NATP, TECHNICAL BULLETIN: 33

RAIN WATER MANAGEMENT TECHNIQUES FOR COTTON-BASED CROPPING SYSTEMS

K. S. Bhaskar
S. M. Wasnik
M. R. K. Rao
M. R. Suryavanshi
P. N. Mendhe
N. P. Barabde

Central Institute for Cotton Research
Nagpur

RAIN WATER MANAGEMENT TECHNIQUES FOR COTTON-BASED CROPPING SYSTEMS

Foreword

Cotton is one of the most important cash, commercial and fibre *kharif* crop being grown by the farmers in area of about 8.5 Mha both under rainfed and irrigated conditions in the country. Soil is the resultant products of the process of its formation over a period of time in a certain landform by the action of climate and biosphere. Toposequence exist in continuous and are heterogeneous in their physical and chemical properties. Toposequencial and variation in the soil, affects the overall productivity of the crops and cropping system. However, the productivity of any crop and cropping system depends upon the soil-site characteristics, climatic parameters, genotypes and management levels. The productivity of any crop varies from one toposequence to another even under uniform level of management. In this view, soil and water resources become very precious looking to ever increasing population of the country at faster rate, and due to that management of soil and water resources for sustainable production of rainfed crops become paramount importance. Considering cotton scenario at world level, India is having maximum area under cotton with minimum (440 kg lint ha^{-1}) yield in the world. The situation of cotton in Maharashtra (170 kg lint ha^{-1}) is the worst not only within India but also at the world level. The main reason of low yield of this white gold in the country, that maximum (65-70%) area is under rainfed situation. In case of Maharashtra, it is as high as 97%. Undulating topography is also not helpful for rainfed cotton cultivation and this is the second most important factor in reducing the yield of rainfed cotton. Although, total rainfall in cotton growing regions in the country is quite favourable, the time of occurrence of rainfall and its distribution playa crucial role in successful rainfed crop production. If cotton is sown with intercrops on suitable soils with one or two protective irrigations, the seed cotton yield could be increased significantly even on shallow soils. Scarcity of rainfall and degraded soil conditions could be managed by adopting watershed-based technologies, which are nowadays a dependable source for conservation and protection of soil and water resources for sustainable crop production.

I feel pleasure in writing this foreword and congratulate Dr. K.S. Bhaskar, Principal Scientist (Agronomy) and his team who have done commendable work by conducting NATP field experiments on different toposequences at Thugaon Micro-watershed, Distt. Amaravati, Maharashtra. They have gathered national level valuable additional information besides the experimental data and compiled it in the form of bulletin. I am sure and confident that this bulletin will be very useful to crop and land use planners, natural resource managers, extension workers, students and the farmers in the country.

Date : June, 2005 **(B. M. Khadi)**

Director

Acknowledgement

It is a matter of great pleasure to develop this bulletin on "Rain water management techniques for cotton-based cropping systems" based on the collective research efforts put in by the team in the project entitled "NATP, RCPS-5: Rain water conservation, harvesting and recycling/recharging techniques for enhanced productivity of cotton-based cropping system" at Thugaon Micro-watershed Distt. Amravati, Maharashtra.

Authors are grateful to Dr. M.S. Kairon, Dr. C.D. Mayee, former Directors, Dr. Phundan Singh, former Acting Director and Dr. B.M. Khadi, present Director, Central Institute for Cotton Research, Nagpur for their constant help and encouragement to bringing out this bulletin. Authors are highly thankful to Dr. H.P. Singh, Director and Dr. B.Venketeshwarlu, Production System Scientist, NATP, Rainfed Agro-ecosystem, CRIDA, Hyderabad for timely financial assistance for conducting experiments for last 5 years. Authors are also thankful to Dr. S.K. Banerjee, Chief Co-ordinator, NATP Cell, CICR, Nagpur and his team members for the help rendered in the management to conduct project work.

Besides the above, authors are very thankful to the following scientists / officials, who have directly / indirectly helped and co-operated in identification and development of the Thugaon micro-watershed.

- Vice Chanceller, Amravati University, Amravati.
- Dr. B.A. Lakhadive, Dr. V.N. Deshmukh and Er. D.S. Sonkusale, Princial Investigators of the Project, Dr. P.D.K.V. Akola.
- Dr. Sheo Raj, Head, Division of Crop Protection, CICR Nagpur.
- Dr. S. R. Singh, Principal Scientist, NBSS&LUP, Nagpur.
- Dr. G.B. Pachade, Reader, Department of Chemistry, Sri Shivaji Science College and Secretary, Chandrabhaga Nadikhore Vikash Mitramandal, Chandur Railway, Amravati.
- Shri. G.B. Wagh, Propriter, Trimurti, Krishi Seva Kendra and President Chandrabhaga Nadikhore Vikash Mitramandal, Chandur Railway, Amravati.
- Shri. P.N. Raut, Joint-Director Agriculture, Government of Maharashtra, Amravati Division.
- Shri.K.J. Nandeshwar, Superintending Agriculture Officer, Government of Maharasthra, Amravati.
- Shri. M.G. Deshmukh, Sub-divisional Officer, Department of Agriculture, Chandur Railway, Amravati.
- Dr. M.A. Jaipurkar, Head Regional Research Station, Dr. PDKV, Amravati.
- Dr. (Mrs.) Varsha Tapre, Senior Research Assistant, Dr. PDKV, Regional Research Station, Amravati.
- Dr. S.R. Manik, Professor, Depertment of Botany, Amravati University, Amravati.
- Shri. Sudam Rao Tambekar, Sarpanch, Gram Panchayat, Mardi, Amravati.
- Shri. Naneswar Kharwade, Progressive Farmer, Mardi, Amravati.
- Shri. Pralhad* Rao Barabde, Agriculture Officer (Retired), Amravati.

Contents

Figures

Plates

Tables

1. INTRODUCTION

Soil is the resultant product of the processes of its formation over a period of time in a certain landform by action of climate and biosphere. Toposequences exist in continuity and are heterogeneous in their physical and chemical properties. The variation in soil characteristics affect the crop production potential. Soil and water are precious for agriculture. Every drop of water and every soil particle has to be protected and conserved and excess runoff water is to be disposed off safely, for enhancing water and soil conservation. For efficient utilization of limited soil and water resources, it is essential to increase food production per unit area and per unit time on sustainable basis. Soils are subject to heavy erosion (5.3Mt) and nutrient loss (8.0Mt) per year due to faulty land use management practices at farm level. Proper soil and water conservation measures on different toposequences, supported by introduction of improved agronomic practices to increase the total biomass production on each toposequence are necessary based on watershed for sustainable crop production, not only to cater to the existing needs as a part of development of the farming community, but for posterity also.

Watershed is a hydrological unit covering a definite land area with a common drainage point. Inventory of soil, water and vegetative resources is a pre-requisite for undertaking the watershed development, for appropriate land use planning on a sustainable basis. Watershed management approach ensures conservation and protection of these resources and their proper use for agricultural and non-agricultural uses. However, the productivity of any cropping/ farming system is dependent on landform, soil type, climatic characteristics and management levels (Bhaskar *et al.*, 2004).

Out of 329 M ha geographical area of the country, potential human induced land degradation is reported to be as high as 187.7M ha (Paroda, 1998). At least 57.1 % of geographical area of the country suffers from different forms of land degradation and out of it, water erosion accounts for 65% land degradation. A large variety of soils spreading all over Indian sub continent are derived from a wide range of geographical rocks and parent material, interacting with soil forming features like climate, vegetation and topography for varying time period. The capacity of soil to produce is limited by intrinsic characteristics, agro-ecological setting and land and water management practices (Bhaskar *et al.*, 2002). Proper identification, characterization and efficient land use management could increase the productivity of degraded lands (Bhaskar *et al.*, 2004). Cotton is one of the most important cash (commercial and fibre) crop of the country, occupying an area of 8.5 M ha with an average yield of about 440 kg lint ha^{-1}, which is very low as compared to world average (650 kg lint ha^{-1}). Cotton productivity in Maharashtra is the lowest (170 kg lint ha^{-1}) in the country. Low yield of cotton in the state is mainly associated with cultivation of cotton under rainfed (97%) situation on very shallow to medium deep soils with poor management levels. Cultivation of cotton on very shallow to shallow soils is not good and such soils are not economically suitable for rainfed cotton production (Bhaskar et al., 1987). About 67.8% soils in Maharashtra are topographically very shallow to moderately shallow and not supporting plant growth under rainfed situation mainly due to shallow profile depth with low available water capacity (NBSS & LUP). The variability in climate, soil type, crop, variety and management inputs are also affecting seed cotton yield adversely. Under such circumstances, proper management of rainfed cotton is not only essential, but also is the need of the hour and that is possible only with the adoption of watershed-based technologies for efficient crop management. In order to test such technologies under the NATP funded research project (RCPS-5) experiments were conducted to evaluate rain water conservation, harvesting and recycling/ recharging techniques for enhanced productivity of cotton-based cropping system on different toposequences at Thugaon microwatershed, District Amaravati, Maharashtra for four (2000-2004) years.

2. WHY RAIN WATER MANAGEMENT IS ESSENTIAL

Any form of water is from rain and any thing can be made but not water in true sense. Water is life and without it no production is possible. Water is essential for all the activities either related with soil, plant or human resources. Water is essential to support about 17% world's human population, (71 billion) and 15% livestock (about 453 million) from 2-3% area, 4% fresh water and 1 % forest cover. We need water and land use more judiciously to ensure:

- Food security
- Lively hood security
- Health security and
- Ecological security

However, in the word's of Dr Kofi Annan, U.N. Secretary General, that "by 2025, two third of the world's population is likely to live in countries with moderate or severe water shortage". However, rainfed crop production is mainly affected by soil degradation and decreasing availability of water for irrigation as detailed below:

3. PROBLEM OF SOIL DEGRADATION IN INDIA

Natural resources, which form the basis for agriculture are under greater pressure due to the growing demand for food, feed, fibre, fuel and shelter by burgeoning population. Oldman (1994) assessed that globally about 15% of the land is severally degraded. In India alone, about 187. 7 M ha (57.1 %) area is degraded and due to that about 17% cumulative productivity loss between 1945 to 1990 has been recorded (Crosson, 1994). Lal (1995) estimated that yield reductions due to erosion in the past have averaged to about 6% with a range of about 2-40% and the global estimates show that 1.965 billion ha of land area is subjected to different kinds of soil degradation. Since, the productivity of crops in irrigated situation is plateauing, bulk of rising food demand in the country has to be met by enhancing the productivity of the rainfed areas through judicious use of soil and water resources, at field level within the boundary of the watershed, for which location specific technology has to be developed. To achieve this goal, productivity of food grain needs to be enhanced from the current level of 0.8-1.0 t ha^{-1} by 2025 (Anonymous, 1997). Similarly, the productivity of cotton is also to be enhanced to meet the estimated cotton requirement of 230 Lakh bales by 2020 (Vision, 2020). At present the productivity of cotton and cotton based crops such as sorghum, pigeonpea, soybean, greengram and chickpea is considerably low and these crops suffer due to severe moisture stress. However, the yield of these crops could be increased by proper management of rainwater in-situ, adoption of suitable cropping system and collection of excess runoff water and recycling to the crops as protective irrigation as per need on each toposequence for realizing higher yields.

Plate 1. A view of side cutting of soil in Nallah due to heavy rainwater

Plate 2. Over exploitation of soil resource due to faulty cultivation of cotton on severely eroded soils

Over exploitation of natural resources (Plate 2) is causing environmental and soil degradation and due to that, soil erosion is increasing along with decline of yield in upper to lower toposequence. In this view, the yield of the crops could be increased and the soil loss could be minimized by following effective in-situ water harvesting and recycling to cotton and cotton based crops as protective irrigation.

4. PROBLEM OF DECREASING PER CAPITA WATER AVAILABILITY FOR IRRIGATION

It is estimated that the per capita per annum water availability for irrigation, which is presently at the level of 2001 M^3, will be reduced to the stress level of 1700 M^3 in the next 2-3 decades. The ultimate irrigation potential of the country has been estimated at 139.5 M ha comprising of 58.5 M ha from major and medium schemes, 15 M ha from minor irrigation schemes and 66 M ha from ground water exploitation. However, even after achieving full irrigation potential, nearly 50 % of the total cultivated area will remain rainfed. Water availability in India is following a decreasing trend (Table 1). During 1955, the water availability was 5.3 (thousand m^3) which was reduced to 2.5 in 1990 and in 2025, it will be reduced to 1.5 (thousand m^3) which is a very bad sign for a country like India, although the situation in other countries except Bangladesh, U.K. and USA is also not so good. Except for a few countries, shortage of water in the whole world is alarming and protection, conservation and judicious use of rainwater is a must for realizing higher yields and sustainable management of precious natural resources in the country.

Table 1. Per capita water availability in different countries (Thousand m3)

Country	1955	1990	2025
India	5.3	2.5	1.5
China	4.6	2.4	1.8
Pakistan	10.6	4.0	1.8
Bangladesh	51.8	20.7	10.6
Nepal	19.8	8.7	4.2
UK	2.3	2.1	2.0
USA	14.9	9.9	7.7

5. METHODOLOGY

Upper, middle, lower and bottom toposequences were identified, characterized and tested for rain water management and higher yield realization of cotton, sorghum, soybean and greengram crops during *Kharif* and chickpea under protective irrigation during *Rabi* 2000-2004 after following different moisture management practices on different toposequences.

The study was conducted by Central Institute for Cotton Research, Nagpur under NATP (Rainfed Agro-ecosystem) RCPS-5 to fulfil the requirement of the project entitled **"Rain water conservation, harvesting and recycling / recharging techniques for enhanced productivity of cotton-based cropping systems"** with the following major objectives:

Major objectives

- To develop suitable toposequence-based cropping systems for efficient use of moisture, improved productivity and gross monetary return (GMR)
- To develop suitable land configuration and cropping systems to minimize the adverse effect of excess moisture
- To estimate the harvested runoff water in farm pond and recycling through drip and also to increase recharge capacity of irrigation wells.

5.1 Technical Programme

Onfarm Research Programme

Experiment 1: Upper toposequence

T1 Farmer's practice, sale Cotton *(hirsutum)* on flat bed + 100% recommended dose of fertiliser

T2 Cotton *(arboreum)* + Sorghum on flat bed + 100 % recommended dose of fertiliser

T3 Cotton + Sorghum on ridges and furrows+ 100% recommended dose of fertiliser

T4 T3 + Supplemental irrigation + 100% recommended dose of fertiliser

Experiment 2. : Middle toposequence

T1 Sowing of *hirsutum* Cotton as a sale crop on flat bed

T2 Cotton *(hirsutum)* + Greengram on flat bed

T3 Cotton *(hirsutum)* on contour

T4 T3 + recycling of water

Experiment 3: Lower toposequence

T1 Sowing of Cotton *hirsutum* as a sale crop on flat bed

T2 Cotton in ridges and furrows + Soybean followed by Chickpea

T3 Soybean followed by Chickpea

T4 Cotton followed by Chickpea under harvested rainwater as life saving irrigation

Experiment 4: Excess moisture management in bottom toposequence

T1 Sowing of Cotton on flat bed

T2 T1 + Ridges and furrows at 30 days after sowing

T3 Broad-bed and sunken-bed sowing (30 - 180 - 30)

T4 Raised and sunken bed layout

Before commencing field experimentation, detailed information about soil-site characteristics, major land form, land capability, soil type, cropping pattern, land use pattern, rain water availability etc. the essential pre-requisites for efficient land use management for sustainable cotton production in the micro-watershed was collected.

5.2 Technologies Given

Field preparation: Farmers in the watershed area were advised for undertaking one deep ploughing once in two years during summer and keep the fields open till the onset of monsoon. Two harrowings followed by planking and leveling were advised for enabling better sowing. Besides these agronomic practices, farmers were advised to apply 5-10 cartloads of FYM.

Sowing: Generally, square sowing of the cotton crop is preferred by the farmers in the watershed area with different sowing distances. However, they were advised for cotton sowing at 60x60 cm on upper toposequence, 90x90 cm in middle and lower toposequences and 120x90 cm on bottom toposequence. The intercrops were adjusted between two rows of cotton as per plan.

Time of sowing: Farmers who were having sufficient seeds were advised for dry sowing a week before the onset of regular monsoon and those having limited seeds were advised to sow @ two seeds hill^{-1} after the receipt of 4-5 inches cumulative rainfall. During the cropping seasons, almost every year there was a rainfall gap from 8 days to 22 days and during this period crop germination was very poor on upper to lower toposequences and in some years in all the toposequences and hence the gap filling/resowing of cotton, soybean, sorghum and greengram crops was done regularly to get proper plant stand.

Fertiliser application: No soil based fertilizer recommendations for rainfed crops are existing in the country. It was suggested that farmers should apply fertilizer to the cotton and cotton-based crops at the following rates after weeding of the fields.

Toposequence	Fertilizer dose (kg ha^{-1})		Remark
	Nitrogen	Phosphorous	
Upper	60	40	No separate fertilizer was applied to pigeonpea, greengram, soybean and sorghum crops grown as strip/inter crop with cotton
Middle	60	40	
Lower	80	40	
Bottom	80	40	

Half dose of nitrogen and full dose of phosphorous was applied through ring method or deep placement below the crown of plant. Remaining half dose of nitrogen was applied in two splits, first at 40 days after sowing and rest half at 60-65 days after sowing depending on the availability of moisture in the soil.

Thinning of the plants: Farmers were advised to keep two plants per hill on upper to lower toposequences and one plant per hill on bottom toposequence at 15-20 days after sowing.

Weed management: Weed management in cotton and cotton-based crops is essential to keep the field free from weeds and improve soil and water use efficiency with higher yield and economic return. When spot sowing of cotton is being followed, weed problem is not that acute and hand weeding is preferred by the farmers rather than the use of costly weedicides.

Moisture management: After sowing of the rainfed crops, interculture operations like light hoeing is very essential in cotton and cotton-based cropping systems, to break the upper crust of the soil and improve aeration in the soil to improve available water in the soil for proper plant stand and good growth. It is also essential to keep field free from weeds before application of fertilizer to cotton crop. Under rainfed situation, moisture management is very important and various moisture conservation practices as per plan were followed on different toposequences.

Water harvesting: The excess runoff water was harvested from different toposequences and stored in the water harvesting pond for recycling to cotton and cotton-based crops as per need and plan.

Recycling: Recycling of harvested rainwater from available sources was done as per program to cotton and cotton-based crops at the rate of 6 ha cm of water at early and peak boll development stages on different toposequences.

5.3 Soil-site and Climatic Characteristics

The soils of the study area are very shallow to medium deep, moderately sloppy (3-15%), severely eroded, excessively well drained, loamy, skeletal, mixed, hyperthermic Lithic Ustorthents (Plate 3). The climate of the area is semi-arid tropical, falls under agro-ecosystem number 6 (Deccan plateau, hot, semi-arid region with shallow and medium (with inclusion of deep black soils) and LGP 90-150 days.

Plate 3. A view of toposequencial changes in Thugaon micro-watershed

Generally, there are two distinct rainy seasons prevalent in the area. The summer monsoon (June to September) and the winter (October to February) retreating rainy season. Summer monsoon is the principal rainy season for almost the entire India. It starts in June and lasts till September and contributes almost 70-90 % of the seasonal rainfall. This area comes under moderate (800-1000 mm) rainfall zone. The mean annual rainfall in the area is 959 mm and the mean annual temperature is 27.1°C, which goes highest (35.0^0C) in May and the lowest (21.8°C) in December. Although total rainfall in the area is almost sufficient for rainfed crop production, its distribution is very poor which effects adversely seed germination, crop growth and finally seed cotton yield (Annexure I).

5.4 Physico-chemical Properties of Different Toposequences

The physico-chemical properties of different toposequences were evaluated. It is very clear from the data (Table 2) that the chemical properties such as soil pH, available N, P and K and organic carbon showed an increase from upper to lower toposequences, with lowest values in upper plain and the highest under lower plain. The availability of these nutrients in middle plain was almost in between. This is due to varying soil depths and soil slopes and all soluble nutrients were being carried with runoff water and deposited in soils of lower toposequences. As regards the soil Ec, the trend was just reversed. It was highest under upper plain and the lowest under bottom plain. It is also clear from the data that with increase in soil pH, Ec was in declining trend (Table 2).

Table 2. Physico-chemical properties of different toposequences at Thugaon micro-watershed

Toposequence	Name of the parameters					
	pH	Ec (dsm^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Organic carbon (%)
Upper	7.69	0.140	213.18	13.972	192.67	0.373
Middle	7.81	0.138	242.35	14.288	204.50	0.397
Lower	7.80	0.126	284.15	14.287	223.95	0.390
Bottom	8.00	0.114	282.05	14.574	221.74	0.418

5.5. Major landforms and soil types

The major landforms and soil types in the watershed area were developed on recent alluvial plains located along the small streams mainly formed by the basaltic and colossal material. The plain is highly dissected forming gullies at places and also formed plain land after deposition of sediments in patches in valley bottom (Table 3). The major land forms/soil types characterised in the area are given below.

Table 3. Major landforms and soil types

Toposequence	Soil depth (cm)	Soil characteristics	Present land use	Land capability classes
Foot hills	Extremely shallow to shallow (<25cm deep)	Extremely shallow to very shallow, 10-15 % slope, very severe erosion, calcareous and stony	Mixed tree and shrub	IV
Upper plain	Shallow to slightly deep (25-50cm deep)	Shallow to slightly deep, gravelly, sandy clay loam, gently slopping (3-5%) to strongly slopping (5-	Silvipasture, forestry, agro-forestry, fruit crops and cotton-based cropping system.	IIIst

		10%), severe to very severe erosion, moderately to strongly stony and calcareous		
Middle plain	Moderately deep to deep (50-100cm deep)	Moderately deep to deep, gravelly sandy clay to clay loam, gently slopping (3-5%), moderate erosion, calcareous and slightly stony to stony	Agro-forestry, agro-horticulture and cover crops like greengram, blackgram, soybean mothbean and cotton based cropping system.	IIst
Lower and bottom plain	Very deep (>100cm deep)	Deep, silty clay loam, gently slopping, moderate erosion and slightly stoney	Agro-horticulture, cotton, sorghum and greengram crops etc.	IIst

5.6. Soil Depth Pattern

The soil depth pattern in the watershed and around the area, varied as that in Amravati district as a whole (Table 4). The cultivated area in Chandur Railway is 11.27 and 13.59% respectively under very shallow and shallow (Plate 4), 9.94% in medium deep, while 9.13 and 13.05% respectively under deep and very deep Vertisols (Plate 5). The productivity of deep to very deep soils is high with better management, but the percentage of these soils is about 22% only. Shallow to medium deep soils are scattered in patches on upper toposequence, which are mainly cultivated for cotton, sorghum, pigeonpea, greengram and soybean crops and the productivity of these crops is considerably low. Low Yield of these crops is mainly associated with severe soil erosion, low water holding capacity, poor soil fertility and less growing period.

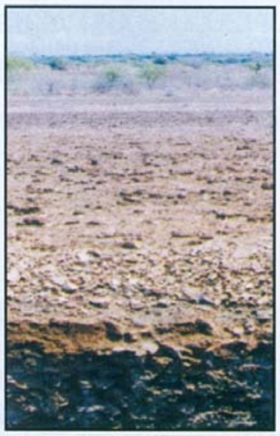

Plate 4. Shallow soil (<15cm depth) on upper toposequence

Plate 5. Very deep (>90 cm depth) on bottom toposequence

Table 4. Soil classification according to soil depth of Tahsil Chandur Railway, and District Amravati

Soil type	Soil depth (cm)	Area (ha)		% area in Chandur Railway tahsil, district Amravati
		Amravati	Chandur Railway	
Very shallow	0-15	25,090	2,828	11.27
Shallow	15-25	229,890	31,260	13.59
Medium deep	25-50	116,368	11,571	9.94
Deep	50-100	113,962	10,409	9.13
Very deep	100-150	356,225	46,474	13.05
Total		841,535	102,54	12.18

5.7. Daily Rainfall

The daily rainfall at the study area was collected for four (2000-2004) years from village Karla and Chandur Railway, Dist. Amaravati. Daily rainfall was used for calculation of per day rain water availability, runoff collection and loss of water due to evaporation (Annexure II).

5.8. Land Capability

The entire geographical area of Thugaon micro-watershed is categorized into six land capability classes. Maximum (365.81 %) area is under class IV, followed (28.19%) by class III and the minimum (10.61 %) under class VI soils (Table 5). This showed that there is no soil under class 1 catagary. However, soils under class II covered 24.48% area only. Maximum (65.80%) soils are under class III and class IV category and no soil is available in class V, while as 10-16 % soils are under class VI category which are steep to very steep, stony and covered under forest with undulating topography (Table 5).

Table 5. Land capability classification of soils of Thugaon micro-watershed

S. N.	Particular	Total area (ha)	Area (%)
1.	Geographical area of watershed	227.16	100
2.	Land capability classification		
	Class I	-	-
	Class II	55.60	24.48
	Class III	64.03	28.19
	Class IV	83.82	36.81
	Class V	-	-
	Class VI	24.11	10.61
3.	Soil depth classification		
	Shallow soil	24.11	10.61
	Medium deep soil	147.45	64.91
	Deep soil	55.60	24.48

Maximum (75.52%) soils in the watershed area are shallow to medium deep, which falls on upper to lower toposequences and having low available water and nutrient holding capacity and due to that yield of major crops is less and hence not suitable for rainfed crop production. About 24.48% soils are deep and which are suitable for rainfed crop production and their productivity is high and utilised mostly cultivation of cotton and cotton-based crops with Citrus plantation in patches depending upon irrigation water availability.

5.9. Land Use Pattern in Watershed Area

In micro-watershed area; Thugaon, Mardi, Karla and Pathergaon are the 4 villages covered under this study. In these villages, more than 80 % land area is rainfed and only 0.6 to 5.4 % is under irrigated condition (Table 6). Of the total land holding, cotton is the main cash crop followed by sorghum, pigeonpea and greengram as associate crops being grown by the farmers during *Kharif* as intercrop. Wheat, gram and vegetables are being grown in patches, mainly where soils are deep and irrigation facilities are available during *Rabi* season. Due to good efforts of the Soil and Water Conservation Department, District Amravati , number of watershed structures have been developed and due to that recharge capacity in the irrigation wells has increased over the years and due to that area under irrigation through drip and sprinkler is slightly increasing under cotton, oranges and vegetable crops.

Table 6. Land use pattern in different watershed villages

S. N.	Watershed village	Total land (ha)	Irrigated (ha)	Rainfed (ha)	Forest land (ha)	Fallow land (ha)
1.	Mardi	2084.80	14.32	645.70	20.63	1403.96
2.	Karla	1722.79	37.11	901.59	595.38	259.54
3.	Thugaon	410.40	11.00	325.74	-	41.50
4.	Pathergaon	762.64	51.20	620.87	-	94.17
	Total	4980.63	62.43	2493.9	616.1	1799.17

6. HUMAN POPULATION

The human population in watershed villages of the watershed farmers was estimated (Table 7). It was found that total population in the watershed villages was 9471 with family population of 1958. Out of the total family population, 297 and 448 families belongs to scheduled caste and scheduled tribe communities respectively (Table 7).

Table 7. Human population in different watershed villages.

S.N.	Name of village	Total population	Number of families	Number of schedule caste families	Number of schedule tribe families
1.	Mardi	2193	817	74	39
2.	Karla	2993	995	107	391
3.	Thugaon	3850	43	49	07

4	Pathergaon	435	103	67	11
	Total	9471	1958	297	448

7. ANIMAL POPULATION

The animal population of the watershed villages was evaluated (Table 8). The total population in watershed area of all the animals was 3278, and out of that 1407 were cows, 134 buffaloes, 269 goats, 1107 sheep and the poultry was 361 , which were scattered in Mardi, Karla, Thugaon and Pathergaon villages (Plate 6). Very shallow to shallow soils on foot hill slope are full of grasses, bushes and minor forest trees and found suitable for grazing of the animals to a maximum extent. Over grazing is being done in the area and due to that the problem of soil erosion has come into being from severe to very severe grade.

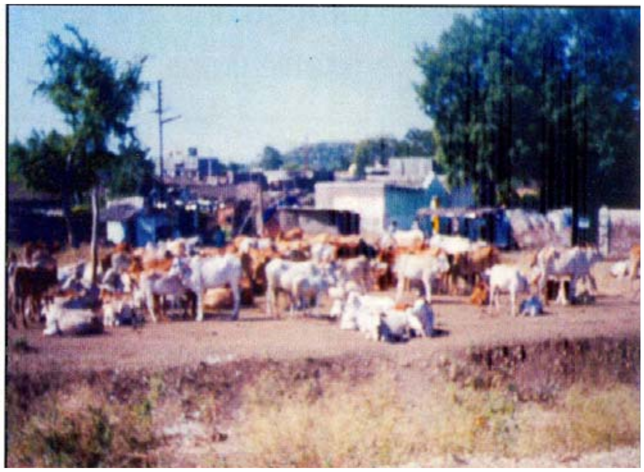

Plate 6. A view of heard of cows in Karla village in watershed area

Table 8. Animal population in different watershed villages

S.N.	Village	Cow			Buffalo			Goat	Sheep	Poultry	Total
		Male	Female	Total	Male	Female	Total				
1.	Mardi	310	215	525	2	55	57	-	600	180	1362
2.	Karla	300	230	530	2	49	51	130	371	99	1181
3.	Thugaon	128	66	194	1	13	14	60	-	39	307
4.	Pathergaon	116	420	158	1	11	12	79	136	43	428
	Total	854	931	1407	6	128	134	269	1107	361	3278

8. EXISTING CROPPING PATTERN IN AMRAVATI DISTRICT

The existing cropping patterns in Amaravati district were studied for crop yield performance and identified the best suited cropping pattern in the watershed area.

Cotton (*Gossypium hirsutum*) : It is very clear from the cotton production trend that very little improvement in seed cotton yield has been recorded prior to 1991 followed by a slight slow decline upto 1995-96 (Fig. 1 a). However, after this period, area was fluctuating and even than significant increase in cotton production and productivity has been recorded. During the last, 5-6 years, crop has been suffering from vagaries of monsoon. Further, yield trend showed that despite decease in total cropped area under this crop, the production and productivity has increased significantly, may be due to adoption of better crop management practices by the farmers and development of location specific suitable cotton genotypes in the recent past.

Sorghum (*Sorghum bicolor*) : Sorghum is a poor man's food. The area of this crop is almost constant with decrease in total yield, while productivity has shown an increasing trend (Fig.1 b). Higher productivity of sorghum in the district may be due to introduction of good genotypes and adoption of better crop management practices by the farmers. However, decrease in area in this crop, might be due to replaced cotton area by soybean and greengram crops.

.

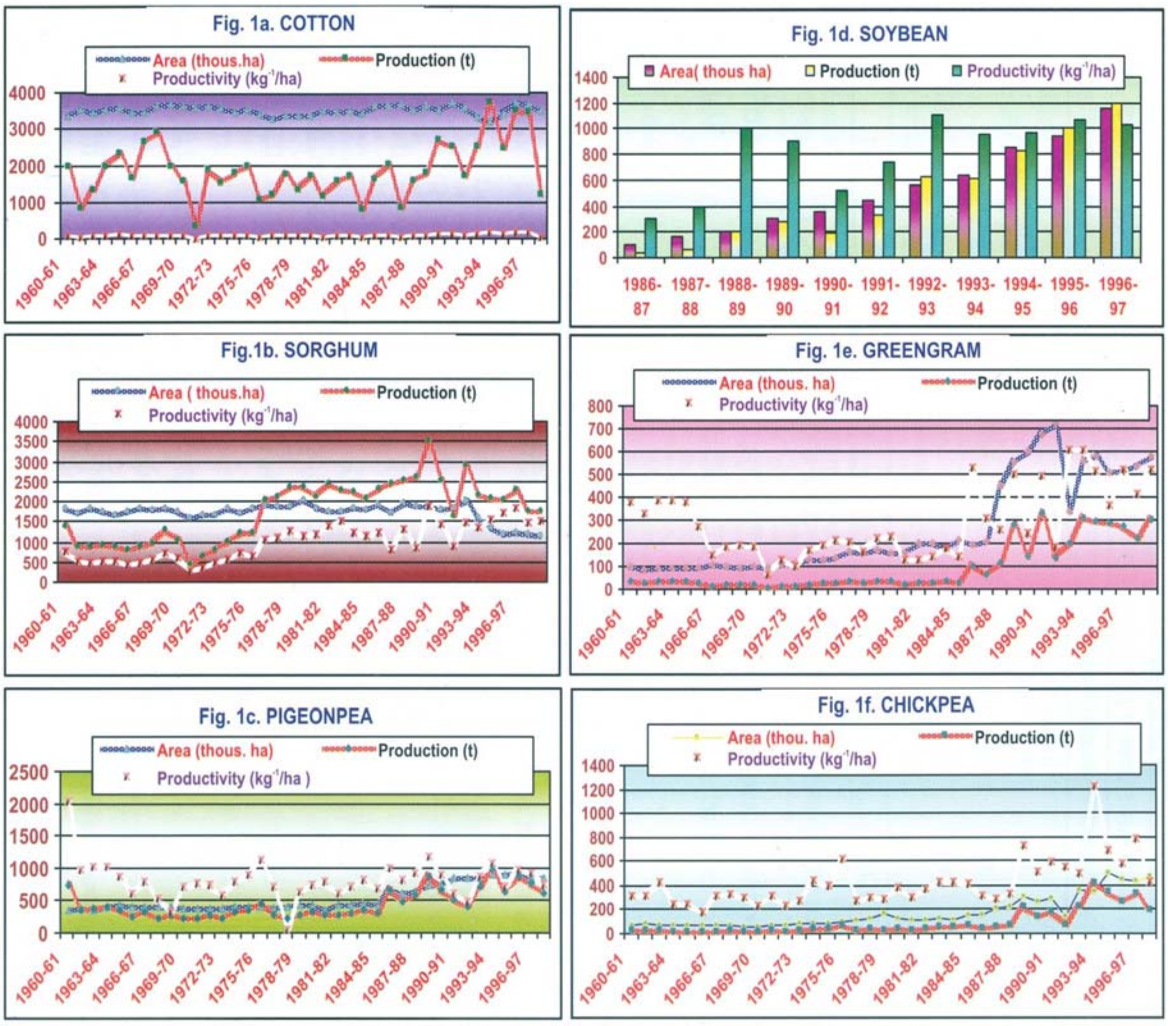

Fig. 1a, 1f. showing area, production and productivity of crops in Amravati district during 1960-1997.

Pigeonpea (C*ajanus cajan*): Initially, no significant increase in area, production and productivity of this crop has been noticed prior to 1985 (Fig.1 c). However, after this period, there was a quantum increase in area, production and productivity of this crop. The average productivity upto 1985 was 449 (kg ha^{-1}) only, while beyond that both production and productivity have increased in the same manner as that of area.

Soybean (*Glycin max*): Initially, the area, production and productivity of this crop were very low and gradually the crop gained popularity in the district and due to that area under this crop has increased significantly along with productivity (Fig.1 d). However, after 1991-92, there was a sudden increase in area form 157.6 to 657.6 thousand ha and due to that production and productivity of this major oilseed crop has increased significantly. But, after 1993-94, inspite of increase in area, the productivity has not increased proportionally. However, after 1995-96, although there was increase in area, productivity showed a decline probably due to unfavourable climatic conditions experienced during past few years.

Greengram (*Vigna mungo*) : In case of greengram, the area, production and productivity were stagnant upto 1986-87 and increased sharply with little ups and downs (may be due to scanty rainfall condition), increase of area under summer greengram and adoption of better management practices (Fig.1 e). The concept of protecting soil from erosion hazards and improving soil fertility has also increased among the farmers and greengram being the short duration leguminous crop is also well fitted in. greengram-safflower, greengram-chickpea and greengram-wheat double cropping system under irrigated condition as well as an inter crop in cotton.

Chickpea (*Cicer aeritinum*): Chickpea has been taken as *Rabi* crop on conserved moisture in deeper soils or with one or two protective irrigation just after the harvest of soybean, greengram, sorghum or short duration cotton crop. The area, production and productivity of this crop upto 1998-99 was almost constant and increased thereafter due to the introduction of good varieties, better crop management practices for soybean-chickpea crop sequence under protective irrigation (Fig. 1 b).

9. SOCIO-ECONOMIC APPRAISAL OF WATERSHED FARMERS

9.1 Socio-economic Profile

The socio-economic profile of the 65 watershed farmers was evaluated and based on that socio-economic analysis of the watershed farmers was carried out. Different variables viz. size of holding, cropping intensity, information sources, contact with extension personnel, adoption of recommended package of practices on watershed basis were taken into account (Table 9). Study revealed that majority of the respondents possess medium (49%) to small (23%) size of farm holdings upto 4 ha and the major portion (52%) of the land sites are not suitable for cultivation of cotton-based crops confined to mono cropping system only. Majority of the respondents (54%) had low annual income of Rs1 0,000 to Rs 25,000 only from their farming and allied resources. In the watershed area, about 45% of the total farmers, work as skilled labour on the fields of big farmers and deriving income from that occupation for their livelihood. About the mass media adoption, trend showed that 32-45 % watershed farmers used mass media such as radio, newspapers and television for getting agricultural information. It was noteworthy to mention that two agricultural post graduate progressive farmers reported that they are availing cable network facilities and taking keen interest in "Annadata" Agricultural programme telecast in local Marathi language by ETV channel. Farmers expressed very weak extension contacts between them and extension personnel of state agricultural department in watershed areas. With regards to technological situation in study area, it was noted that in majority of the cases use of organic fertilizers is not practicised in proper form. The basal dose of fertilizers and top dressing is not being done properly at proper time with adequate quantity, integrated pest management and use of proper weedicide is also not followed. The traditional methods of soil and water conservation practices viz, collection of excess runoff water in dug out ponds, planting of fruit and fodder trees, planting of vetivera, sowing of crops across the slope, mulching, vegetative hedges on border lines etc. are also not being paid proper attention. It was revealed from the study that the efficiency of utilizing agricultural equipments and farm machinery by the farmers is either rated to poor or only handful of farmers mechanized their farm. The key reason behind such result is lack of knowledge and resources, and untimely availability of agricultural machinery. Over all, it has been recorded that the knowledge and adoption gaps in Agri-horticultural technologies were observed to be 50-60% in cotton, arhar, gram, wheat, soybean and citrus crops (Table 9).

Table 9. Socia-economic status of watershed farmers

S. N.	Farmers characters		Respodents	Per cent
1	Age	Upto 25 years	3	4.62
		26-40 years	23	35.38
		41 and above	39	60.00
2	Family size	Small (upto 3 members)	11	16.92
		Medium(4-6 members)	47	72.31
		Large (7 and above)	7	10.77
3	Caste	Scheduled caste	26	40.00
		Scheduled tribe	7	10.77
		Other backward community	20	30.77
		Others	12	18.46
4	Education	Illiterate	9	13.85
		Can read	0	0.00
		Can read and write	4	6.15
		Primary	13	20.00
		Secondary	25	38.46
		College	8	13.31
		Post graduate	5	7.69
		Any others	1	1.54
5	Land holding	<2 ha	19	29.23
		2-4 ha	32	49.23
		>4 ha	14	21.54
6	Credit facilities	Co-operative society	15	23.08
		Bank	18	27.69
		Private money lenders	1	1.54
		Friends and relatives	12	18.46
7	Annual income	Low (Rs 10,000-25,000)	35	53.85
		Medium (26,000- 50,000)	17	26.15
		High (51 ,000 and above)	13	20.00
8	Occupational status	Only cultivation	19	19.23

		Cultivation + skilled labour	19	44.62
		Cultivation business	10	15.38
		Cultivation + service	7	10.77
9	Cropping intensity	High (triple)	11	16.92
		Medium (double)	20	30.77
		Low (single crop)	34	52.31
10	Mass media exposures/ information sources used	Radio	29	44.61
		Television	21	32.31
		Cable network	5	7.69
		Newspapers	19	44.61
		Farmers magazine	11	16.92
		Printed publications	9	13.85
		Others (Computers, e-mail etc.)	2	3.08
		Networks demonstrations	11	16.92
		Films	9	13.85
11	Contact with extension personnel	Agril. Extn. Officer/ VEWs	14	21.54
		Agril. Bank	11	16.92
		Local cooperatives	18	27.69
		Agril. University and ICAR Institute	12	18.46
		Neighbours and friends	20	30.77
		Fertilizer dealing agency	16	24.62

9.2. Socio-techno-economic Constraints

The socio-techno-economic constraints of the watershed farmers were evaluated (Table 10). Study revealed that the major social constraints perceived by the watershed farmers were less regard of society towards scientific methods of soil and water conservation practices with high intensity rank of 75.38%, followed by lack of employment opportunities due to less economic farming. Social taboos among as of the castes and lack of education among villagers were also considered as barriers for better development of the society. Overall, resistance to social change was felt as constraints by 42% respondent farmers. Under technological constraints, majority of the respondents were confronted with poor and irregular production of cotton-based crops (95%). The other severe technological constraint perceived by the watershed farmers was complex crop cultivation, which was stated by 94% farmers and assigned second rank. Similarly, lack of technical guidance and practical oriented training about watershed technology were accorded III (92%) and IV (89%) ranks respectively. As regards the use of bio-fertilizer and its application methods, lack of decomposition and use of FYM, vermi-compost, non-availability of suitable toposequence- based crop production technologies, lack of literature in local language on watershed concept and its management were accorded V, VI, VII and VIII ranks respectively as technological constraints. However, under financial constraints, the respondents were confronted with difficulties in borrowing loans, which was perceived by 78% respondents as a major constraint with top priority. Respondents also accorded IIInd rank with 77% each to lack of resources and money and also delayed payment from sale of produce respectively. About 66% respondents perceived lack of government initiative in funding of loans and granting of subsidies as one of the major constraints. High input costs were accorded by 61 % respondents (Table 10). In marketing and inputs supply constraints, the respondents were confronted with poor market value (89%).

The other constraints were evaluated as lack of regular market, malpractices by middle men, nonavailability of good quality seeds, nonavailability of cotton co-operative society near the village, vermicompost in time and irregular transport facilities were the other marketing and input constraints (Table 10).

Table 10. Socio- economic constraints of watershed formers

S.N.	Constraints	Per cent	Rank
1	Social Constraints		
1.1	Lack of education among villagers about scientific cultivation	61.54	V
1.2	Less regards of society towards scientific methods of soil and water conservation practices	75.38	II
1.3	Lack of employment opportunities	66.15	III
1.4	Unfavorable attitude of watershed farmers regarding watershed management practices	53.8	VI
1.5	Lack of proper extension services	89.23	I
1.6	Social taboos among some of the castes	64.61	IV
1.7	Overall resistance to change	42.10	VIII
1.8	Religious sentiments	49.23	VII
2	Technological Constraints		
2.1	Complex cultivation	93.85	II
2.2	Lack of technical guidance	92.31	III
2.3	Lack of awareness of bio-fertilizer use and its application method	80.0	V
2.4	Poor and irregular production	95.38	VI
2.5	Lack of knowledge of composting, vermicompost etc.	69.99	VII
2.6	Non-availability of suitable technology for different toposequences	64.61	IV
2.7	Lack of practical oriented training	89.23	VIII
2.8	Lack of literature in simple language on watershed management	58.46	I
3	Economic/Financial Constraints		
3.1	Delayed payment from sale of produce	76.92	II
3.2	Difficulty in borrowing loans	78.46	I
3.3	Lack of government initiatives in funding loans and granting of subsidies due to high costs of inputs	66.15	V

3.4	High costs of inputs	73.85	IV
3.5	Lack of resources and money	76.92	III
3.6	Costs of produce/cultivation	61.23	VI
3.7	Non-availability of cooperative societies	49.23	VII
3.8	Fragmentation of holdings	38.24	VIII
4	Marketing Constraints		
4.1	Poor market value	89.23	I
4.2	Lack of regular market	69.23	II
4.3	Lack of transport facilities	63.08	IV
4.4	Malpractices by middlemen	66.15	III
5	Input Supply Constraints		
5.1	Nonavailability of compost, vermicompost etc.	69.23	I
5.2	Nonavailability of good quality seed/hybrid	64.62	II
5.3	Nonavailability of timely farm machinery	53.85	III

10. RAIN WATER MANAGEMENT STRATEGY

10.1 Development of Watershed Structure

Water harvesting pond: A pond of size 20 X20 x 1 .5 m^3 outer upper, and 14 x 14 x 1.5 m^3 inner lower part (Total 20x20x3m^3) was developed on lower toposequence in the watershed area during 2001 (Plate 7). Besides the water harvesting pond, six percolation tanks, one farm pond and two water stop dams were constructed in the area by the soil conservation department, Amravati, Maharashtra through our initiatives (Plate 8). The catchment area of the pond was nearly 5.3 ha.

Plate 7. A view of water harvesting pond in micro-watershed at Thugaon

The digging work of the water-harvesting pond was done during summer 2001. The excess runoff water was collected and stored in the pond for recycling. The excess runoff water from upper, middle and lower toposequences was collected on daily basis and stored in the water harvesting pond (Plate 7). The total cumulative quantity of the runoff water was measured and total quantity of water available in the pond was determined every year (Annexure II). Due to high percolation, evaporation and seepage rates, water in the pond was not available for irrigation at peak boll development stage and hence no irrigation to cotton crop was given from the harvested rain water in respective toposequences. But, due to construction of water harvesting pond on lower toposequence, the moisture availability in bottom toposequence was increased due to retention of seepage water and the seed cotton yield was increased to as high as 22.5 qha^{-1} (Plate 14). However, the rain water was recycled as per plan to cotton and cotton--based cropping systems from the water available in nallah, ponds and recharged wells for irrigation in the watershed area.

Plate 8. A view of stop dam construted in watershed area.

10.2 In-situ Moisture Conservation Practices

10.2.1 Comparative yield performance of crops at the time of watershed adoption

The crop yield performance of cotton, sorghum and pigeon pea crops on different toposequences of the watershed farmers was evaluated during *Kharif*, 2000 at the time of watershed adoption (Table 11). It was found that the gross yield of these crops varied from one toposequence to another, it was highest (52.82 qha-^{1}) in valley floor followed by lower plain (30.08 qha^{-1}) and the lowest (5.87 qha^{-1}) under upper plain.

Table 11. Toposequence-based gross yield (q ha^{-1}) and gross return (Rs ha^{-1}) of principal crops under farmer's management practices at the time of watershed adoption

Toposequence	Soil depth (cm)	Soil characteristics	Yield (q ha^{-1})			Gross yield (q ha^{-1})	Gross return (Rs ha^{-1})
			Cotton	Sorghum	Pigeonpea		
Foot hills	Extremely shallow to shallow (<25 cm)	Extremely shallow to very shallow, 10-15 % slope, very severe erosion, and calcareous	-	-	-	-	-
Upper plain	Shallow to slightly deep (25-50cm)	Shallow to slightly deep, gravelly sandy clay loam, gently slopping (3-5%) to strongly sloping (5-10%), severe to very	1.36 (Rs 2992.00)*	2.50 (Rs 1125.00)	2.01 (Rs 3618.00)	5.87 -	7735.00

		severe erosion,moderately to strongly stony and calcareous					
Lower plain	Moderately deep to deep (50-100cm)	Moderately deep to deep, gravelly, sandy clay to clay loam, gently sloping (3-5%), moderate erosion, calcareous and slightly stony to stony	4.66 (Rs 10252.10)	19.17 (Rs 8626.50)	6.25 (Rs 11250.00)	30.08 -	30128.50
Valley floor	Very deep (>100cm)	Deep, silty clay loam, gently sloping, moderately eroded and slightly stony	7.50 (Rs 16500.10)	36.57 (Rs 16456.50)	8.75 (Rs 15750.00)	52.82 -	48706.00

* in parenthesis economic return of crops

This showed that toposequences have a prime role in yield maximization of rainfed crops in the watershed area. Higher gross yield in lower toposequences may be due to more soil depth, fine clay, higher organic matter and higher water retention and water holding capacity of these soils as compared to lower and upper toposequences (Table 11). As regard the gross return of different crops on different toposequences is concerned, it was maximum (Rs 48,706.00 ha^{-1}) in valley floor followed by lower plain (Rs 30,128.50 ha^{-1}) and the minimum (Rs 7,735.00 ha^{-1}) in upper plain (Table 8). However, the trend of higher gross return was noted from lower plain and valley floor, showing an increase by 389.5 and 630 % respectively over upper plain. This may be due to higher soil depth, clay content, water and nutrient retention capacity of these toposequences (Table 11).

11. RESEARCH HIGHLIGHTS

11.1 Moisture Conservation Practices in Relation to Seed Cotton Yield

11.1.1 Toposequence wise seed cotton yield

11.1.1.1 Upper toposequence: Significantly highest (10.47 qha^{-1}) seed cotton yield was recorded in T4, closely followed by T3 (10.09 qha^{-1}) and the minimum (6.13 qha^{-1}) in T1 (Table 12). However, the seed cotton yield increase in T2, T3 and T4 treatments due to imposition of moisture conservation practices was 1.32, 3.39 and 4.34 q respectively alongwith significant increase in number of bolls $plant^{-1}$. However, the boll weight variation in all the treatments was non-significant (Table 12).

Table 12. Effect of moisture conservation practices on yield and yield contributing characters of cotton and cotton-based cropping systems in upper toposequence. 3 (2001-2003) years pooled mean

Treatments		Yield and yield attributing characters		
		Seed cotton yield (q ha^{-1})	Number of bolls $plant^{-1}$	Boll weight (g)
T1	Farmers practices-sole cotton (*hirsutum*) on flat bed+100% recommended dose of fertilizer	6.13	12.31	2.91
T2	Cotton (*arboreum*)+sorghum on flat bed+100% recommended dose of fertilizer	7.45	13.60	3.22
T3	Cotton+sorghum on ridges and furrows+100% recommended dose of fertilizer	10.09	15.87	3.31
T4	T3+supplemental irrigation+100% recommended dose of fertilizer	10.47	16.84	3.29
C.V. (%)		7.17	3.81	4.59
C.D (P=0.05)		1.22	1.12	NS

11.1.1.2 Middle toposequence: It is very clear from the data (Table 13) that the seed cotton yield in T2, T3 and T4 treatments was increased significantly over T1. This showed that moisture conservation practices have a significant role in increasing the yield of cotton and cotton-based crops, along with significant increase in number of bolls per plant. Seed cotton yield increased significantly in T2, T3 and T4 treatments due to imposition of moisture conservation practices by 1.98, 3.05 and 4.92q over T1 respectively (Table 13).

Table 13. Effect of moisture conservation practices on yield and yield contributing characters of cotton and cotton-based cropping system in middle toposequence. 3 (2001 - 2003) years pooled mean

	Treatments	Yield and yield attributing characters		
		Seed cotton yield (q ha^{-1}')	Number of bolls $plant^{-1}$	Boll weight (g)

T1	Sowing of *hirsutum* cotton as a sale crop on flat bed	6.57	14.68	3.04
T2	Cotton (*hirsutum*) + greengram on flat bed	8.55	15.70	3.23
	T3 Cotton (*hirsutum*) on contour	9.62	16.80	3.28
T4	T3+ recycling of water	11.49	19.80	3.46
	C.V. (%)	10.39	7.68	5.34
	C.D (P=0.05)	1.88	2.57	NS

11.1.1.3 Lower toposequence: Significantly, maximum (11.51 q ha^{-1}) seed cotton yield was recorded in T4 followed by T2 (9.44 q ha^{-1}) and the minimum (7.23 q ha^{-1}) in T1 (Table 14). It is very clear from the data (Table 14) that the moisture conservation practices playa very important role and are very effective in increasing seed cotton yield by 2.21 and 6.49 q (30.56 and 59.20 per cent increase) in T2 and T4 treatments respectively over T1 (Farmer's practice).

Table 14. Effect of moisture conservation practices on yield and yield contributing characters of cotton and cotton-based cropping system in lower toposequence. 3 (2001-2003)

	Treatments	Yield and yield contributing characters		
		Seed cotton yield (q ha^{-1})	Number of bolls $plant^{-1}$	Boll weight (g)
T1	Sowing of *hirsutum* cotton as a sale crop on flat bed	7.23	14.33	3.03
T2	Cotton on ridges and furrow+soybean followed by chickpea	9.44	15.07	3.20
T3	Soybean followed by chickpea	0.00	0.00	0.00
T4	Cotton followed by chickpea under harvested rainwater as life saving irrigation	11.51	17.65	3.22
	C.V. (%)	29.57	29.18	10.96
	C.D (P=0.05)	4.16	6.85	0.51

It is very clear from the data (Table 14) that the moisture conservation practices were considered essential and very effective in increasing seed cotton yield by 2.21 and 6.49 q (30.56 and 59.20 per cent) respectively in T2 and T4 treatments over T1 (Farmers practice) even though the response was nonsignificant.

11.1.1.4 Bottom toposequence: It is very clear from the data (Table 15) that with the imposition of moisture conservation treatments, seed cotton yield was found to increase in all the treatments over farmers practice. It was maximum (13.42 q ha^{-1}) in T4 and minimum (8.87 q ha^{-1}) in T1 (Farmer's practice).

Table 15. Effect of moisture conservation practices on yield and yield contributing characters of cotton and cotton-based cropping system in bottom toposequence. 3 (2001-2003) years pooled mean

	Treatments	Yield and yield contributing characters		
		Seed cotton yield (q ha^{-1})	Number of bolls $plant^{-1}$	Boll weight (g)
T1	Sowing of cotton on flat bed	8.87	2.92	3.29
T2	T1+ridges and furrows at 30 days after sowing	11.16	3.22	3.63
T3	Broad-bed and sunken-bed sowing (30-180-30)	12.05	3.31	3.61
T4	Raised and sunken-bed layout	13.42	3.29	3.57
	C.V. (%)	13.20	12.21	4.00
	C.D (P=0.05)	3.00	NS	NS

11.2. Moisture Management Practices in Relation to Seed Cotton Yield

11.2.1 Soil moisture management practices

Among the various moisture conservation practices, tested on different toposequences, for conservation of excess rain water in situ in different cropping systems, results showed that the trend of per cent moisture in the soil was varying from one toposequence to another. It was lowest at the upper and the highest at the bottom toposequence even under flat bed system. The effect of cotton+sorghum on ridges and furrows was the highest (29.82%) followed by cotton + sorghum on flat bed (23.90%) and the lowest (13.34%) under sole cotton on flat bed in upper toposequences. Cotton + greengram as intercrop on middle toposequence conserved maximum moisture as compared to cotton alone. Similarly, cotton + soybean on ridge and furrow system was found effective in retaining maximum (28.92%) soil moisture, while cotton (hirsutum) as sole crop under flat bed method was the lowest under lower plain. Soil moisture increase in different cropping systems was found to be associated with higher yield of cotton and cotton-based cropping system in each toposequence.

11.2.2 Toposequence-based moisture conservation practices

The effect of various moisture conservation practices on seed cotton yield on different toposequences was evaluated, the yield differences under scientific and farmer's management practices were compared for higher

Plate 9. Ridge and furrow moistureconservation practice in cotton.

yield potential (Plate 9 and Table 16).

Result showed that under scientific management practices, seed cotton yield increased considerably in all the toposequences over farmer's management practices. It was highest (3.96 q) in upper and the lowest (2.21 q) in lower toposequence. In upper to lower toposequences, there was a serious problem of excess erosion and due to that cotton crop suffered from severe soil moisture stress, (associated with low water holding capacity) but in case of bottom toposequence, situation was reversed, with excess soil moisture due to poor drainage conditions causing adverse impact on plant biomass and finally on seed cotton yield.

Table 16. Comparative performance of seed cotton yield as influenced by moisture conservation practices in different toposequence. 3(2001-2003) years mean.

Toposequence	Moisture conservation practices	Seed cotton yield (qha^{-1})		Yield improvement over formers management (q ha^{-1})
		SM	FM	
Upper (Very shallow soil)	Cotton + Sorghum (strip cropping) on ridges and furrows + 100% recommended dose of fertilizer	10.09	6.13	3.96
Middle (Shallow to medium deep soil)	Cotton (*hirsutum*) on contour + 100% recommended dose of fertilizer	9.62	6.57	3.05
Lower (Medium deep to deep soil)	Cotton on ridges and furrows + Soyabean	9.44	7.23	2.21
Bottom (Very deep soil)	Broad-bed and sunken-bed sowing (30-180-30)	13.42	8.87	4.55

SM=Scientific management; **FM**=Farmers management

Cotton crop requires good drainage with well distributed rainfall. Broad-bed and sunken-bed moisture conservation practices also improved the condition of cotton crop, and at the same time broad-be and sunken-bed system also used as channel to drain out excess rain water and saved the crop from bad effects of excess moisture. However, due to adoption of proper moisture management practices, mean maximum (13.42 q ha^{-1}) seed cotton yield was recorded under scientific management, which was higher by 4.5 q ha^{-1} over farmers practice (Table 16).

11.2.3 Toposequence-based cotton yield improvement due to recycling of harvested rain water

The protective irrigation to cotton and cotton-based cropping systems from harvested rain water was applied in different toposequences (Plate 10 and Table 17). Results showed that one protective irrigation to cotton crop at peak boll development stage @ 6 ha cm of stored rainwater was found very effective in increasing seed cotton yield by 4.27 to 4.92 q ha-1 in different toposequences over farmers management. The effect of protective irrigation was higher in middle toposequence as compared to lower toposequence. However, upper and middle toposequences were found deficit in soil moisture availability, may be due to occurrence on shallow and sloppy topography coupled with low water holding capacity as compared to lower and bottom toposequences (Table 17). It may be inferred from the above results that upper and middle toposequences are located on eroded basaltic soil strata along with low soil depth, low AWC, low OM, low CEC, low Clay content and low nutrient and water holding capacity and hence these toposequences need special treatment on and over the normal soils on lower to bottom toposequences for higher crop production. Water is the main yield limiting factor under rainfed condition.

Plate 10. Recycling of harvested rainwater

Table 17. Comparative performance of cotton as influenced by recycling of harvested rainwater in different toposequences. 3(2001-2003) years mean

Toposequence	Recycling of harvested/stored water to cropping system	Seed cotton yield (q ha^{-1})		Yield improvement (q a^{-1})
		SM	FM	
Upper (Very shallow soil)	Cotton + Sorghum on ridges and furrows + 100% recommended dose of fertilizer + supplemental irrigation	10.47	6.20	4.27
Middle (Shallow to medium deep soil)	Cotton *hirsutum* on contour + recycling of water	11.49	6.57	4.92
Lower (Medium deep to deep soil)	Cotton under harvested rain water as life saving irrigation	11.51	7.23	4.28

SM=Scientific management; **FM**= Farmers management

Any effort in-situ moisture conservation or application of protective irrigation to cotton in these soils to improve moisture availability will give a boost to crop yield under rainfed conditions (Table 17).

11.3 Comparative Yield Performance of Cotton Crop on Different Toposequences

The comparative yield performance of cotton crop on different toposequences under scientific and farmers management practices was evaluated. Results showed that the mean maximum (11.72 q ha^{-1}) seed cotton yield was recorded under scientific management (T2) and the mean minimum (7.20 q ha^{-1}) under farmers management (T1) practice.

Table 18. Yield performance of cotton on different toposequences as influenced by management practices. 5 (2000-2004) years mean yield

Treatments	Toposequence				Mean seed cotton yield (q ha^{-1})
	Upper	Middle	Lower	Bottom	
T1 Flat bed sowing (Farmers management)	6.13	6.57	7.23	8.87	7.20
T2 Ridges and furrows + recycling of water (Scientific management)	10.47	11.49	11.51	13.42	11.72
Yield difference (±)	4.34	4.92	4.28	4.55	4.52
Seed cotton yield increase (%) under scientific, over farmers management practices	70.80	74.88	59.19	51.29	62.78

The actual seed cotton yield in scientific management was found to increase from upper to bottom toposequence, it was highest (70.80%) under upper and the lowest (51.29%) in bottom toposequence (Table 18). This showed that better crop management was found helpful in increasing the seed cotton yield from upper to bottom toposequence. It is also clear from the yield trend that the yield performance of cotton varied from one toposequence to another (from upper to bottom toposequence) (Table 18).

12. TOPOSEOQUENCE-BASED GROSS MONETARY RETURN (Rs ha^{-1})

The gross monetary returns of different cropping systems was evaluated on different toposequences and based on results are as given below:

12.1 Upper Toposequence

The mean maximum (Rs 36,525.7 ha^{-1}) GMR was recorded in T4, closely followed by T3 (Rs 34,014.0 ha^{-1}) and the mean minimum (Rs 13,640.0 ha^{-1}) under T1 (Plate 11 and Table 19). Further, results showed that GMR of strip cropping of sorghum in cotton alongwith moisture conservation practices was found to be significantly superior over farmers practice resulting in an increase by Rs 98,05.50 ha^{-1} in T2,

Rs 20,374.00 ha^{-1} in T3 and Rs 22,885.70 ha^{-1} in T4 (Table 19). However, the treatment comprising cotton + sorghum on ridges + 100% recommended dose of fertilizer + supplemental irrigation was evaluated as the best over rest of the cropping systems (Table 19).

Plate 11. Sorghum as strip crop with cotton on upper toposequence

Table 19. Effect of moisture management practices on gross monetary return (Rs ha^{-1}) of different cropping systems in upper toposequence

	Treatments	GMR (Rs ha^{-1})			Mean	GMR (Rs ha^{-1}) increase over T1
		2001	2002	2003		
T1	Farmers practices-sole cotton (*hirsutum*) on flat bed + 100% recommended dose of fertilizer	17,072.0	11,726.0	12,122.0	13,640.0	-
T2	Cotton (*arboreum*)+ sorghum flat bed + 100% recommended dose of fertilizer	30,353.0	16,577.5	23,406.0	23,445.5	9,805.5
T3	Cotton + sorghum on ridges and furrows + 100% recommended dose of fertilizer	38,814.0	29,370.5	33,857.5	34,014.0	20,374.0
T4	T3+supplemental irrigation + 100% recommended dose of fertilizer	42,249.0	30,645.5	36,682.5	36,525.7	22,885.7

12.2 Middle Toposequence

The mean maximum (Rs. 29,394.0 ha^{-1}) GMR was recorded in T2 followed by T4 (Rs 24,302.7 ha^{-1}) and the mean minimum (Rs. 14,461.3 ha^{-1}) in T1 (Table 20). Intercropping of greengram in cotton is the best cropping system over rest of the treatments (Plate 12). However, GMR in all the treatments increased significantly by Rs 14,932.7, 5,008.7 and 9,841.4 respectively in T2, T3 crop and T 4 over T1 (Table 20).

Plate 12. Greengram as intercrop with cotton evaluated economically a best suited ping system on middle toposequence

Table 20. Effect of moisture management practices on gross monetary return (Rs ha^{-1}) of different cropping systems in middle toposequence

	Treatments	GMR (Rs ha^{-1})			Mean	GMR (Rs ha^{-1}) increase over T1
		2001	2002	2003		
T1	Sowing of *hirsutum* cotton as a sole crop on flat bed	19,558.0	12,034.0	11,792.0	14,461.3	-
T2	Cotton *hirsutum* + greengram on flat bed	32,574.0	25,153.0	30,455.0	29,394.0	14,932.7
T3	Cotton *hirsutum* on contour	24,882.0	13,420.0	20,108.0	19,470.0	5,008.7
T4	T3 + recycling of harvested water	29,986.0	18,876.0	24,046.0	24,302.7	9,841.4

12.3 Lower Toposequence

The mean maximum (Rs 36,950.7 ha^{-1}) GMR was recorded in treatment T2 followed by T 4 (Rs 34,104.0 ha^{-1}) and the mean minimum (Rs 16,610.0 ha^{-1}) in T1 (Table 21). Further, results showed that cotton + soybean during *Kharif* and chickpea during *Rabi* has given maximum GMR over other cropping systems (Plate 13). However, GMR under scientific management practices showed an increase by Rs 20,340.7, Rs 14,678.7 and Rs 17,494.0 ha^{-1} in T2, T3 and T4 treatments respectively over T1 (Table 21).

Plate 13. Cotton + Soybean environmentally and economically best suited cropping system for lower toposequence

Table 21. Effect of moisture management practices on gross monetary return (Rs ha^{-1}) of different cropping systems in lower toposequence

	Treatments	GMR (Rs ha^{-1})			Mean	GMR (Rs ha^{-1}) increase over T1
		2001	2002	2003		
T1	Sowing of cotton hirsutum as a sole crop on flat bed	21,23.0	11,242.0	17,358.0	16,610.0	-
T2	Cotton in ridges and furrow + soybean followed by chickpea	51,796.0	26,249.0	32,807.2	36,950.7	20,340.7
T3	Soybean followed by chickpea	30,867.5	31,690.5	31,308.0	31,288.7	14,678.7
T4	Cotton followed by chickpea	45,120.0	22,868.0	34,324.0	34,104.0	17,494.0

	under harvested rainwater as life saving irrigation					

12.4 Bottom Toposequence

The mean maximum (Rs 29,736.7 ha^{-1}) GMR was recorded in T4 followed by T3 (Rs 27,118.7 ha^{-1}) and the mean minimum (Rs 19,536.0 ha^{-1}) in T1 (Table 22). It is very clear from the data that the moisture conservation practices in bottom toposequence were found very effective in conservation of soil moisture and at the same time it also worked successfully to drain out the excess rain water from the field in continuous rainy days during rainy season. Hence, moisture conservation practices were found very effective in increasing the seed cotton yield in bottom toposequence (Plate 14). However, GMR in T2, T3 and T4 treatments showed an increase by Rs 6,284.7, 7,582.7 and 10,200.7 respectively over T1 (Table 22).

Plate 14. Bumper crop of cotton in bottom toposequence

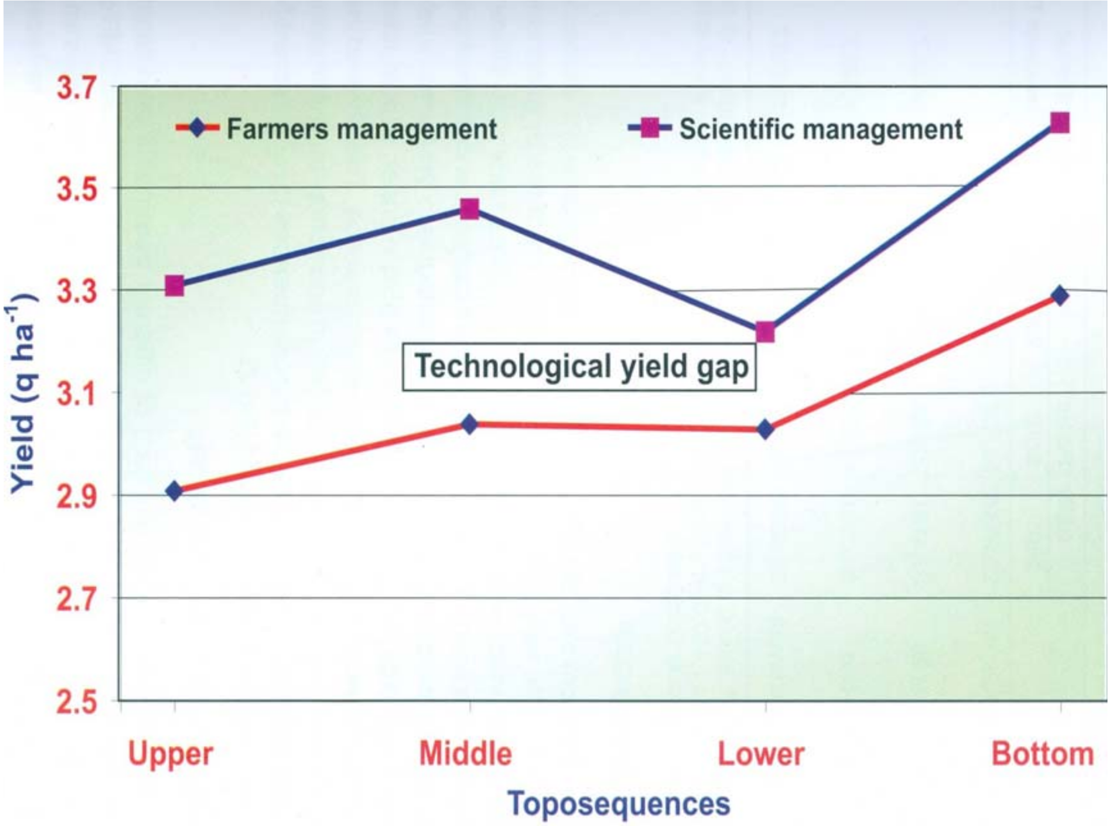

Fig. 7. Comparative yield (qh-1) performance of different cropping systems on different toposequences under Farmers and Scientific management practices. 3 (2001-2003) year mean

Table 22. Effect of moisture management practices on gross monetary return (Rs ha^{-1}) of different cropping system in bottom toposequence

		GMR (Rs ha-1)			Mean	GMR (Rs ha) increase over T1
		2001	2002	2003		
T1	Sowing of cotton hirsutum on flat bed	23,958.0	16,258.0	18,392.0	19,536.0	-
T2	T1 + ridges and furrows at 30 days after sowing	33,418.0	20,482.0	23,562.0	25,820.7	6,284.7
T3	Broad-bed and sunken-bed sowing (30-180-30)	36,036.0	17,600.0	27,720.0	27,118.7	7,582.7
T4	Raised and sunken-bed layout	38,566.0	18,370.0	32,274.0	29,736.7	10,200.7

Where as: Cotton @ Rs 2,200.00 q^{-1}, Soybean grain @ Rs 1,300.00 q^{-1}, Greengram @ Rs 1,700.00 q^{-1}, Chickpea @ Rs 1,400.00 q^{-1}, Sorghum grain @ Rs 4,50.00 q^{-1}, Sorghum stover @ Rs 50.00 q^{-1} and Soybean straw @ Rs 50.00 q^{-1}

13. ECONOMIC YIELD GAP

It is very clear from the data (Fig.7) that a big yield gap came into existence due to introduction of the suitable moisture conservation practices by enhancing the seed cotton yield under scientific management practices tested on different toposequences over the years. The yield gap in different toposequences developed was mainly due to the introduction of improved technologies in the farmer's field which resulted in a yield gap of 4.34, 4.92, 4.28 and 4.55 q in upper, middle, lower and bottom toposequences respectively over farmers practice. This showed that there is ample scope for increasing the yield of cotton and cotton-based cropping systems in upper, middle, lower and bottom toposequences through scientific management at Thugaon micro-watershed (Fig.7).

14. GROSS MONETARY RETURN (GMR)

The gross monetary return (Rs ha^{-1}) of different treatments on different toposequences was evaluated (Fig.8). Result showed that the maximum GMR of different cropping systems tested in different toposequences over the years was increased by 167.8, 103.3, 122.5 and 52.2% over farmers practice in upper, middle, lower and bottom toposequences respectively (Fig.8).

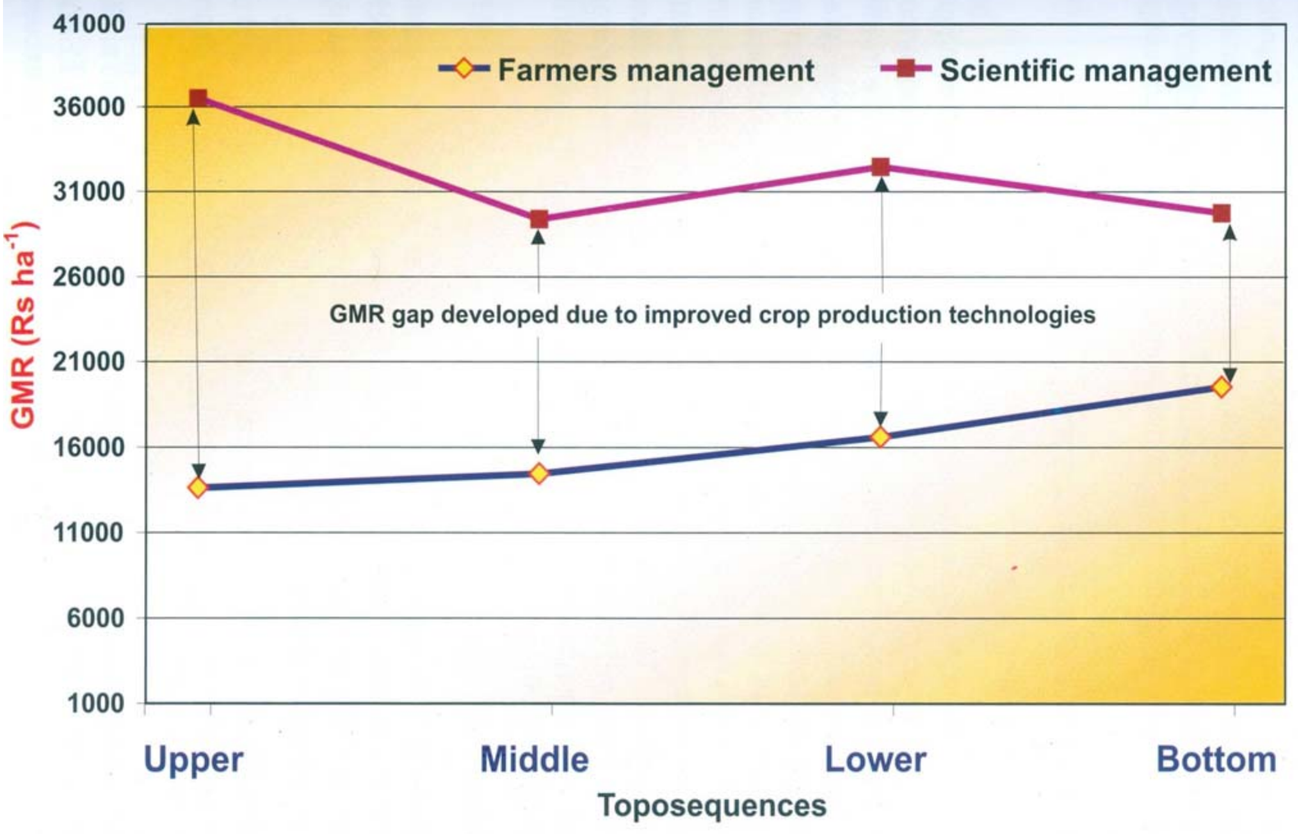

Fig. 8. Economic Gap (Rs ha-1) of different cropping systems under, Farmers and Scientific management practices. 3 (2000-2003) year mean

However, based on gross monetary return (Rs ha^{-1}), yield gap was found to be the highest in upper and the lowest in bottom toposequences. Significantly, higher seed cotton yield due to imposition of moisture conservation practices to the tune of 2.29,3.18 and 4.55 q in T2, T3 and T 4 treatments respectively over T1 was evident along with significantly higher number of bolls and boll weight per plant.

15. QUALITY PARAMETERS IN COTTON

15.1 Ginning (Per cent) (GP)

Moisture management practices were found helpful in improving ginning per cent. Ginning (per cent) was highest in middle and lower toposequences and the lowest under valley bottom and upper toposequences in all the treatments (Fig. 9). Further, results showed that low level of management (farmers practice) lead to poor ginning per cent. However, improved levels of management viz. recommended level of fertilizer, proper and timely inter culture operations and life saving irrigation were found helpful in improving ginning percentage in different toposequences. In case of valley bottom, the ginning percentage was lowest, over other toposequences. This showed that highest soil moisture in cotton adversely affected the ginning per cent. However, excess soil moisture with poor drainage reduced boll size, delayed boll bursting, enhanced crop maturity and decreased ginning per cent (Fig. 9).

15.2 Seed Oil (Per cent)

Upper plain: Oil per cent of the cotton seeds was evaluated in different toposequences (Fig.1 0). Results showed that oil per cent increased with increase in soil moisture in different treatments on different toposequences, it was highest (20.34%) in T4 and the lowest (19.84%) in T1 (Fig. 10).

Middle plain: The trend for seed oil per cent was similar as that in case of upper plain. However, the oil per cent was highest (20.73%) in T4 followed by T3 and the lowest (18.02%) in T1 (Fig.10).

Lower plain: The per cent seed oil content in this toposequence was similar as that in upper plain in all the treatments. It was lowest (19.77%) in T1 and the highest (21.11 %) in T4 (Fig.1 0). This showed that neither low nor excess soil moisture has any impact on oil per cent in cotton seed.

Valley bottom: No significant difference in oil content was recorded due to moisture conservation practices. However, oil content was decreased due to high moisture conditions. This showed that oil per cent in cotton seeds is associated with changing pattern of toposequences and moisture availability in soil (Fig. 10).

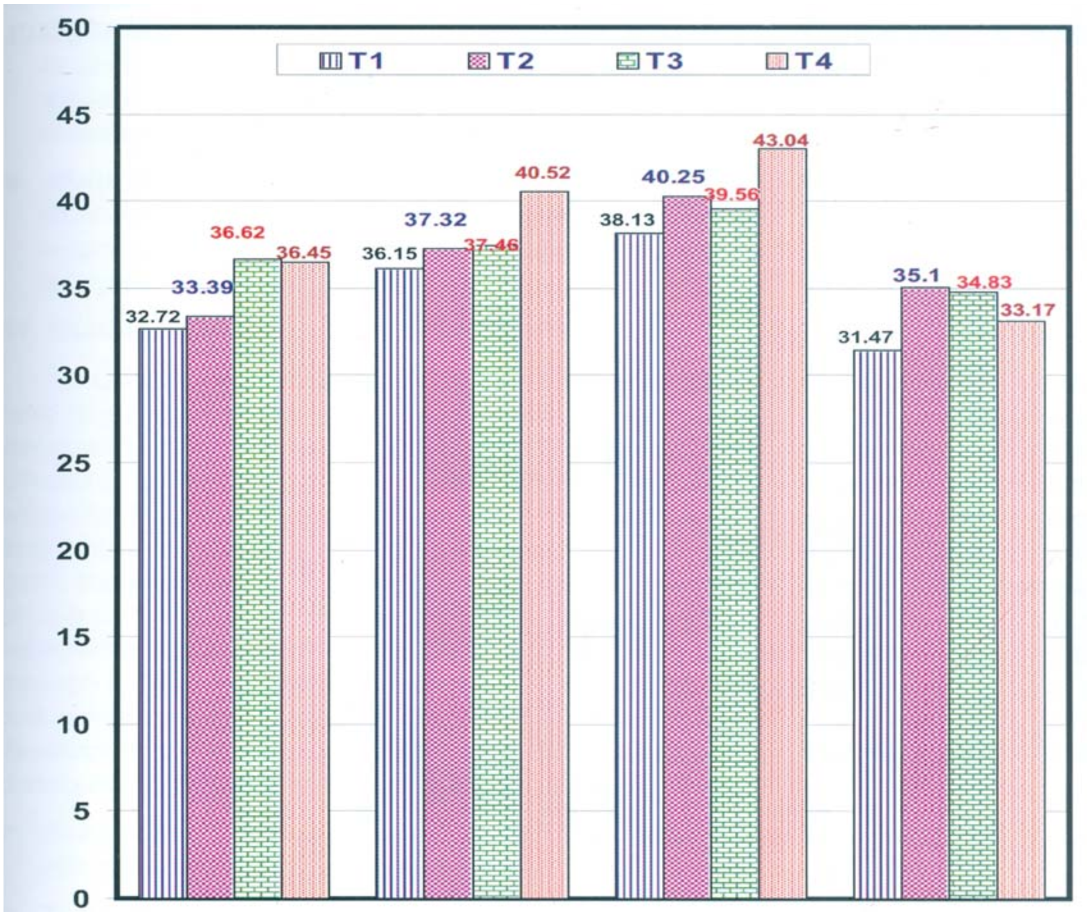

Fig.9. Effect of different moisture conservation practice on ginning percent of cotton in different toposequences

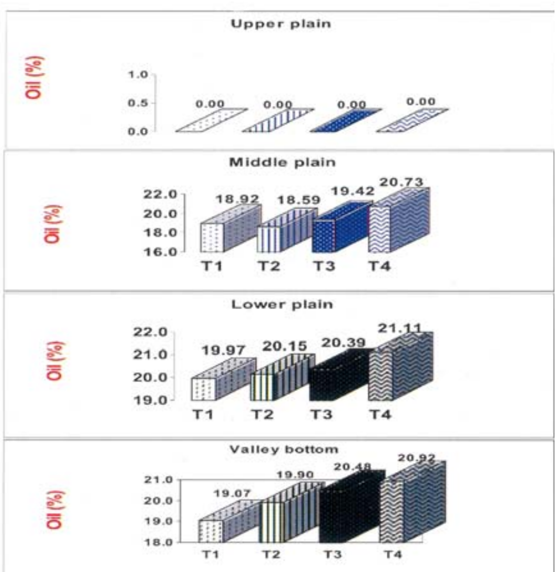

Fig.10. Effect of different levels of management on oil per cent in cotton seeds in different toposequences

16. TECHNOLOGIES DEVELOPED

- **Among the various moisture conservation practices tested over the years on different toposequences; ridges and furrow system across the slope was found to be the best system and effective in reducing runoff, increasing percolation, conserving rain water and improving the yield of cotton-based cropping systems on degraded soils in different toposequences at Thugaon.**
- **Similarly, the response of recycling of harvested rainwater was higher than the moisture conservation practices, and brought about significant improvement in the yield of cotton and cotton-based cropping systems in upper to lower toposequences.**

17. SUMMARY AND CONCLUSION

Over exploitation of soil and water resources is causing environmental and land degradation and due to that soil erosion is increasing and crop yield is decreasing. The productivity of irrigated crops has reached a plateau and it is very difficult to further improve our it. In the rainfed areas, however there is tremendous scope for increasing the productivity of rainfed crops through judicious use of soil and water resources within the boundary of the watershed. To achieve this goal, the productivity of rainfed crops has to be enhanced from the average limit of 0.8 to 1.0 t ha^{-1}. Crossing this limit under rainfed situation is difficult but not impossible. However, the yield of rainfed crops, specially cotton could be increased through judicious use of rain water, its storage and recycling at early boll to peak boll development stages on different toposequences. The research and developmental work carried out at Thugaon Micro-watershed on 40 farmers fields during 2000-2004 is summarized as under:

- ☞ Soils of the watershed area are very shallow to medium deep and severely affected due to heavy erosion.
- ☞ The climate of the area is semi-arid tropic with moderate mean annual rainfall of 959 mm.
- ☞ Entire watershed area is distributed on foot hill, upper, middle, lower and bottom toposequences within land capability class II to VI.
- ☞ Mardi, Karla, Thugaon and Pathergaon were the watershed villages covered under the study with varying human and animal population.
- ☞ Major crops grown in the watershed area were cotton, sorghum, pigeonpea, soybean, greengram and chickpea.
- ☞ One water harvesting pond of size 20x20x3 m^3 was developed and found sufficient to harvest 5-6 lakh litres of excess runoff water from 1.0 to 1.5 ha cotton field.
- ☞ Watershed farmers possess medium to small size of farm holdings upto 4 ha and confined to mono cropping.
- ☞ The educational standard of the watershed farmers is low to medium dominated by weaker sections of the society.
- ☞ It has been observed that productivity of cotton and cotton-based cropping systems varies from one toposequence to another even under similar set of management level.

- Under experimental fields, seed cotton yield varied from 6 to 10 q ha^{-1} on upper; 6.5 to 11.5 q ha^{-1} on middle; 7.2 to 11.5 q ha^{-1} on lower and 8.8 to 13.4 q ha^{-1} on bottom toposequences followed by moisture conservation practices.
- Moisture conservation practices improved seed cotton yield by as high as 4.5 q ha^{-1}, it was highest (4.55 q ha^{-1}) under bottom toposequence and the lowest (2.21 q ha^{-1}) under lower toposequence over farmer's practice.
- Recycling of harvested rainwater was effective in increasing seed cotton yield by about 5 q ha^{-1} over farmer's practices in middle toposequence.
- The influence of in-situ moisture conservation practice was more than that of protective irrigation in yield maximization of rainfed cotton.
- Among moisture conservation practices, ridge and furrow system was found to be the best over other practices.
- Seed cotton yield increased with increasing soil depth and decreasing slope per cent. It was highest in bottom toposequence and the lowest under upper plain.
- Through scientific management practices, the yield of cotton and cotton-based crops could be increased by 50 to 75 % over farmer's practice in different toposequences.
- Due to introduction of improved technologies, yield gap of 4.28 to 4.55 qha^{-1} became evident in different toposequences over farmers practice.
- Through scientific management practices, an increase in gross return by Rs 22,885.7; 14,932.7; 20,340.7 and 10,200.7 could be realized respectively in upper, middle, lower and bottom toposequences over farmers management.
- In all the toposequences, the gross monetary return was found to increase by 52.2 to 167.8% under scientific management over farmer's practice.
- Excess runoff from rain water is the main cause of severe soil erosion in the watershed area. If rain water is controlled and managed properly within the boundary of the field, the problem of soil degradation would be minimized and the yield of rainfed crops can be maximized.
- Quality parameters such as, ginning and oil per cent were found to improve due to imposition of moisture conservation practices and protective irrigation in cotton on different toposequences.

It may be concluded from the above findings that there is an ample scope for increasing the yield of cotton and cotton-based cropping systems on different toposequences under scientific management practices.

Efficient soil and water management is a must for the development of rainfed agriculture in the country, other than this, there is no alternative, for sustainable cotton production without damaging soil, water and vegetative resources. However, the technology thus developed need to be transferred to other areas with similar soil and climatic conditions.

17. REFERENCES

Anonymous (1997). Vision, 2002: CRIDA Perspective Plan. Central Research Institute for Dryland Agriculture, Hyderabad. p-80.

Bhaskar, K.S., Lal, S., Challa, O. and Madavi, S.H. (1987). Effect of soil depth on cotton yield. J. Maharashtra Agric. Univ. 12 (1): 139-140.

Bhaskar, K.S.; Wasnik, S.M.; Mayee, C.D. and Mendhe, P.N. (2002): Drought management in rainfed cotton. Seminar on "Drought and water resources, IWRS, Nagpur. April 16, 2002. Proceedings, PP. 162-170.

Bhaskar, K.S. (2004): Soil and water conservation under rainfed situation for sustainable cotton production. Recent Advances in Cotton Research and Development in India. Lead paper presented at the National Symposium on "Changing world-order cotton research, development and policy in context" at Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad, Aug. 10-12, 2004. PP. 93-103

Crosson (1994). Degradation of Resources on Threat to Sustainable Agriculture. Paper presented at First World Congress of Professionals of Agronomy, 5-8 September, 1994, Satiago, Chille.

Lal, R. (1995). Global Soil Erosion by Water and Dynamics. In soils and global change (R. lal, J.Kimble, E. Levine and B.A. Steward eds). CRC Lewis Publishers, Boca Raton F1. PP.131-141.

Oldman, L.R. (1994). The Global Extent of Soil Degradation in Soil Resilience and Sustainable Land Use (D.J. Greenland and Iszaboles eds.) CAB International Willingford, U.K. PP. 99-118.

Paroda, R.S. (1998). Plenary lecture, First International Agronomy Congress, 23-27 November, 198, New Delhi, PP. 1-27.

Annexure I

Weekly rainfall recorded at Thugaon micro-watershed during the cropping season. 5 (2000- 2004) years mean

Met. week	Duration (Month)	Year									
		2000		2001		2002		2003		2004	
		Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days
22	28-03 June	00.00	0	00.00	0	18.00	0	00.00	0	0.00	0
23	04-10 June	26.90	2	46.00	3	22.00	4	00.00	0	59.00	2
24	11-17 June	5.00	1	269.00	5	5.00	1	59.00	3	88.00	4
25	18-24 June	00.00	0	10.00	1	157.00	3	54.00	3	00.00	0
26	25-01 July	32.00	3	00.00	0	199.60	5	33.00	2	17.00	1
27	02-08 July	53.00	4	22.00	1	00.00	0	59.00	5	1.00	0
28	09-15 July	129.09	5	81.00	4	00.00	0	13.20	3	56.00	4
29	16-22 July	153.00	4	8.00	1	13.40	2	48.00	3	47.00	2
30	23-29 July	00.00	0	00.00	0	8.00	2	84.00	3	28.20	5
31	30-05 August	00.00	0	257.00	3	4.00	1	6.00	1	118.50	3
32	06-12 August	64.00	5	71.80	4	35.00	4	23.00	3	32.80	5
33	13-19 August	16.00	1	48.00	2	9.00	2	9.00	1	7.00	1
34	20-26 August	36.00	4	29.30	2	54.00	5	83.00	3	11.20	1
35	27 -02 September	12.00	4	00.00	0	126.00	4	79.00	3	00.00	0
36	03-09 September	00.00	0	31.60	1	136.00	7	6.00	1	27.00	2
37	10-16 September	00.00	0	16.00	1	1.00	0	00.00	0	00.00	0
38	17-23 September	31.00	1	00.00	0	6.20	1	100.00	1	13.40	2
39	24-30 September	29.04	1	00.00	0	00.00	0	00.00	0	00.00	0
40	01-07 October	00.00	0	00.00	0	00.00	0	7.00	1	7.00	1
41	08-14 October	23.00	1	00.00	0	00.00	0	00.00	0	20.00	1
42	15-21 October	00.00	0	00.00	0	00.00	0	00.00	0	00.00	0
43	22-28 October	00.00	0	00.00	0	00.00	0	00.00	0	00.00	0
44	29-04 November	00.00	0	00.00	0	00.00	0	4.00	1	-	-
45	05-11 November	00.00	0	00.00	0	00.00	0	00.00	0	-	-
46	12-18 November	00.00	0	00.00	0	00.00	0	00.00	0	-	-
47	19-25 November	00.00	0	00.00	0	00.00	0	00.00	0	-	-
48	26-01 December	00.00	0	00.00	0	00.00	0	00.00	0	-	-
49	02-08 December	00.00	0	00.00	0	00.00	0	00.00	0	-	-
50	09-15 December	00.00	0	00.00	0	00.00	0	00.00	0	-	-
51	16-22 December	00.00	0	00.00	0	00.00	0	00.00	0	-	-
52	23-31 December	00.00	0	00.00	0	00.00	0	00.00	0	-	-
Total	--	611.2	36	889.7	28	794.2	41	667.2	37	533.1	34

Annexure II

Daily runoff water available in water harvesting pond during *Kharif* (2001-2004) at Thugaon micro-watershed

Date	Runoff water available (m^3)								
	2001	2002	2003	2004	Date	2001	2002	2003	2004
1st June	-	-	-	-	1st July	-	137.20	98.00	-
2nd June	-	-	-	-	2nd July	-	98.00	196.00	-
3rd June	-	-	-	-	3rd July	-	78.40	156.80	-
4th June	-	-	-	-	4th July	-	39.20	98.00	-
5th June	-	-	-	-	5th July	-	19.60	78.40	-
6th June	-	-	-	-	6th July	-	-	78.40	-
7th June	-	-	-	-	7th July	-	-	39.20	-
8th June	-	-	-	-	8th July	-	-	-	-
9th June	-	-	-	-	9th July	-	-	-	-
10th June	-	-	-	-	10th July	-	-	39.20	-
11th June	-	-	-	-	11th July	-	-	-	-
12th June	-	-	-	-	12th July	-	-	-	73.14
13th June	-	-	-	-	13th July	-	-	-	76.20
14th June	-	454.00	-	-	14th July	-	-	-	85.10
15th June	-	374.00	-	-	15th July	-	-	-	90.00
16th June	-	374.00	-	-	16th July	-	-	-	120.17
17th June	-	334.00	-	-	11th July	-	-	-	115.00
18th June	-	294.00	-	-	18th July	-	-	39.20	101.00
19th June	-	334.00	-	-	19th July	-	-	-	90.00
20th June	-	334.00	-	-	20th July	-	-	19.60	85.00
21st June	-	374.00	-	-	21st July	-	-	19.60	80.00
22nd June	-	374.00	-	-	22nd July	-	-	-	85.00
23rd June	-	294.00	-	-	23rd July	-	-	-	80.00
24th June	-	614.00	-	-	24th July	-	-	-	76.00
25th June	-	534.00	-	-	25th July	-	-	-	78.00
26th June	-	454.00	-	-	26th July	-	-	-	73.00
27th June	-	274.40	-	-	27th July	-	-	-	74.00
28th June	-	196.00	94.08	-	28th July	-	-	98.00	71.00
29th June	-	176.40	47.04	-	29th July	-	-	58.80	83.00
30th June	-	137.20	98.00	-	30th July	-	-	-	81.00
-	-	-	-	-	31st July	-	-	-	76.00

Annexure III

Daily runoff water available in water harvesting pond during *Kharif* (2001-2004) at Thugaon micro-watershed

Date	Runoff water available (m^3)								
	2001	2002	2003	2004	Date	2001	2002	2003	2004
1 August	-	-	-	67.00	1 September	-	694.00	235.20	-
2 August	-	-	-	60.00	2 September	-	734.00		-
3 August	-	-	-	55.00	3 September	-	774.00		-
4 August	98.00	-	-	165.00	4 September	-	774.00	196.00	-
5 August	196.00	-	-	161.04	5 September	-	774.00	156.80	-
6 August	594.00	-	-	155.03	6 September	-	774.00	98.00	-
7 August	794.00	-	-	147.00	7 September.	-	514.00	58.80	-
8 August	894.00	-	-	140.00	8 September	-	454.00	19.60	-
9 August	694.00	-	-	137.00	9 September	-	274.40	-	-
10 August	694.00	-	-	133.05	10 September	-	196.00	-	-
11 August	494.00	-	-	134.15	11 September	-	156.80	-	-
12 August	494.00	-	-	125.07	12 September	-	98.00	-	-
13 August	294.00	-	-	120.00	13 September	-	58.80	-	-
14 August	258.40	-	-	117.00	14 September	-	29.40	-	-
15 August	235.20	-	-	110.00	15 September	-	13.72	-	-
16 August	215.60	-	-	107.00	16 September	-	-	-	-
17 August	414.00	-	-	95.00	17 September	-	-	-	-
18 August	334.00	-	-	90.07	18 September	-	-	-	-
19 August	294.00	-	-	85.00	19 September	-	-	-	-
20 August	294.00	-	-	80.00	20 September	-	-	-	-
21 August	98.00	-	-	75.00	21 September	-	-	-	-
22 August	0.00	-	-	65.00	22 September	-	-	-	-
23 August	-	29.40	-	60.00	23 September	-	-	78.40	-
24 August	-	33.32	-	55.00	24 September	-	-	-	-
25 August	-	45.08	-	47.00	25 September	-	-	-	-
26 August	-	58.80	-	37.00	26 September	-	-	-	-
27 August	-	68.60	-	26.00	27 September	-	-	-	-
28 August	-	88.20	294.00	17.00	28 September	-	-	-	-
29 August	-	107.80	274.40	11.00	29 September	-	-	-	-
30 August	-	117.60	274.40	5.00	30 September	-	-	-	-
31 August	-	98.00	254.80	0.00	31 September	-	-	-	-

---- End of the reports ----

Digitized & Designed by M.Sabesh, CICR
Report Published in 2005