG-1 for vegetable purpose and TTB-7 for dhal purpose.

The farmer was very happy with the performance of improved pigeonpea varieties which gave higher yields. Surrounding farmers were also convinced about success of improved and high yielding varieties and adopted these varieties in the next season. The seeds of these varieties were distributed by the farmer to the interested farmers for the further spread on cost basis.

C. Groundnut + Pigeonpea (8:2) cropping system for sustainable production

Sri Gangahanumaiah son of Gangabylappa of Chikkaputtayyanapalya village, Mahadeavpura post, Nelamangala taluk, Bangalore Rural district was having 1.60 ha rainfed and 0.40 ha irrigated land. He was also a member of Milk producer's Co-operative society. He has to support his family with agriculture and livestock only.

Operational Research Project on dryland agriculture with its main focus on participatory technology demonstration motivated the farmer to follow improved technology with production practices, timely intercultural operations and plant protection measures. The required inputs like seeds and fertilizers based on soil test were given.

An amount of 625 mm rainfall was received during the cropping season with 4 dry spells of 10-15 days duration. With improved technology *viz*., Simultaneous sowing of groundnut + pigeonpea (8:2) cropping system and opening of conservation furrow in between paired rows of pigeonpea at 30 days after sowing with improved high yielding varieties and production practices, the farmer has harvested 715 kg groundnut and 940 kg pigeonpea ha^{-1} with 2.30 B:C ratio as against 535 kg groundnut and 318 kg pigeonpea ha^{-1} with B:C ratio 1.56 in case of traditional production practices of growing groundnut + pigeonpea in 14-20:1 row proportion. The yield of main and intercrop was higher in case of improved technology with production practices as compared to traditional production practices.

The farmer was very happy with the performance of both main and intercrop. Surrounding farmers were also convinced about relative advantage of the technology and improved production practices and adopted these improved production practices in the next season. The improved technology was disseminated by the farmer to the neighbouring farmers.

D. Finger millet + Pigeonpea (10:2) cropping system for sustainable production

Sri Chikkavajrappa, son of Munigangaiah Mudlupalya village, Mahadeavpura post Nelamangala taluk, Bangalore rural district was having 1.20 ha land and was following traditional production practices. His major source of income was from agriculture and livestock.

Operational Research Project on dryland agriculture with its main focus on participatory technology demonstration motivated the farmer to follow improved technology with production practices.

The required inputs like seeds and fertilizers based on soil test were given. Timely sowing, maintenance of required spacing and plant population on thinning, timely weeding and plant protection measures were attended.

An amount of 367.4 mm rainfall was received during the cropping season with 4 dry spells of 10-15 days duration. With improved technology and production practices *viz*., Simultaneous sowing of finger millet + pigeonpea (10:2) cropping system and opening of conservation furrow in between paired rows of pigeonpea with improved high yielding varieties, the farmer has harvested 2230 kg ha^{-1} finger millet and 210 kg ha^{-1} pigeonpea with 2.32 B:C ratio as against 1252 kg ha^{-1} finger millet and 853 kg ha^{-1} green fodder with B:C ratio 1.11 in case of local production practice of growing finger millet + akkadi crops in 7-14:1 row proportion. The yield of main and intercrop was higher in case of improved technology with production practices as compared to traditional production practice.

The farmer was very happy with the performance of both main and intercrop. Surrounding farmers were also convinced about the relative advantage of improved technology with production practices and adopted these improved production practices in the next season.

E. Pigeonpea + Cowpea (1:1) cropping system for higher yield

Smt.Rudramma, Hosapalya village, Mahadeavpura post Nelamangala taluk, Bangalore rural district was having 0.40 ha rainfed area. Her cultivated field was selected for new introduction of cowpea + pigeonpea (1:1) cropping system. Agriculture and livestock was the major source of income.

Operational Research Project on dryland agriculture with its main focus on participatory technology demonstration motivated the farm woman to follow improved technology with production practices *viz*., simultaneous sowing of pigeonpea + cowpea (1:1) cropping system.

The required inputs like seeds and fertilizers based on soil test were given. Timely sowing, maintenance of required spacing and plant population on thinning, timely weeding and plant protection measures were attended.

Total of 582.4 mm rainfall was received during the cropping season with 6 dry spells of 10-15 days duration. With the improved technology and production practices *viz*., simultaneous sowing of pigeonpea + cowpea (1:1) cropping system with improved high yielding varieties, the

farm woman has harvested 1079 kg ha^{-1} pigeonpea and 756 kg ha^{-1} cowpea with 5.16 B:C ratio.

Smt. Rudramma, was quite satisfied with the performance of both main and intercrop. Surrounding farmers were also got convinced about success of improved technology with production practices and adopted for the next season.

F. Cropping system for sustainable production and income

Shri.Hanumantharayappa son of Doddabylappa, Chikkaputtayyanapalya, Mahadevapura Post, Nelamangala taluk, Bangalore Rural district was having 1.00 ha land and was following traditional production practices. His major source of income was from agriculture and livestock.

The farmer has experience in taking double cropping system even under dryland condition. He used to grow vegetable cucumber during May month by taking advantage of pre-monsoon showers followed by high yielding short duration finger millet variety GPU-48 during 1st week of August.

Operational Research Project on dryland agriculture with its main focus on participatory technology demonstration motivated the farmer to follow improved technology with production practices *viz*., cropping system comprising pigeonpea + cowpea (1:1) in 0.60 ha, groundnut + pigeonpea (8:2) in 0.2 ha and groundnut + castor (8:1) in 0.50 ha was demonstrated along with livestock (4 No.), poultry (10 No.) and small ruminants (15 No.) which he has on his farm.

The required inputs like seeds and fertilizers based on soil test were given under ORP. Timely sowing, maintenance of required spacing and plant population on thinning, timely weeding and plant protection measures were attended.

In-situ water harvesting practices viz., fall plouging immediately after receipt of rains, frequent intercultural operations using bullock drawn implements during vegetative stage and opening of moisture conservation furrow between paired rows of pigeonpea and in wide row spaced crops were adopted in the farm. The farmer adopted improved varieties and procuction practices for higher yields (Groundnut:TMV-2, Castor:DCS-9, Pigeonpea: BRG-1, Cowpea: IT-38956-1).

He was awarded as innovative farmer with a certificate, memento and cash prize of Rs.1000/- during the foundation day of the Central Research Institute for Dryland Agriculture (CRIDA) Hyderabad on 12th April 2012 for his significant contribution in implementing the dryland technologies under the "Biophysical resource based groundnut intercropping systems" during the year 2010 under the Operational Research Project of the DLAP, UAS, GKVK, Bangalore.

G. Modified Bullock drawn Seed drill for finger millet sowing

Finger millet is the main crop of Tumkur, Bangalore (Rural & Urban Districts), Ramanagara, Kolar, Chikkaballapur, Chitradurga, Mysore and Mandya districts of central, eastern and southern

dry zones of Karnataka. In this region most of the small farmers sow finger millet by broadcasting and using locally available seed drill. Existing bullock drawn seed drill for finger millet is quite uncomfortable to farmers to cope up with sowing operation. Due to heaviness of the seed drill and two labourers for dropping the seeds and fertilizer, apart from the operator walking behind the implement and drudgery to the operator has been a major issue expressed by the operator.

Sowing finger millet using modified seed drill ensures recommended row spacing (30 cm) with reduced drudgery of operation and timely operation covering larger area.

Modified seed drill helps in maintaining recommended row to row spacing of 30cm with reduced implement weight by reducing one bowl, as compared to local implement. It reduces sowing operation cost up to 30% (Operational cost is Rs. 400- 500/- per hectare).

The cost of the modified seed drill is Rs.3000/-. This seed drill has been used by many farmers in few villages of Kanakapura through Operational Research Project and also in Nelamangala through National Initiative on Climate Resilient Agriculture project. Farmers realized that newly modified seed drill is good and convenient with reduced weed growth. Many of the farmers by seeing the performance of the modified seed drill the farmers have fabricated seed drills of their own.

XII. WITHDRAWAL MECHANISMS

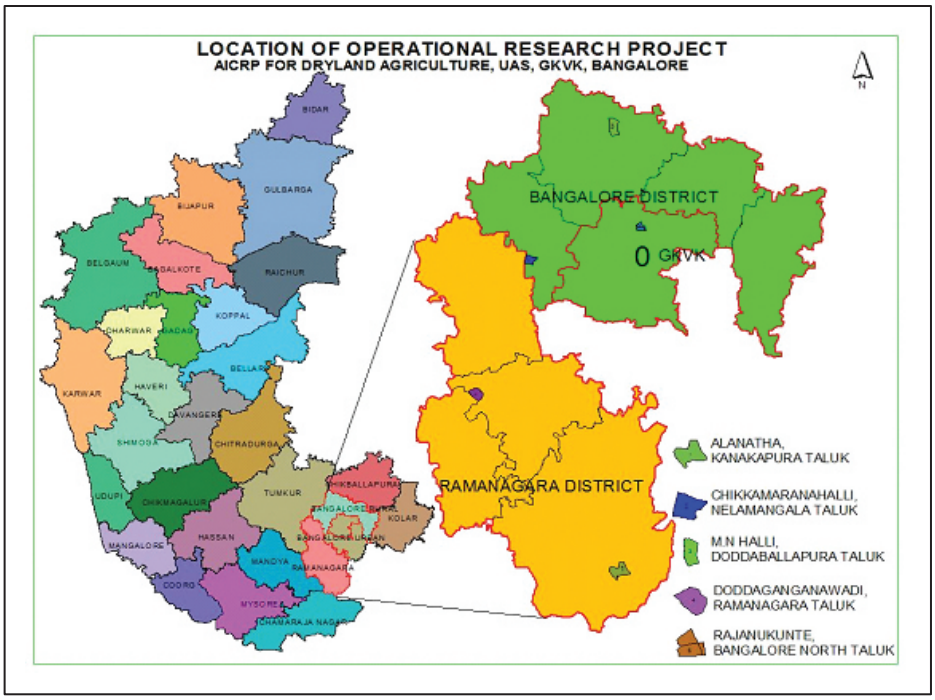
The concept of Operational Research Project approach has convincingly demonstrated the potentiality of improved practices in soil and moisture conservation, rain water management, cropping system approach, soil fertility and sustainability, integrated faming system and value addition to make nutritional and livelihood security of rainfed farmers. With an intention on horizontal spread, the ORP approach for a particular location is restricted for 4-5 years. The farmers in the ORP cluster may reap the benefits of scheme during the period of its operation. Later, though the farmers enjoyed the sustainability may partially switch back for the traditional practices due to timely non-availability of inputs, machineries, supervision and lack of investment capacity. In this context, to make the technologies to continue in and around the ORP locations after withdrawal, the following measures are essential.

- There is a need to identify and recognize the Resource management committee at the village level for the post project maintenance.
- Local youths needs to be encouraged to set up agro service center with modern equipment, implements on custom hiring basis and other agricultural inputs on credit basis or through Raitha samparka kendras(RSK's).
- Institution support from the line departments should be ensured as a follow up programme after the withdrawal of the project to sustain production and productivity.
- Non-Governmental Organizations (NGO's) need to be encouraged to monitor the technologies.
- The RAWE program of the Under-graduate Agriculture students of the University through RSK's may be linked to follow up.
- The KVK's of the district may be linked with 1or 2 programs of their mandate in the ORP site. Which, may help for the follow up.
- The Officials of the revenue department (Village accountant / gram sevak) can also co-ordinate for the follow up.
- Follow up visits by Agriculture scientists during intervention and critical cropping stage will help in continuation of successful technologies even after withdrawing from the area.

XIII LINKAGES DEVELOPED WITH STAKE HOLDERS

Organizations	Programme planning	Purpose Implementation	Capacity building of farmers
Self Help Groups	✓	✓	—
Village Organizations (VOs)	✓	—	—
Panchayat Raj Institutes	✓	—	—
Dept. of Agriculture, Govt. of Karnataka	✓	✓	✓
Dept. of Horticulture, Govt. of Karnataka	✓	✓	✓
Dept. of Animal Husbandry, GoK	✓	✓	✓
Dept. of Forestry, Govt. of Karnataka	✓	—	—
Watershed Development Department, GoK	✓	✓	✓
KVK	✓	—	✓

Modified Bullock drawn Seed drill



Finger millet + Pigeonpea (8:2)

Finger millet + Akkadi

Groundnut + Pigeonpea (8:2)

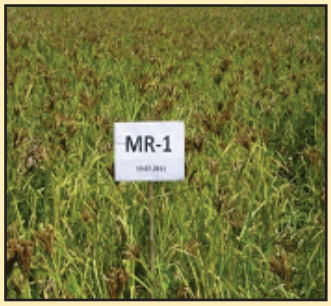
Groundnut + Castor (8:1)

Finger millet + Soybean (4:1)

Opening of moisture conservation furrow

Pigeonpea + Cowpea

(1:1)Pigeonpea + field bean(1:1)



Finger millet varieties


Pigeonpea varieties

Multiple use of Farm pond

Samrudhi chilli

Animal Health camp


Improved method of storage

PRA Exercise

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