“स्थायी कृषि में समकालीन जल प्रबंधन नवाचारों के
कृषि-पारिस्थितिक आधारों का एक विश्लेषणात्मक अध्ययन”

“An Analytical Study of Agro-Ecological Bases of Contemporary Water Management Innovations in Sustainable Agriculture”

BY

SANJAY KUMAR GUPTA

DIVISION OF AGRICULTURAL EXTENSION

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"An Analytical study of Agro-Ecological Bases of Contemporary Water Management Innovations in Sustainable Agriculture"

BY

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This is to certify that the thesis entitled "An Analytical study of Agro-ecological Bases of Contemporary Water Management Innovations in Sustainable Agriculture" submitted to the Faculty of the Post-Graduate School, Indian Agricultural Research Institute, New Delhi, in partial fulfillment of the requirements for the degree of **Master of Science in Agricultural Extension**, embodies the results of bona fide research work carried out by **Mr. Sanjay Kumar Gupta** under my guidance and supervision, and that no part of this thesis has been submitted for any other degree or diploma.

It is further certified that any assistance and help availed during the course of investigation as well as source of information have been duly acknowledged by him.

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Place: **New Delhi**

Dated: **(Sanjay Kumar Gupta)**

Dedicated

To

“Indian farmer, my parents and Nanima”

CONTENTS

LIST OF TABLES

List of Figures

List of Maps

List of plates along with captions of photographs

Chapter-1

INTRODUCTION

"Agro ecology is at the heart of all alternative farming systems. Agro ecology is a way of life to live in harmony with nature in an agro-ecosystem"

Water is the essence of life. It is indeed true that *living in harmony with Nature* is what the farmers in dryland ecosystems have mastered and survived all these centuries though better ways of using water resources judiciously.

Water has no colour, smell, taste or calories, but water is a vital element for all life forms. No human, animal or plant can live without it. The water quantity on Earth is very constant and covers two-thirds of area of Earth. The water on Earth is on a continuous cycle, called *'hydrological cycle'*, from oceans to atmosphere, then on the ground, rivers and back on the oceans. But in many areas water is a scarce resource.

Water is the most important input in agriculture. A farmer cannot think of cultivating any crops without water to irrigate the crops. From ages, agriculture has been dependent on water from rainfall. Rainwater gets soaked into soil, percolates and gets collected in ground water reservoirs, which are another source of irrigation. Water has a vital role to play in securing the prosperity of an agriculture based nation such as India.

Ground water crisis accounts for 60 percent of the irrigated areas in the country and critical to food security. It is estimated that over 70 percent of India's food grain production now comes from irrigated agriculture, in which groundwater plays a dominant role. Ground water crisis is a great problem in arid and semi-arid regions of the country.

Drought-prone Districts in India

Among the states of India, about 100 districts are drought prone and face acute water scarcity during crop growth periods. The most number of drought affected districts are in Karnataka (14), Rajasthan (13), Gujarat (12), Madhya Pradesh (11), Maharashtra (9), Andhra Pradesh (8), Tamil Nadu (8), Bihar (7), Uttar Pradesh (6) and other states (11). But among the arid districts of India with around 500 mm of annual rainfall, Rajasthan, Gujarat, Maharashtra, Karnataka and Andhra Pradesh stand apart. Water crisis looms large in these five states. This study on water management innovations relates to dryland agro-ecosystems in southern parts of Andhra Pradesh.

Very grave situation in Ananthapur of Andhra Pradesh

One of the most drought prone districts of Andhra Pradesh, Ananthapur receives very scanty rainfall with a mean of 568.5 mm, that is way below the average for the State. Agriculture is primarily rain-fed but fluctuating monsoons and near-perennial drought had forced the villagers to rely on groundwater for their agricultural and personal needs. Bore wells had been drilled in large numbers to extract groundwater, as a result of which the water table had gone down to below 400 feet. This, in turn, had led to drying up of bore wells, open wells and other sources of water. Though they were aware of the gravity of the situation, farmers continued to drill bore wells in the absence of any alternatives, aggravating the state of affairs.

Water management was virtually unknown to them. They had been using scarce water resources injudiciously, which had resulted in undue wastage of water. Defunct water harvesting structures were not being repaired in time. The farmers also never saw *'water sharing'* and *'water economy'* as a priority issue. Social exclusion was at a high and the Dalit community had no access to major sources of irrigation water.

Contemporary Innovations related to water use

Among the many problems that Indian farmers face today, the most important are the vagaries of monsoon, depleting ground water resources and climate change aberrations. The crisis in farming sector has increased in the last two decades resulting in large tracts of farm lands reporting severe ecological problems due to high levels of water scarcity, both from rainfall and from ground water resources, leading to agro-ecological crisis.

In response to the agrarian crisis, several innovations, both technological and institutional, have emerged across the country and have showed promising results. These innovations are driven by scientific problem-solving approaches and agro-ecological concepts and principles.

These innovations have been evolved through the traditional wisdom and indigenous technical knowledge evolved by farmers over long years of their experiences of survival in the particular agro-ecosystems. Although these are essentially indigenous in nature, these have been tested and refined by few interested researchers, informal water technologists and non-government agency's water experts and farmers and hence, can be termed ***'Contemporary water management innovations'***. These innovations from non-formal sector have not been considered as a subject of study for the innovation system researchers.

What are Contemporary Innovations?

Contemporary water management innovations are those innovations developed by farmers and few researchers, and occurring in the present living times, or being in practice at the same time as new formal research-based integrated technology and practices. Some examples of contemporary innovations are organic farming, alternative (non-chemical) soil and plant nutrition techniques, on-farm resource use, low external input sustainable agriculture (LEISA), non-pesticidal management (NPM) of crops, mixed and inter cropping, trap cropping, border cropping, water harvesting and sharing, community mobilization, etc.

The striking characteristics of these contemporary innovations are that they address the community mobilization and elicit farmers' participation for concerted group actions for solving all inter-related problems through farming systems approach in the whole agro-ecosystem.

Agro-ecology

A thorough analysis of all these different alternative solutions to agrarian crisis has revealed that agro-ecology is at the heart of all these alternative farming systems.

Hence, farmers need to understand the science of agro ecological bases of sustainable agricultural practices. Agro-ecology is therefore increasingly recognized as the way forward for sustainable agriculture, capable of delivering productivity goals without depleting the environment and disempowering communities.

Agro-ecology is "the application of ecological science to the study, design, and management of sustainable agriculture" (Altieri, 1995). Agro ecology, which uses ecological concepts and principles for the design and management of sustainable agricultural systems, has consistently proven capable of sustainably increasing the total output of diversified farms, and has far greater potential for fighting hunger, particularly during economically and climatically uncertain times.

Altieri (2002) stated that the scientific basis to sustainably enhance productivity, agro-ecology emphasizes the capability of local communities to innovate, evaluate and adapt themselves through farmer-to-farmer research and grassroots extension approaches. Agro-ecological approaches emphasize diversity, synergy, recycling and integration, and social processes that value community involvement, with human resource development as the cornerstone of any strategy aimed at increasing options for rural people and especially resource-poor farmers.

When the ecosystem gets disturbed adversely, agro ecological crisis may set in, which can be seen as the adverse conditions of climate change endangering the sustainability and enhancing the vulnerability of dryland agro-ecosystem system. Agro-ecological crisis can be witnessed in terms of loss of landscape diversity of vegetation, farm crops and farm animals, loss of soil quality and signs of degradation or resource losses due to soil erosion, deforestation, habitat fragmentation, decline in on-farm resource use efficiency especially of water and nutrients, dependence on external inputs and incidence of pests, diseases and weeds resulting in, crop damage.

Statement of Problem

Understanding the sustainability of an agro-ecosystem is quite essential for generating innovations for a particular agro-ecosystem. Sustainability should be at the core of all pursuits of knowledge and solutions for problem-solving approaches in various agro-ecosystems.

The importance of sustainability starts with, preserving natural resources in order to protect present day farm families and for future ones, those who will come after us. Sustainable agriculture means farming systems that are capable of maintaining their productivity and usefulness to society indefinitely. Such systems must be resource-conserving, socially supportive, commercially competitive and environmentally sound. Such sustainable agriculture aims at providing a more profitable farm income, promoting environmental stewardship and promoting stable, prosperous farms for families and communities.

Appropriate sustainable innovations should be risk-averse, adapted to heterogeneous circumstances, should be based on indigenous knowledge and rationale; be economically viable, be accessible to everyone, and based on local resources; be environmentally sound and friendly, socially compatible, culturally acceptable, gender sensitive, ensure yield stability and finally enhance total farm productivity.

The importance of these contemporary water management innovations is great for those farmers, who have survived in a specific agro-ecosystem, faced several crises and evolved new indigenous innovations. These innovations are culturally compatible, environmentally friendly and in harmony with nature. The Farmers, who innovated, have amply understood comprehensively the rationale behind these water management innovations in their specific agro-ecosystems. Now in order that these contemporary innovations get diffused to other farmers living in similar dryland agro-ecosystems, the farmers of those agro-ecosystems need to first understand comprehensively the agro ecological bases or rationale of the contemporary water management innovations to accept, adopt and continue their sustained use.

The scientific explanations behind the agro-ecological components of contemporary water management innovations need to be understood thoroughly by the farmers. Agro-ecological principles associated with any of the sustainable farming practices and reasons and rationale behind the science of agro-ecology have great significance for sustainable agriculture.

Hence, in order to understand the different contemporary water management innovations being practiced by farmers of dryland agro-ecosystem, the knowledge of the agro-ecological rationale of the farmers, and the extent of adoption, a research investigation is planned. The following are research questions.

Researchable issues

1. What are the critical issues behind agro-ecological crises in the recent years that our farmers have faced?
2. What are the prominent aspects of water harvesting, water sharing and water management practices in sustainable agriculture?
3. What is the level of knowledge of farmers about the agro-ecological bases of water management technology and what are its correlates?
4. What is the extent of adoption of farmers on the selected water management practices and what are its correlates?
5. What are the constraints and suggest extension strategies for diffusing water management practices in similar agro-ecological conditions?

In order to address these research issues, a research investigation entitled ***"An Analytical Study of Agro ecological bases of Contemporary Water Management Innovations in Sustainable Agriculture"*** is planned with the overall objective of assessing the knowledge and understanding of agro-ecological bases of the farmers' contemporary water harvesting and water sharing innovations for achieving sustainable agricultural production in dryland agro-ecosystems. However, the specific objectives are given below.

Objectives

1. To analyse the causes of agro-ecological crises faced by farmers of dryland agro-ecosystem.
2. To document and analyse the water harvesting, water sharing and water management practices in sustainable agriculture.
3. To assess the level of knowledge of agro-ecological bases of water management practices in dryland agro-ecosystem and analyse their correlates.
4. To measure the extent of adoption of farmers on the selected water management practices and analyse their correlates.
5. To analyse the constraints and suggest extension strategies for diffusing water management practices in similar agro-ecological conditions.

Scope of the Study

These contemporary water management innovations from non-formal sector have not become a subject of study for the innovation system researchers. It would be useful to learn from these contemporary water management innovations so that the main stream agricultural research and extension system can improve and become more relevant, resilient and sustainable.

Hence, in order that the farmers understand, appreciate and adopt the various contemporary technological and institutional innovations for achieving sustainability in agriculture, we need to create awareness, teach and educate farmers on the beneficial effects and the agro-ecological reasons behind these contemporary innovations of sustainable agriculture. A systematic study is imperative here to analyse and comprehend the real agro-ecological reasons and bases behind the contemporary technological and institutional innovations.

In addition to many formal public research organizations' innovations, some NGOs have evolved few innovations through refining and standardizing farmers' traditional wisdom and indigenous technical knowledge to sustain and survive in an agro-ecosystem. These are innovations being in practice in the contemporary times. Hence these are called contemporary innovations. Although these are essentially indigenous in nature, these have been tested and refined by few interested researchers and farmers in informal settings.

Contemporary water management innovations are those innovations belonging to or occurring in the present living times. They are occurring at the same time as conventional government sponsored and recommended new integrated technologies. These contemporary water management innovations or practices are widely accepted and adopted by farmers. This study would also highlight the farmers' level of understanding of agro-ecological principles for sustained application of water management practices in drylands.

Limitations of the study

The major limitation was with respect to the duration of the study. Water management practices would have a cumulative effect, which will gather momentum with continuous use. These aspects, which require longitudinal studies and are time dependent, could not be studied as it will be beyond the scope of this study.

Chapter II

REVIEW OF LITERATURE

Researchers recently have been paying serious attention to the need and importance of contemporary water management innovation and dryland agriculture, as it is an important aspect in sustainable agriculture. The present research effort is the one of its kind in analyzing and documenting the contemporary water harvesting and sharing institutional innovations in Andhra Pradesh. Keeping this in view, a comprehensive review of the previous research studies related to the topic has been done in accordance with the objectives of the present study and is presented under the following sub headings.

2.1 Agrarian crisis and causes of agro-ecological crisis

2.2 Water management innovations

2.2. a. Water harvesting

2.2. b. Ground water and aquifer management

2.2. c. Protective micro irrigation

2.2. d. Conservation agronomic practices

2.2. e. Canal irrigation water distribution systems

2.3 Agro-ecological aspects of dryland eco-systems

2.4 Institutional innovations for organizing water sharing among farmers

2.5 Interventions and lessons

2.1 Agrarian crisis and causes of agro-ecological crisis

Carlson (1989) reported that wind, water and movements of agricultural implements, carry pesticide across property lines leading to negative and positive effects on neighboring producers and other individuals.

Browder (1989) in his research suggests that many small farmers cope and even prepare for climate change, minimizing crop failure through increased use of drought-tolerant local varieties, water harvesting, mixed cropping, opportunistic weeding, agro-forestry and a series of other traditional techniques.

Singh (1992) reported that decline in water table has encouraged farmers to explore deeper aquifers through digging deeper tube wells. The decline in water table was attributed to inadequate rainfall and excessive water use in intensive paddy cultivation. New methods of irrigation like drip and sprinklers should be used wherever suitable, which would save water greatly.

Singh (2002) studied in arid and semiarid regions of Rajasthan, depletion of aquifer was a serious problem. In such a situation, the poor well owners were not in a position to undertake deepening of their wells every year. Similarly, water table was considerably deeper in Kukanwali village as compared to Srichandpura. Chasing of water table was beyond the reach of resources poor individuals. In such situation, they had to depend upon the other well owners for groundwater irrigation.

Agro-ecological crisis occurs when the vulnerabilities of an agro-ecosystem increase and endanger the very sustainability and includes the following dimensions: loss of landscape diversity of vegetation, decline in on-farm crop and animal diversity (number of species), loss of genetic diversity, loss of soil quality and signs of degradation or resource losses due to soil erosion, deforestation, habitat frag-mentation, state of water courses, efficiency in use of water, nutrients, etc., incidence of pests, diseases and weeds, crop damage and dependence on external inputs and ultimately resulting in lower levels of food self-sufficiency. Significant feature of agro-ecological crisis can be observed in declining interactions and bio-resource flows between farm components (recycling of crop residues and manure, effective use of biomass, complementarities between plants, level of natural pest control, etc.) (Altieri, 2002)

2.2 Water management innovations

Rogers (2003) defined an *innovation* as an idea, practice, or object that is perceived as new to an individual or another unit of adoption.

The *innovation-development process* consists of all of the decisions, activities, and their impacts that occur from recognition of a need or problem, through research, development, and commercialization of an innovation, through diffusion and adoption of the innovation by users, to its consequences.

Usually, the innovation development process in formal research organisations follow the steps mentioned here. But in non-formal situations, the activists and well-wishers living in an agro-ecosystem would take initiative in ameliorating the deteriorating situations and begin mobilizing awareness and participation among the people and find ways and solutions to the problems. However, the first step suggested by Rogers (2003) would definitely assume importance as it is the precursor for action and conducting other steps of innovation development process. The first step, '*Recognizing a Problem or Need' has been well considered in finding the solutions for solving the problems of water scarcity in dryland agro-ecosystems.*

One of the ways in which the innovation-development process begins is by recognition of a problem or need, which stimulates research and development activities designed to create an innovation to solve the problem/need (Rogers, 2003).

When an attempt was made to search for innovations in water management in drylands, a dearth of literature was felt. Formal research organisations were proving solutions to water crisis in bits and pieces on technologies per se, but no information was available on social processes of farmer's involvement in large scale adoption of all the innovations related to water harvesting, storing, saving, sharing, and using through micro-irrigation systems. Some of the available literature on water management innovations are presented here.

2.2. a. Water harvesting

Mann and Ramana Rao (1981) conducted study on rainwater harvesting management and its implications. The study revealed that the better rainwater utilization by harvesting and recycling increased the efficiency of available land and water resources. The potential productivity of treated regions appeared to be two to three times higher than what was attained by the traditional system of production.

Tiwari (1991) conducted a study on rainwater harvesting technology. The study revealed that there was a great scope of for improving agriculture productivity of arid and semi-arid regions through efficient utilization of rainwater. He further stated if water storage ratio was less than 1:6 then the structure may become uneconomical.

Arun (1994) observed that farmers responded to well failure by going in for an additional well, reducing area under water intensive crops, shifting to low water intensive crops like mulberry or by investing on water saving technologies like drip or sprinkler irrigation systems.

Tiwari and Mal (2000) observed that the water harvesting structure, collection and storage of run-off water in suitable reservoir or pond, reducing the seepage and evaporation losses and use of conserved water most efficiently at critical time to provide lifesaving irrigation to crops.

Rockstrom (2002) observed that water harvesting structures have the potential of contributing to mitigate rainfall fluctuations, and thereby stabilize yields over time and increase overall yields level.

Ngigi (2003) revealed that rainwater harvesting structures increases cropland water conservation to enhance soil infiltration and water holding capacity of the soils. And he observed that though rainwater harvesting practices can yield positive results through effective increase of soil moisture for crops in water scarce areas.

Bewket (2007) observed that the rainwater harvesting structures were effective measures for soil erosion and improving land productivity.

Saha *et al.* (2007) revealed that the water harvesting structure restricts the potential losses like infiltration, percolation, seepage flow and evaporation at great extent.

Vohland and Barry (2009) observed that *in situ* rainwater harvesting systems that improve hydrological indicator such as, infiltration and ground water recharge, soil nutrients are enriched, and biomass production increases with subsequent higher yields leading to food security.

Biazin *et al.* (2012) reported that the rainwater harvesting techniques could improve the soil water content of rooting zone, nearly six fold of crop yields have been obtained, reduces risk of crop failure due to dry spells but also improving water and crop productivity.

Farm Ponds

Wangkahartt *et al.* (2004) revealed that the farm pond impacts indicate not only increasing crop yields in both rainy and dry seasons, but also reduction of downstream sediment load.

Kunnal *et al.* (2015) observed that farm ponds are water harvesting structure used for storing the monsoon rainwater, which is used for irrigation. Farm ponds are expected to have an impact on cropping pattern, productivity, employment and income of farmers.

Rajeswari *et al.* (2007) observed that the farm ponds are water harvesting structures which can make changes in cropping pattern and providing additional employment among farmers.

2.2. b. Ground water and aquifer management

Dhawan (1991) found that for sustainable and thriving groundwater based farming both conservation of stock of groundwater resources and simultaneous exploration of ways and means of enhancing the recharge are crucial. The conservation is best achieved by restricting the very demand for groundwater use through sprinkler and drip systems, which may be quite effective in efficient groundwater use. Appropriate electricity pricing is needed to discourage in bore well digging for extracting ground water.

Khanna and Rai (1997) suggested that the cropping pattern should be decided commensurate with the status of the ground water table and soil characteristics. This could be a state policy based coping mechanism to depleting water resources.

Satyasai *et el.* (1997) observed strategies to save water from shifting cropping pattern in the water scarce area. The shift in cropping pattern brought involvement in water use efficiency and thus save water. Out of various alternative crops that could be grown in place of Rabi paddy, chilies offered better alternative in terms of income, employment, productivity of water.

Hanumantharao *et al.* (1988) have stressed the importance of promoting dry land farming in areas facing severe scarcity of groundwater. In areas which provide sufficient groundwater, they recommended concentration of high yielding and high value crops. Other areas should specialize in drought resisting or avoiding crops, fodder and trees with complementary marketing and processing facilities. Research on drought resistant crops, fodder and trees appropriate for different zones had been inadequate in the past and needed to be urgently stepped up.

Mirina and Kowasar (2000) reported the artificial recharge of ground water where practicable is an easy and economical method for desertification control in arid and semi-arid zone, where over-pumping has critically lowered the water, which is prerequisite for the artificial ground water recharge.

2.2. c. Protective micro irrigation

Patil (1990) observed that micro irrigation provided congenial wet and pulverized soil condition conducive for peg penetration and pod development in groundnut. Micro irrigation is considered to be the best irrigation system as compared to surface method of irrigation.

Bosu *et al.* (1995) the sprinkler irrigation to black gram gave higher net return than surface irrigation and sprinkler irrigation was 1:1.76. Micro sprinkler irrigation at 100% evapo-transpiration resulted high net returns.

Kijne *et al.* (2003) found opportunities for improving crop water productivity mainly lie in choosing adapted, water-efficient crops, reducing unproductive water losses and ensuring ideal agronomic conditions for crop production. In general, agronomic measures directed at healthy, vigorously growing crops favour productive water losses (transpiration) over unproductive losses.

Sankar *et al.* (2005) reported that micro-sprinkler irrigation system offers high irrigation efficiency on account of reduced losses such as runoff and percolation as compared to other irrigation systems and it performs well in condition where drip-irrigation system is not feasible.

Veeresh (2006) reported that micro-irrigation as an irrigation system was originally introduced for irrigating high-value crops but now, adopted for close-spaced crops also. Micro-irrigation systems' water use efficiency lies between the conventional sprinklers and drip systems which have much larger area of coverage than drip emitters but lower than that of the conventional sprinklers.

Bhagyawant *et al.* (2012) observed that the benefit cost ratio of drip irrigation system (1.62) was better than the surface irrigation methods (1.39). The profitability and reduced labour costs favors the use of drip irrigation system over surface irrigation for small land holders to marginal farmers.

2.2. d. Conservation agronomic practices

Natarajan and Willey (1986) stated that polycultures exhibit greater yield stability and less productivity declines during drought than in the case of monocultures. They examined the effect of drought on enhanced yields with polycultures by manipulating water stress on intercrops of sorghum (*Sorghum bicolor*) and peanut (*Arachis spp.*), millet (*Panicum spp.)* and peanut, and sorghum and millet.

Jarvis *et al.* (2007) found that considerable crop genetic diversity continues to be maintained on farm in the form of traditional crop varieties, especially of major staple crops. In most cases, farmers maintain diversity as an insurance to meet future environmental changes or social and economic needs.

2.2. e. Canal irrigation water distribution systems

Das *et al.* (1993) suggested the performance evaluation parameters of irrigation canal systems should involve factors such as command area, canal network, control structures, cropping patterns, weather conditions as well as human factors. Appropriate tools are needed to predict the possible outcomes of operational decisions.

Bos and Nugteren (1990) presented most widely the concepts and definitions of irrigation efficiencies. They divided the overall project efficiency into various components so that the efficiencies associated with different components of the water delivery system-conveyance, distribution, and field application can be separately stated.

An integrated simulation and optimization approach is proposed to improve the irrigation delivery system operation and management strategy. This will help in providing optimal water levels in the main system, which in turn will guarantee proper flow diversion to laterals and farm turnouts.

Mollinga *et al.* (2001) studied the implementation of participatory irrigation management in Andhra Pradesh. He reported on the impact of the introduction of participatory irrigation management in two secondary canals (distributaries) in the Tungabhadra Right Bank Low Canal irrigation system. A significant amount of physical rehabilitation works had been undertaken resulting in a water distribution so far as it did not lead to increase in irrigation area. It was suggested that the lack of demand for policy reform was a feature not exclusive to Andhra Pradesh.

Nelson (2002) studied performance indicators for irrigation canal system managers of water users' associations. Indicators as tail-end ratio, area uniformity, delivery timeline's ratio, carrying capacity ratio, poor structure ratio, fee collection performance, maintenance budget ratio, personal cost ratio, manpower number ratio, financial self-sufficiency, sustainability of irrigated area, relative groundwater depth and area/infrastructure ratio were used.

Mini (2006) carried out a study on water users' association (WUA) and irrigation management with special reference to environmental problems. There were two villages selected in Tungabhadra Left Bank Canal, Guntur (With WUA) and Hagedal (without WUA). WUA's parameters studied were irrigation management, water distribution, reason of violation of cropping pattern and unauthorized cultivation, production of grains in terms of higher yield and higher value crop, cases of water-logging, salinity and range of strategies currently used to manage them.

Yavuz *et al.* (2006) studied performance evaluation of water users' associations (WUAs) in Seyhan basin. Eight performance criteria *viz.,* standard gross value of production (SGVP) per unit of scheme command area, SGVP per hectare irrigated, SGVP per unit of water diverted, SGVP per unit of water needed, relative water supply, irrigation ratio, financial sufficiency ratio and fee collection rate were used to evaluate the seventeen irrigation associations. Evaluation was done on four aspects, *first,* production per unit area, *second,* production per unit water, *third,* water supply and *fourth,* expenditures involved.

Tyagi (1993) studied the performance of irrigation system (Fatehabad Branch of Bhakra Canal system in Haryana) at farm as well as watercourse level. Equity (in terms of uniformity coefficient and modified inter-quartile ratio), adequacy (in terms of relative water supply) and water productivity, which reflected both adequacy and timeliness, were evaluated. The equity of water distribution decreased with the size of the watercourse (flow rate). The average relative water supply (ratio of water supply and water demand over a period of time) was observed to be 0.72 in summer and 0.65 in winter at the head reach and 0.58 in summer and 0.50 in winter at the tail reach of watercourse. This clearly indicates the insufficiency of the available canal water supply to meet the demands. The significant reduction in relative water supply towards the tail end is due to seepage losses occurring in the watercourses.

Unal *et al.* (2004) reported on water delivery performance of the Menemen Left Bank Irrigation system in the west of Turkey. Performance evaluated at tertiary canal level, using the adequacy, efficiency, dependability and equity indicators. The water delivery performance to the territories in each irrigation season rated worse for adequacy, dependability and equity then for efficiency. The indicators showed that factors causing the problem derived in part from physical and from management.

Ray and Williams (2002) studied and reported on illegal water diversion irrigation canal calibrated to a canal in Maharashtra on which farmers voted to cooperate to control water theft. The solution of the crop choice and profits of individually optimizing farmers who differ in their location. It reveals the spatial distribution of gain and losses from cooperation. It illuminates why voluntary bargaining will rarely achieve an efficient water allocation.

Reddy (2005) reported the impact of water management on production of rice in Balipatna command area of Orissa, India. The results indicated that irrigation through field channels had positive impact on the yield of kharif paddy. The variables like application of fertilizers, irrigation cost, seed and labour cost had significant positive impact on the paddy yields. The marginal productivity of inputs indicated fertilizers and seeds are not efficiently utilized as compared to other inputs.

2.3 Agro-ecological aspects of dryland eco-systems

Gliessman (1998) reported that the science of agro-ecology is defined as the application of ecological concepts and principles to the design and management of sustainable agro-ecosystems, with a minimal dependence on high agrochemical and energy inputs, emphasizing complex agricultural systems in which ecological interactions and synergisms between biological components provide mechanisms for the systems to sponsor their own soil fertility, productivity and crop protection.

Molden (2013) noted that while potential productivity gains are available in irrigated agriculture, perhaps the biggest opportunities lie with rainfed agriculture, which largely involves improving rainwater retention by soils. Some ecosystem-driven aspects of the water cycle that merit better attention need to be studied.

De Schutter and Vanloqueren (2011) see agro-ecology as an effort to mimic ecological processes in agriculture, while increasing productivity and improving efficiency in the use of water, soil, and sunlight as sustainably as possible.

Levidow (2015) stated that agro ecological methods have been incorporated into ‘sustainable intensification’, where they are combined with other methods (including biotech) to increase yields, while also lowering the pressure on land and natural resources.

2.4 Institutional innovations for organizing water sharing among farmers

Pant and Verma (1983) stated that the irrigation projects with their complex engineering and bureaucratic organizations cannot be successful without the active participation of beneficiary farmers in the management process. Consequently, the literature on irrigation management in the recent years has given increasing attention to the value of organized participation by water users in the management process.”

Uphoff (1986) argued that the number of levels of management should correspond to the hydrological system. In the more specific context of water users’ associations, the relationship between physical scarcity and level of participation has been understood as being akin to an inverted U-shaped curve, peaking at some medium level of scarcity.

Cernea and Meinzen-Dick (1994) the emphasis in this body of work is on the conditions of management and organization under which “farmers’ participation” will succeed. The major themes are organizational size, social and economic homogeneity of members, legal status of WUAs, and conferment of secure property rights and the creation of a favorable bureaucratic and policy environment. Discussions in this body of work focus on how each of these factors influence the likelihood of success of water users’ associations. This view is inspired by the socio-technical nature of irrigation systems. The *‘software’* of irrigation needs much the same emphasis as the *‘hardware’*. Social engineering is as important as technical engineering.

Pant (1999) showed that the management transfer to the WUAs in Maharashtra is terms of area expansion under irrigation as well as water use efficiency. The WUAs have considerably improved the recovery of water charges thereby bringing revenue to the government. Moreover, by charging higher amount from the water users, the WUAs have accumulated funds for the maintenance of their microstructures and continue to survive and thrive even after management subsidy of the government has ceased to exist.

Chandran *et al.* (2008) had quantified farmers' participation through Water Users' Associations (WUAs) under Command Area Development Programme (CADP) in Malampuzha Irrigation Project, Kerala State. The study has shown that only about 30 percent of participatory activities envisaged for WUAs were being undertaken by farmers and hence participation is low. However, landholding size was found to influence participation.

Hooja (2005) described water user association as a parallel or lower than Panchayati Raj which is considered as third tier of India's federation, which has to operate, manage and maintain the canal system. In India WUA's functions are preparing and implementing a *'warabandi'* scheduling, planning and implementing the maintenance of irrigation system, regulating the use of water and water budgeting. WUA's main aim is to increase water productivity in command area development.

Reddy and Reddy (2005) studied the Water Users' Associations (WUA's) in Andhra Pradesh. They observed that though substantial amount of money were spent on the reform process, money was mainly for improving the ailing irrigation systems rather than strengthening formal institutional structures. Despite the fact that WUA's were promoted as non-political institutions, elite captured the system and political involvement dominated their functioning. Devolution of powers to WUA's had not taken place, as most of the important functions like assessment, collection of water charges and sanctioning of works remained in the irrigation department.

Puranik (2008) described that WUA perform different functions namely increasing agro-economy and socio-economy of farmers, determine reason of poor utilization of irrigation potential, iniquitous and unreliable supply of water and system deficiency. Construction focused approach of water resources development causing neglect of operation and maintenance of irrigation system.

Cakmak *et al.* (2009) evaluated the irrigation system performances of the Water User Associations in Asartepe irrigation scheme in Turkey. Financial performance, productive performance and water delivery performance were determined. From the result, it was concluded that Asartepe irrigation association is successful in decision making on system development.

Basnett *et al.* (2011) performed a social assessment of the irrigation users of the Rani, Jamara and Kulariya system using two components. The study completes the development of a socioeconomic profile of the project, map out stakeholders in the project area, assess various social, economic and political factors that play in the design and implementation of the project and assess likelihood of the social impacts of the project. On the basis of the social assessment finding, it develops necessary interventions and mitigation strategies under the project in line with relevant government and World Bank requirements.

Yakubov (2012) stated that irrigation performance important tools that irrigation service providers at various levels of the water management hierarchy can use for monitoring, benchmarking and self-improvement. Attempt was made to explore and sensitize farmers' views about irrigation service and related performance dimensions using qualitative research methods. Based on focus group discussions with a purposive sample of farmers from a range of water users' associations in Central Asia and a grounded theory approach the study lays a conceptual foundation for future practical applications.

Phadnis and Kulshrestha (2012) evaluated the efficiency for WUAs of irrigation project Samrat Ashok Sagar (Halali) in India, using benchmarking by data envelopment analysis as the performance evaluation tool and to integrate the outcome of the benchmarking process for planning, design and effective management of available water resources. In the analysis the gap was compared with the scheme. The performance gap and the action required for closing the performance gap were explored. It is evident that considerable variations occur amongst the various WUAs in terms of the operational characteristics reflected by the independent variables. Choice of performance indicators and some of the issue that emerge in using them, starting with the irrigation water delivery, sub-system bio-economic and social organizational sub-system then moving up to the irrigated agriculture system and the agriculture economic system.

2.5 Interventions and lessons

Meinzen-Dick (1996) and Meinzen-Dick *et al.* (2000) argued that water must be scarce enough to induce collective action at the same time, beyond a certain level of scarcity, collective action may not be rewarding at all. Where there is effective rainfall, there would be limited dependence on irrigation, and hence limited incentives for participation. Similarly, a large number of wells could encourage farmers to opt out. Those with plentiful water do not need to be active, and those who expect too little water have no incentive to be involved. Thus it is argued that areas with moderate scarcity have higher returns to participation and organized actions of farmers.

Sinha (2000) discussed farmer's participation in the Partapgarh sub project of the Uttar Pradesh Sodic Land Reclamation Project in India. The project aims to develop appropriate water-management strategies, including drainage infrastructure, with farmers' participation. The survey confirmed that because the farmers' association would not be able to sustain drainage activity alone, farmers in the pilot sub-project should be organized under canal water management, with drainage as an additional function.

Synoptic Note:

A review of all the available literature has revealed that no formal institutions were providing a complete package of water management solutions for the dryland farmers. There is indeed a great dearth of information on rain water harvesting techniques, rain water storage, and micro-irrigation systems. Although there is a great deal of information on canal irrigation systems, canal water use efficiency and canal water distribution systems and canal water users' groups, etc., there is very little information available on rain water use efficiency and rain water harvester's groups. Hence this study on contemporary rain water sharing innovations can be a new step in this direction.

All the water conservation measures were focused and directed towards individuals to accept and adopt. But these water harvesting and sharing innovations demand the concerted group actions of the whole agro-ecosystem. Hence, rain water harvesters and users group was a unique institutional innovation that is addressed in this research investigation.

To enable, group mobilization and formation of rain water sharing groups, the whole ideology, principles and conceptual understanding among farmers need to be comprehensively based on principles agro-ecology. This understanding is necessary for the institution building and sustainability of the water sharing groups the research gaps were found in the absence of efforts to inculcate the agro-ecological rationale of equitable sharing of common property of water resources among farmers. Sustainable agriculture stands firmly on such community participation initiatives.

Chapter III

RESEARCH METHODOLOGY

The purpose of the chapter is to describe the research methods and procedures followed to carry out the research study. Various aspects associated with conducting this research; design, sampling, measurement of variables, data collection methods and statistical tools are presented under the following sub headings:

3.1 Research Design

3.2 Selection and description of locale of study

3.3 Sampling Procedure and Selection of respondents

3.4 Selection of the variables and their measurement

3.5 Methods and tools of data collection

3.6 Statistical tools applied

3.1 Research Design

Kerlinger (2004) defined research design as the plan, structure and strategy of investigation conceived so as to obtain answers to research questions and to control variance. It includes an outline of whatever the investigator does from writing the hypothesis to the final analysis of the data. The basic purpose of the research design is to enable the researchers to answer research questions with validity, objectivity and accuracy.

For this study, *ex-post facto* design was used. This is systematic empirical enquiry in which the researcher does not have direct control over the variables because their manifestations have already occurred. A survey approach was adopted to collect quantitative data. A case study approach was also adopted to collect qualitative data.

3.2 Selection and Description of study area

Under this section, the locale of the study, general geographic data, climate and crops are presented. A map is also given to locate the mandals, and villages selected for the study.

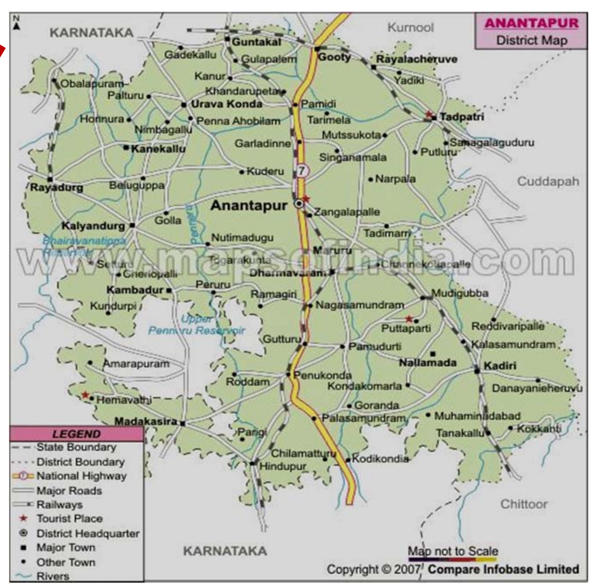
Locale of the study: The study was conducted in dryland agro-ecosystem of Andhra Pradesh. District Ananthapur was purposively selected as large number of farmers were adopting contemporary water harvesting and water sharing practices for managing crops-water in dryland system. A brief description of the district is given below.

Ananthapur district lies in the south western part of Andhra Pradesh in the Rayalaseema region. It is bounded by Karnataka to the west, YSR Kadapa district to the east, Chittoor district to the South, and Kurnool district to its North. In 1882 the district was constituted separating it from the district of Bellary. The district comprises of 3 revenue divisions consisting of 63 Revenue Mandals and 63 C.D. blocks. It is located between 13'-40' and 15'-15' Northern Latitude and 76'-50' and 78'-30' Eastern Longitude. Ananthapur district is occupying an area of 19130.0 sq. km. with a population of 4,081,148 of which males and females were 2,064,495 and 2,016,653 respectively, as per 2011 census. The population density is 213 persons per sq.km. About 76 per cent of the population is living in villages with a sex ratio of 977 females for every 1000 male population in villages. Total literacy rate is 63.57 percent, with male literacy rate at 73.02 percent and female literacy rate at 53.97 percent.

Climate: Ananthapur has a semi-arid climate, with hot and dry conditions for most of the year. Summers start in late February and peak in May with average high temperatures around the 37 °C (99 °F) range. Ananthapur gets pre-monsoon showers starting as early as March, mainly through north-easterly winds blowing in from Kerala. Monsoon arrives in September and lasts until early November with about 250 mm (9.8 in) of precipitation. A dry and mild winter starts in late November and lasts until early February; with little humidity and average temperatures in the 22–23 °C (72–73 °F) range. Total annual rainfall is about 22 in (560 mm).

Crops: The economy is principally agrarian. Ananthapur receives very less rainfall due to its location in the rain shadow area of Indian Peninsula. Prominent crops include groundnut, sunflower, rice, cotton, maize, chillies, sesame, tomatoes, horse gram, tur, sorghum and sugarcane. Ananthapur town is known as Groundnut city. Ananthapur

Selected district of Andhra Pradesh: Ananthapur



Anantapur district

Fig. 3.1 Maps showing the study area of the research investigation

Plate I

Focused group discussion

Structured and semi structured interview

Informal interview

climate is also known for its tomato exports to other states, because its climate is suitable for tomato cultivation because of being thermos-periodic, a phenomenon of cool night temperatures and hot day temperatures.

3.3 Sampling Procedure and Selection of respondents

Sampling procedure: Both the purposive and random sampling were used for selection of respondents.

Selection of Mandals: Since the purpose of the study is to analyse the contemporary water management innovations and sustainable approaches involved in promotion of innovations like water sharing technology, ground water management, aquifer recharge techniques, protective irrigation, etc. in the villages, three mandals from Ananthapur district were selected purposively. The criterion adopted is the large scale adoption of water management practices by the farmers and Mandals being well known as for its dryland agricultural practices in the district.

Selection of Villages: Eight villages were randomly selected from three Mandals. The villages selected for this study of contemporary innovations on water management practicing farmers are given below:

Table 3.1: List of selected Mandals and Villages for the study

Mandals	Villages
1. Gandlapenta	1. Karnamwaripalli 2. Kumarwandlapalli 3. Narasappagaripalli 4. Kamathampalli
2. Kadiri	1. Patnam
3. Nallacheruvu	1. Padllewaldlapalli 2. Bodnepalli 3. Devireddypalli

Selection of the Respondents: For the purpose of village survey, to assess and analyse the causes of the agro-ecological crises, to assess the knowledge level of the agro-ecological bases of contemporary water management innovation practices of farmers, and to measure the extent of adoption of different contemporary water management innovations a survey design was adopted. One hundred twenty farmers were randomly selected from eight villages for personal interviews.

In addition, thirty different extension functionaries like Mandal level officials, village level officials, village activists, community resource persons, and office-bearers of water sharing groups and few experts working on water science and technology were selected for analysing their views on constraints and suggestions for diffusing the contemporary water management innovations in similar dryland agro-ecosystems.

3.4 Selection of Variables and their Measurement

Variables selected for the study are grounded on the basis of the objectives of the study, review of literature, discussion with experts and also the observations made by the researcher. The following variables were chosen for the study:

Table 3.2: Selection of the variables and their measurement

No.	Variables	Scale	Measurement of variables
Independent variables:			
1	Age	Ratio	Actual number of years
2	Sex	Nominal	Scheduled developed
3	Educational status	Nominal	Scheduled developed
4	Family size	Ratio	Actual Number
5	Family type	Nominal	Scheduled developed
6	Farming experience	Ratio	Scheduled developed
7	Irrigation land	Ratio	In acres
8	Dry land	Ratio	In acres
10	Orchard land	Ratio	In acres
9	Total Annual income	Ratio	Actual number in rupees
11	Frequency of Contact with personal localite channels	Ordinal	Scheduled developed
12	Frequency of Contact with extension personnel cosmopolite channels	Ordinal	Scheduled developed
13	Frequency of Contact with mass communication channels	Ordinal	Scheduled developed
14	Goal commitment	Nominal	Scheduled developed
15	Social capital	Interval	Scheduled developed
16	Social Norms (adherence)	Interval	Scheduled developed

Table 3.2: Selection of the variables and their measurement *(continued)*

No.	Variables	Scale	Measurement of variables
Dependent variables:			
17	Level of knowledge	Interval	Scheduled developed
18	Extent of adoption	Interval	Scheduled developed

Age: It was measured as the chronological age of the respondents at the time of investigation. The respondents were categorized into three groups- young, middle and old based on range.

Sex: If the respondent was female, a score of 1 was assigned. If the respondent was male a score of 0 was assigned.

Education: It is referred to the respondents' academic qualification acquired through formal schooling. It was measured based on their level of education. Based on their education level, the respondents were categorized into four categories and their frequency and percentages were worked out. Scoring pattern as given below was followed for statistical analysis.

Category	Code
Illiterate	0
Primary	1
High School	2
Intermediate	3
Degree	4
Diploma	5

Family type: It was measured in terms of cooking arrangements and pooling of income. The families that had pooled all their income and had common cooking arrangement despite the presence of more than a couple were considered joint family and otherwise, nuclear. A code of 1 is given to nuclear and 2 for joint family system.

Family size: It was measured in three categories as small family with less than 3 members, medium family with 4-6 members and large family with more than 7 members.

Farming Experience: It refers to the number of years a farmer has experience in cultivation of crops. The scoring procedure is as below.

Sl. No.	Experience in cultivation	Code
1.	> 10year	1
2	10-20years	2
3	20-30 years	3
4	30-40 years	4
5	>40 years	5

Irrigated land: The extent of irrigated land an individual possessed and cultivated was termed as irrigated land. It was measured by directly asking the question. They were categorized as below.

Sl. No.	Farmers' category	Range in ha
1	Sub marginal farmers	< 1
2	Marginal farmers	1 - 2
3	Small farmers	2 - 4
4	Large farmers	> 4

Dryland: The extent of Dryland an individual possessed and cultivated was termed as dryland holding. It was measured by directly asking the question. They were categorized as below.

Sl. No.	Farmers' category	Range in ha
1	Sub marginal farmers	< 1
2	Marginal farmers	1 - 2
3	Small farmers	2 - 4
4	Large farmers	> 4

Orchard land: The extent of orchard land an individual possessed and cultivated was termed as orchard land holding. It was measured by directly asking the question. They were categorized as below.

Sl. No.	Category of farmers	Range in ha
1	Marginal farmers	< 1 ha
2	Small farmers	1 – 2 ha
3	Semi-medium farmers	2 – 4 ha
4	Medium farmers	4 – 10 ha

Total annual income: It was measured in the actual terms: Rupees per year. The sources of family income were from farming, livestock, and non-farm like other business.

Frequency of Contact with personal localite channels: Personal localite referred as both acquaintance and contact of respondents with local leaders and local people who belonged to the respondents' own social system. To measure the extent of personal localite, a schedule was developed. The scores 4, 3, 2, 1 were assigned for the four points continuum viz., most often, often, sometimes and never respectively.

Frequency of Contact with extension personnel cosmopolite channels: Extension contact referred as both acquaintance and frequency of respondents contact with village extension officers, A.D.O., B.D.O., cooperative official, expert from research, ATMA officials, stockman *etc*. To measure this extension contact, a schedule was developed. The score of 4, 3, 2 and 1 were assigned on a four-point continuum, viz., most often, often, sometimes and never respectively.

Frequency of Contact with mass communication channels: Mass media exposure is the degree of utilization of mass media by the respondents. To measure this different mass media were identified like TV, Radio, Newspaper, *Krishi mela etc*. Then respondents were asked to express their frequency of using those media on a four point continuum (1 to 4).

Social capital: "Social capital is founded upon shared beliefs, norms and values depending upon trust existing between the actors involved" For measuring social capital, three components i.e. faith, norms and social interactions among the members of a group. This was measured using a schedule developed for the study.

Goal commitment: How strongly people are participating in water management practices, this scale developed to measure how frequently farmers are committed toward their goals of participation. This scale possesses 6 statements. The scores were added on the statement to measure goal commitment.

Social Norms: Compliance to social norms refers to the degree to which a traditional farmer adheres to group-held beliefs and values and the degree to which his or her community or society approves his or her behavior. A total of 9 statements were developed to measure the given variable in a five-point continuum. The maximum possible score was 45 and the minimum was 9.

Measurement of Dependent Variables

Level of knowledge of agro-ecological bases of water management innovations

The level of knowledge can be measured as level of awareness and accuracy of information on the agro ecological bases (roots / principles) of selected five water management practices of dryland agriculture. The responses of farmers were taken in the form of close ended questions and coded as 1 for correct answer and zero for wrong answer given by the respondent. A total of 26 items were developed in which maximum possible scores is 26. The knowledge index was developed by dividing obtained scores over obtainable scores multiplied by hundred for all five water management innovations separately and for the whole knowledge test.

Extent of adoption of water management innovations

The extent of adoption of different water management innovations were analysed through an arbitrary scale developed for the purpose and responses were scored as below.

Category	Code
Fully adopted	3
Partially adopted	2
Not at all adopted	1

The index was developed by dividing obtained scores over obtainable scores multiplied by hundred for all five water management innovations separately and for all 32 items of the whole set of water management innovations.

3.5 Methods and tools of data collection

For the collection of data, a well-structured questionnaire was developed. Necessary precautions were taken to ensure that the questions in the questionnaire were presented in an unambiguous, clear, concise, complete and comprehensive way. The questions were asked in Telugu language to farmers for their easy understanding. The questionnaire was pre-tested with non-sample respondents and then it was finalized for the study. After finalizing the interview schedule the data collection was carried out by personally contacting the respondents.

Case Study: A case study approach was adopted to collect qualitative data for documenting and analysing the water management practices including water harvesting innovations, water saving innovations, soil moisture conservation agronomic practices, water sharing institutions, a descriptive or narrative research design was used. Qualitative data collected from farmers was verified used and triangulated through secondary data sources of NGO's office records.

Delphi method: The Delphi procedure consists of a series of steps undertaken to elicit and refine the perspectives of a group of people who are either experts in the area of focus or representative of the target group (Rothwell and Kazanus, 1997). The first step is to select the panel or participants. The second step is developing structured questionnaire based on the problems to be investigated, or unstructured, in which an open-ended invitation to comment on the issues of interest is distributed individually to the participants. The information generated is processed and used by the investigating team to develop a subsequent more focused questionnaire, which is distributed together with the results of the previous round to participants in the third step of the procedure. This process of synthesizing data and refining the questionnaire continues until there is a convergence of perspectives among participants (Lang, 1998).

Measuring degree of consensus: The questionnaire for the first round of Delphi was developed by the experts, scientist and extension functionaries after reviewing the existing literature, job description of the experts, scientist and extension functionaries and discussing with the Research Advisory Committee members.

Questionnaires for second round were developed from the responses of first round of Delphi using constant comparative method. Subsequently, the questionnaire for round III (developed using the responses from the round II) was administered in the same manner as in previous two rounds. The data were collected from the experts through questionnaire and electronic mail method.

Furthermore, consensus was said to be high when quartile deviation was less than or equal to 0.5 and IQR less than or equal to 1, medium when quartile deviation was in between 0.5 and 1 and IQR greater than 1 but less than 2 and low consensus if quartile deviation is more than 1 and IQR more than 2. The important levels were: high in which the median value is 4 and above, while medium in which the median value is 3 and low when medium value is less than 3.

In this study, the Delphi technique was used to arrive at consents of various experts working in water science and technology on the constraints coming in the way of diffusing the water management innovations among farmers in similar agro-ecological conditions and the suggest extension strategies to diffuse these water management innovations in arid and semi-arid agro-climatic regions of the country.

3.6 Statistical tools applied

The collected data were subjected to statistical tests to get meaningful interpretations. Descriptive statistical tools such as factor analysis, mean, median, mode, percentage, interquartile deviation (IQD), quartile deviation, correlation and multiple regression analysis were used for analysing the data.

CHAPTER – IV

RESULTS AND DISCUSSION

Results of the present study have been presented in this chapter. Care has been taken to highlight the major findings in tune with the objectives set forth for this research investigation. They are described under the following sections.

4.1 Causes of Agro-ecological crisis faced by farmers of Dryland agro-ecosystem

4.2 Profile characteristics of farmers' respondents

4.3 Case study of selected water management practices in sustainable agriculture

4.4 Level of knowledge of Agro-ecological bases of water management practices

4.5 Extend of adoption of farmers on the selected water management practices

4.6 Constraint faced in water management practices

4.7 Suggestions for diffusing water management practices

Section 4.1 Causes of Agro-ecological crisis faced by farmers of Dryland agro-ecosystem

Farmers in dryland regions were facing severe water crisis and losing crops due to severe moisture stress. While rainfall-amount, timeliness and pattern have all become quite erratic, on one hand, even ground water resources got depleted due to competitive digging of bore wells, Droughts and long dry spells, untimely rains have also been regularly causing stress to farmers. Climate change aberrations have further worsened the already grave situation. As these conditions continued to prevail, at regular intervals, over the years, the agrarian crisis has started over powering large tracts of drylands. Since this agrarian crisis was due to severe damage caused to agro-ecological conditions of the drylands, this crisis was termed agro-ecological crisis.

In this study, it is attempted to delineate the causes of this agro-ecological crisis. First literature was called for possible reasons and the processes that went in for the onset of an agro-ecological crisis. Then group discussions with farmers exclusively focused on the various causes that led to the crisis were done and listed. Then this list was put into interview schedule and the farmers' responses on the degree of severity perceived by them on the listed causes were sought. These responses were recorded, the data were analysed and the results are presented here.

The causes of agro-ecological crisis as perceived by farmers and NGO workers was drawn from them through focused group discussion. Then a list is formed and categorized into sets like causes related to erratic rainfall, depleting ground water, depleting soil moisture, declining soil fertility, and conservative agronomic practices and other causes related to adverse market prices, deteriorating agroforestry and agro-ecological balance in Nature. A schedule was developed with the perceived causes and respondent's perception of degree of severity of these listed causes was measured on three-point continuum *viz., 'most severe', 'severe'* and *'less severe'* and given scores of 3, 2, and 1. Farmer respondents were asked to respond to each cause and state their perceived level of severity. Data were collected from 120 farmers and analysed. The results of analysis are presented and discussed here.

As the objective of this research investigation was to analyse the causes of agro-ecological crisis faced by the farmers in dryland farming agro-ecosystem, the approach followed was to enlist a large number of causes of agro-ecological crisis affecting the farmers, then to reduce this number of causes of agro-ecological crisis to a small meaningful number. To achieve this, a two-step process was adopted. First the respondents of the study were asked to respond on the perceived severity of the causes agro-ecological crisis, then select the top most important causes (based on the mean values arranged in a descending order), and put them to factor analysis to further reduce the number of causes of agro-ecological crisis. Factor analysis was used here as a confirmatory approach. Here this same procedure is adopted for all sets of causes of agro-ecological crisis. While some of the relevant results are presented here and discussed, the rest of the results of factor analysis are added in Appendix II.

Causes of agro-ecological crisis related to rainfall

Erratic rainfall is the major cause of agro-ecological crisis in dryland agro-ecosystems. Out of the 14 causes related to rainfall, only seven were found to be perceived as more important based on the mean scores of severities of causes. Only those were taken which had a mean score of more than 2.5 (out of a maximum score of 3) for factor analysis, which is a data reduction statistical procedure through correlations of correlations.

Table 4.1.1: Mean scores of severities of rainfall related causes of agro-ecological crisis as perceived by farmer respondents n=120

S. No.	Rainfall related causes	Mean	SD	More severe	Severe	Less severe
1.	Uneven distribution of rainfall with no rain during the most important crop growth stages	2.95	0.201	115 (95.8)	5 (4.2)	0.00
2.	No rain in the mid-crop season leading to water shortages	2.89	0.312	107 (89.2)	13 (10.8)	0.00
3.	Weak monsoon winds in the beginning of the season resulting in very little rain	2.87	0.341	104 (86.7)	16 (13.3)	0.00
4.	Early withdrawal of monsoons a few days after start of rainfall	2.82	0.403	100 (83.3)	19 (15.8)	1 (.8)
5.	Lack of facilities for rain water harvesting and storage	2.77	0.419	93 (77.5)	27 (22.5)	0.00
6.	Early withdrawal of winter rains affecting rabi crops	2.60	0.509	73 (60.8)	46 (38.3)	1 (.8)
7.	Late onset of monsoons	2.58	0.629	79 (65.8)	32 (26.7)	9 (7.5)

For factor analysis, only those were taken which had a mean score of more than 2.5 (out of a maximum score of 3). Factor analysis is a data reduction statistical procedure through correlations of correlations. The purpose of this analysis was to arrive at few factors that may be meaningful and relevant.

Before proceeding with factor analysis, 7 variables were finally selected from the 14 causes after deleting those causes which had the mean values less than mean score 2.5. It is evident from the data that 7 rainfall related agro-ecological causes were judged as relatively more important by the farmers. These seven variables were inter-correlated and the variables matrix of correlation coefficients was subjected to principal component factor analysis with *varimax* rotation. The total variance explained, eigen values, number of factors extracted and the factor loadings are presented in tables and discussed here. Only the results of factor loadings are presented and the rest of the results are given in Appendix – II.

Results of Factor analysis of causes of agro-ecological crisis related to rainfall

With respect to the causes related to rainfall, the factors, and factor loadings on different causes are presented in table 4.1.2, showing the percentage of total variance explained by sought out factors.

Table 4.1.2: Factor loadings of causes related to rainfall

Causes of agro-ecological crisis related to Rainfall	Factors		
	1	2	3
Early withdrawal of monsoons a few days after start of rainfall	**0.955**	**0.001**	**-0.06**
Weak monsoon winds in the beginning of the season resulting in very little rain	**0.957**	**0.062**	**-0.01**
Lack of facilities for rain water harvesting and storage	**-0.18**	**0.801**	**0.31**
Early withdrawal of winter rains affecting rabi crops	**0.086**	**0.813**	**0.23**
Not being able to choose appropriate crops when rainfall is very low.	**-0.2**	**-0.72**	**0.405**
Late onset of monsoons	**-0.16**	**0.147**	**0.621**
No rain in the mid-crop season leading to water shortages	**-0.13**	**-0.05**	**-0.84**

The results in the table above indicate the factor loadings on each of the seven causes related to rainfall. These seven were grouped through factor analysis in three factors. Based on the causes (variables) loaded on the factor, a new name is given to the factor. Here for all the three factors the following names are given.

Factor 1: **Early withdrawal of monsoon**

Factor 2: **Lack of contingency crop-water planning**

Factor 3: **Long dry spells leading to drought**

Each of these factors, the major causes of agro-ecological crisis related to rainfall are discussed here.

1. Early withdrawal of monsoon

Under this factor two cause-variables were listed: first, *early withdrawal of monsoons a few days after start of rainfall,* and second, *weak monsoon winds in the beginning of the season resulting in very little rain.*

This factor is named ***'early withdrawal of monsoon'*** because both causes deal with very little rainfall in the early days of monsoons and sooner withdrawal. This may happen when monsoon winds are very weak, without surviving for long, and result in early withdrawal. This can be compared to infant mortality when the infant is under weight and very weak to survive.

Chronic shortage of water may result, if the rains fail early in the monsoon season, jeopardizing the future of crop fields and lives of the dryland farmers.

2. Lack of contingency crop-water planning

Under this factor three cause-variables were listed: first, *lack of facilities for rain water harvesting and storage,* second, early withdrawal of winter rains affecting rabi crops', and third, *'not being able to choose appropriate crops when rainfall is very low'*.

This factor is named ***'Lack of contingency planning'*** as the major cause of agro-ecological crisis. A dryland farmer lives with uncertainties of rainfall every season and so needs to have a plan for every contingency that may happen. If proper water harvesting structures are arranged far earlier to onset of monsoon, enough rain water gets stored and can be used for irrigating crops.

If such rainwater is harvested and stored properly during monsoon months, then this water may be used in Rabi season even if winter rains withdraw early. If these are not planned for, agro-ecological crisis may set in because water harvesting is not done to meet any future irrigation needs in next crop (*Rabi*) season.

Similarly, if rains fail or if rainfall is scanty, farmers do not have any seeds to sow or choose an appropriate crop that survives and gives a yield.

3. Long dry spells leading to drought

Under this factor two cause-variables were listed: first, '*late onset of monsoon*', and *'no rain in mid-crop season leading to water shortage'*.

These two causes have come into one factor and this factor is named *'long dry spells leading to drought'*

When the monsoon arrives late, sometimes delaying the rainy season, farmers face acute shortage of water. In dryland areas, sowing starts immediately after onset of monsoon. If the monsoon is delayed, the farmers face acute crisis of adverse agro-ecological conditions.

Next, if the rains do not fall during the essential crop growth stages, acute water shortage occurs leading to moisture stress in crop fields and psychological distress among farmers.

This factor essentially focuses on the water shortage, soil moisture stress and distress among farmers. Chronic shortage of water will adversely affect productivity of crop plants.

Results of Factor analysis of causes of agro-ecological crisis related to Ground water resources

Among the causes related to depleting ground water resources, only seven were perceived as more important based on the mean scores of severities of causes, as given in table 4.1.3. Only those were taken which had a mean score of more than 2.5 (out of a maximum score of 3) for factor analysis.

Table 4.1.3: Mean ranks of severity perceived by farmer respondents on the ground water related causes of agro-ecological crisis n=120

S. No.	Ground water related causes	Mean	SD	More severe	Severe	Less Severe
1.	Farmers have pumped out all ground water by competitive digging of bore wells. They have wasted ground water resources. They have also wasted lot of money in digging up bore wells.	2.84	0.518	109 (90.8)	3 (2.5)	8 (6.7)
2.	Life-saving irrigation is not available when necessary during a critical crop growth stage.	2.80	0.507	102 (85.0)	14 (11.7)	4 (3.3)
3.	Ground water reserves have depleted and aquifers got dried due to excessive pumping out of ground water.	2.89	0.312	107 (89.2)	13 (10.8)	0.00
4.	Early withdrawal of monsoons leading to lower quantities of ground water reserves.	2.95	3.00	115 (95.8)	5 (4.2)	0.00
5.	Lack of facilities (Water tanks) for storing rain water and allowing for recharging of aquifers under the bore wells.	2.86	0.373	104 (86.7)	15 (12.5)	1 (.8)
6.	Rain water not being able to reach deep ground water reserves	2.71	0.452	86 (71.7)	34 (28.3)	0.00
7.	Leaving away damaged check dams and other water conservation structures without regular maintenance timely repairs.	2.75	0.429	91 (75.8)	29 (24.2)	0.00

In similar manner as has been done in case of causes related to rainfall, the set of causes related to ground water resources were factor analysed and the final factor loadings are given in table 4.1.4.

Table 4.1.4: Factor loadings of causes related to ground water resources

causes related to ground water resources	Factors	
	1	2
Life-saving irrigation is not available when necessary during a critical crop growth stage.	**0.707**	**0.499**
Lack of facilities (Water tanks) for storing rain water and allowing for recharging of aquifers under the bore wells.	**0.803**	**0.096**
Leaving away damaged check dams and other water conservation structures without regular maintenance timely repairs.	**0.836**	**-0.188**
Farmers have pumped out all ground water by competitive digging of bore wells. They have wasted ground water resources. They have also wasted lot of money in digging up bore wells	**-0.123**	**0.886**
Early withdrawal of monsoons leading to lower quantities of ground water reserves.	**0.073**	**0.354**

From among seven, only five have been taken for factor analysis, because these two factors had insignificant eigen values. The results in the table above indicate the high factor loadings on each of the five causes related to ground water resources. These five causes were grouped through factor analysis in three factors. Based on the causes (variables) loaded on the factor, a new name is given to each factor. Here for all the two factors the following names are given.

Factor 1: **Neglect of pro-active interventions**

Factor 2: **Over exploitation of ground water resources without any replenishment**

Under factor 1, three cause-variables have got high factor loadings and three were: first, '*life-saving irrigation is not available when necessary during critical crop growth stages'*, second,' *lack of facilities (Water tanks) for storing rain water and allowing for recharging of aquifers under the bore wells*', and third, *'leaving away damage check dams and other water conservation structures without regular maintenance timely repairs'*. Keeping in mind the essence of these three causes, a new name is given to this factor as ***'neglect of pro-active interventions'***.

Lack of pro-active interventions has been another major cause of the agrarian crisis. While dealing with rainfall in dryland region, farmers need to be pro-active and take few actions for conserving rainfall water in water tanks so that the aquifer below bore wells get adequate supply and fill up ground water resources. Any neglect of maintenance and timely repair of soil conservation structures like check dams, ponds will lead to shortages in storage of rainfall water. Old farmers who have witnessed the construction of water conservation structures and water being stored and used, have also seen these structures being neglected and in repair and maintenance. They have particularly highlighted this as the major cause of agro-ecological crisis.

Under factor 2, two cause-variables have got high factor loadings and these were: first, *'farmers have pumped out all ground water by competitive digging of bore wells. They have wasted ground water resources. They have also wasted lot of money in digging up bore wells'* and second, *'early withdrawal of monsoons leading to lower quantities of ground water reserves'*. This factor has been given a new name: ***Over exploitation of ground water resources without any replenishment.***

The fact that ground water is limited and needs to be replenished every monsoon. Farmers, through their competitive digging of bore wells have over exploited ground water resources without saving rainfall water.

This is a major cause of agro-ecological crisis. On one hand, the ground water is over exploited. On the other hand, the ground water is not getting returned to full capacity due to inadequate rainfall, early withdrawal of monsoon.

These two causes relate to depleting ground water reserves caused by over drawing out and not depositing the ground water reserves. Both relate to unsustainable ways of dealing with ground water resources.

Results of Factor analysis of causes of agro-ecological crisis related to Soil moisture

Among the causes related to soil moisture stress, only four were found to be perceived as more important based on the mean scores of severities of causes, as given in table 4.1.5. Only those were taken which had a mean score of more than 2.5 (out of a maximum score of 3) for factor analysis.

Table 4.1.5: Mean ranks of severity perceived by farmer respondents on the soil moisture related causes of agro-ecological crisis n=120

Sl. No.	Soil moisture related causes	Mean	SD	More severe	Severe	Less severe
1.	Hot winds reduce soil moisture and lets the soil to dry up totally.	2.96	0.180	116 (96.7)	4 (3.3)	0
2.	Due to excessive weed growth, water uptake by weed and excessive evapotranspiration from foliage, soil moisture gets depleted.	2.83	0.374	100 (83.3)	20 (16.7)	0
3.	Very low relative humidity in fields	2.79	0.407	95 (79.2)	25 (20.8)	0
4.	Lack of water harvesting and storage structures in the fields	2.71	0.552	92 (76.7)	22 (18.3)	6 (5.0)

Now these four causes related to soil moisture stress were factor analysed and the final factor loadings are given in table 4.1.6.

Table 4.1.6: Factor loadings of causes related to soil moisture stress

Causes related to soil moisture stress	Factors	
	1	2
Lack of water harvesting and storage structures in the fields	**0.835**	**0.136**
Due to depletion of soil moisture, the roots of crop plants may fail to take up nutrients from dried up soil	**0.830**	**-0.101**
Hot winds reduce soil moisture and lets the soil to dry up totally.	**-0.179**	**0.749**
Due to excessive weed growth, water uptake by weeds and excessive evapotranspiration from foliage, soil moisture gets depleted.	**-0.214**	**-0.712**

Under factor 1, two cause-variables have got high factor loadings and two were: first, '*lack of water harvesting and storage structures in the fields*' and second, *'due to depletion of soil moisture, the roots of crop plants may fail to take up nutrients from dried up soil'*. Considering the key issue in these two causes, this factor is named as ***Soil moisture stress due to lack of field ponds.***

In cases of acute shortage of water during mid-season of a crop, if the water storage is available in field ponds, that will help reduce soil moisture stress. Field ponds would provide immediate access to water in cases of acute shortage. Agro-ecological conditions will be conducive and supportive to plant growth if water storage structures like water tanks, field ponds are available. Since they are not available, crop plants suffer badly due to soil moisture stress and begin withering and drying up. All this leads to poor nutrient uptake from dried up soils.

Under the factor 2, two cause-variables have got high factor loadings and two were: first, 'hot winds reduce soil moisture and lets the soil to dry up totally', and the second, *'due to excessive weed growth, water uptake by weeds and excessive evapotranspiration from foliage, soil moisture gets depleted'*. Hence this factor is named as ***'depletion of soil moisture'***.

Plants require adequate moisture in their root zones for nutrient uptake and water uptake. Keeping soil moisture intact is the most difficult job of dryland farmers. Hence conserving soil moisture is quite essential. If proper measures are not taken, hot winds exhaust soil moisture and dry up the top soil, causing severe case of moisture stress. In the same manner if the weeds are not removed in time, they draw up soil moisture in excess and through evapotranspiration from the excessive weed growth leads to soil moisture loss.

Farmers need to take proper measures to conserve soil moisture by proper mulching to avoid hot winds and removal of weeds to conserve soil moisture. Any neglect of these timely interventions leads to depletion of soil moisture causing severe moisture stress to plants and death of plants.

Results of Factor analysis of causes of agro-ecological crisis related to Soil fertility

Among the causes related to soil fertility, only nine were found to be perceived as more important based on the mean scores of severities of causes, as given in table 4.1.7. Only those were taken which had a mean score of more than 2.5 (out of a maximum score of 3) for factor analysis.

Table 4.1.7: Mean ranks of severity perceived by farmer respondents on the Soil fertility related causes of agro-ecological crisis n=120

No.	Soil fertility related causes	Mean	SD	More severe	severe	Less severe
1.	Indiscriminate use of chemical pesticides	2.91	0.342	111 (92.5)	7 (5.8)	2 (1.7)
2.	Bulk density of soil gets increased due to heavy application of chemical fertilizers. So the water absorption capacity and holding capacity of water in soil gets reduced.	2.89	0.425	112 (93.3)	3 (2.5)	5 (4.2)
3.	Due to soil erosion, soil nutrients get lost.	2.85	0.358	102 (85.0)	18 (15.0)	0.00
4.	Loss of ammonia of urea fertilizers into atmosphere.	2.85	0.496	109 (90.8)	4 (3.3)	7 (5.8)
5.	Sometimes the vegetative growth may be good due to balanced use of fertilizers. But the reproductive stage growth period reduced leading to lower yields.	2.82	0.381	99 (82.5)	21 (17.5)	0.00
6.	Loss of soil micro nutrients adversely affecting soil fertility	2.79	0.538	102 (85.0)	11 (9.2)	7 (5.8)
7.	Continuously cultivating crops without application of any farm yard manure and other organic manures.	2.78	0.433	95 (79.2)	24 (20.0)	1 (.8)
8.	Los of soil fertility due to leaching of soil nutrients into deep layers of soil	2.61	0.488	74 (61.7)	46 (38.3)	0.00
9.	Flow of polluted water in crop fields	2.57	.866	94 (78.3)	6 (5.0)	20 (16.7)

Now these nine causes related to soil fertility were factor analysed and the final factor loadings are given in table 4.1.8.

Table 4.1.8: Factor loadings of causes related to soil fertility

causes related to soil fertility	Factors		
	1	2	3
Continuously cultivating crops without application of any farm yard manure and other organic manures.	**0.911**	**0.04**	**0.108**
Loss of soil fertility due to leaching of soil nutrients into deep layers of soil	**0.626**	**0.501**	**-0.317**
Sometimes the vegetative growth may be good, but the reproductive period gets reduced leading to lower yields.	**0.867**	**-0.201**	**0.132**
Due to soil erosion, soil nutrients get lost	**0.116**	**0.883**	**-0.029**
Loss of soil micro nutrients adversely affecting soil fertility	**-0.21**	**0.693**	**0.212**
Indiscriminate use of chemical pesticides	**-0.03**	**0.115**	**0.832**
Bulk density of soil gets increased due to heavy application of chemical fertilizers. So the water absorption and holding capacity of soil gets reduced.	**0.154**	**-0.008**	**0.823**

From among nine, only seven have been taken for factor analysis, because these two factors had insignificant eigen values. The results in the table above indicate the high factor loadings on each of the seven causes related to soil fertility. These seven causes were grouped through factor analysis in three factors. Based on the causes (variables) loaded on the factor, a new name is given to each factor. Here for the two factors the following names are given.

Factor 1: **Loss in soil structure due to monoculture and chemicals leading to nutrient imbalances in soil**

Factor 2: **Loss of fertile top soil due to erosion**

Factor 3: **Ill effects of agro-chemicals on soil structure**

Under factor 1, three cause-variables have got high factor loadings and three were: first, *'indiscriminate use of chemical pesticides'* the second*, 'bulk density of soil gets increased due to heavy application of chemical fertilizers. So the water absorption and holding capacity of soil gets reduced'*, and the third, *'sometimes the vegetative growth may be good, but the reproductive period gets reduced leading to lower yields'*.

Keeping the key issues in mind, this factor is named as ***'Loss in soil structure due to chemicals, monoculture and leading to nutrient imbalances in soil'***.

Monoculture of crops without adopting any crop rotation or intercropping may result in loss in soil fertility. In the same way, loss in soil fertility may also result due to leaching of essential plant nutrients. Imbalances in plant nutrients in soil may result in excessive vegetative growth and low levels of reproductive growth leading to loss in yields and economic benefits.

Under factor 2, two cause-variables have got high factor loadings and two were: first, *'due to soil erosion, soil nutrients get lost'*, and the second, 'Loss of soil micro nutrients adversely affecting soil fertility. This factor is given a new suitable name as ***'loss of fertile top soil due to erosion'***, as it involves two causes dealing with erosion of fertile top soil. Essential micro-nutrients may get lost due to erosion of top soil, either through run-off water or through hot winds in dryland areas. Loss in essential and micro-nutrients adversely affects soil fertility.

Under factor 3, two cause-variables have got high factor loadings and two were: first, *'sometimes the vegetative growth may be good, but the reproductive stage growth period reduced leading to lower yields'*, and the second, 'Loss of soil micro nutrients adversely affecting soil fertility.

This factor may be named as ***'Ill effects of agro-chemicals on soil'***. Due to indiscriminate application of chemicals—fertilizers and pesticides, the soil structure and nutrient availability may get adversely affected.

Results of Factor analysis of causes of agro-ecological crisis related to Agronomic practices

Among the causes related to soil fertility, only seven were found to be perceived as more important based on the mean scores of severities of causes, as given in table 4.1.9. Only those were taken which had a mean score of more than 2.5 (out of a maximum score of 3) for factor analysis.

Table 4.1.9: Mean ranks of severity perceived by farmer respondents on the causes of agro-ecological crisis related to Agronomic Practices

n=120

S. No.	Causes related to Agronomic Practices	Mean	SD	More severe	severe	Less severe
1.	Completely not adopting any of the traditional cultural practices	2.95	0.218	114 (95)	6 (5.0)	0.00
2.	Not being able to efficiently using the crop residue biomass.	2.90	0.301	108 (90.0)	12 (10.0)	0.00
3.	By growing continuously same crop year after year, agro-ecosystem of the region and its ecological balance in nature gets destroyed beyond repair.	2.86	0.341	104 (86.7)	16 (13.3)-	0.00
4.	By growing same crops according to farmers' choice (without concern for natural resources) may result in stagnation or decline in crop yields	2.74	0.493	91 (75.8)	28 (23.3)	1 (.8)
5.	Growing high-water demanding crops like sugarcane and paddy, ground water resources get depleted	2.65	0.544	82 (68.3)	34 (28.3)	4 (3.3)
6.	Ground water reserves get depleted by growing commercial cash crops	2.61	0.650	85 (70.8)	24 (20.0)	11 (9.2)
7.	Not being able to go for mulching with the weed grasses pulled out and covering soil to protect soil from heating up losing soil moisture.	2.57	0.720	81 (67.5)	23 (19.2)	16 (13.3)

Now these seven causes related to agronomic properties were factor analysed and the final factor loadings are given in table 4.1.10.

Table 4.1.10: Factor loadings of causes related to agronomic practices

Causes related to agronomic practices	Factors	
	1	2
By growing continuously same crop year after year, agro-ecosystem of the region and its ecological balance in nature gets destroyed beyond repair.	**0.923**	**0.03**
Not being able to go for mulching with the weed grasses pulled out and covering soil to protect soil from heating up losing soil moisture.	**0.944**	**0.011**
Not being able to efficiently using the crop residue biomass.	**0.295**	**0.866**
By growing same crops according to farmers' choice (without concern for natural resources) may result in stagnation or decline in crop yields	**-0.22**	**0.896**

From among seven, only four have been taken for factor analysis, because these three factors had insignificant eigen values. The results in the table above indicate the high factor loadings on each of the seven causes related to soil fertility. These seven causes were grouped through factor analysis in three factors. Based on the causes (variables) loaded on the factor, a new name is given to each factor. Here for the two factors the following names are given.

Factor 1: **Destruction of agro-ecological aspects of crop fields**

Factor 2: **Neglect of crop residue incorporation in farm fields**

Under factor 1, two cause-variables have got high factor loadings and two were: first, *'by growing continuously same crop year after year, agro-ecosystem of the region and its ecological balance in nature gets destroyed beyond repair'*, and the second, *'not being able to go for mulching with the weed grasses pulled out and covering soil to protect soil from heating up losing soil moisture'*. These two were bad practices in cultivating crops and so this factor is named as ***'destruction of agro-ecological aspects of crop fields'***.

Destruction of agro-ecosystem may be the right name to represent these two causes. Due to greed, farmers have been cultivating aggressively the same cash crops every year and exploiting their crop fields excessively without even taking action or giving time for the agro-ecosystem to recover and repair itself. So the agro-ecology of the crop fields get destroyed beyond repair.

In addition, crop residues are being burnt away (causing air pollution) and not incorporating into soils. Farmers have stopped to understand the real worth of crop residue biomass for nurturing micro flora in the soil and for restoring soil structure and soil physical properties beneficial to crop growth.

Under factor 2, two cause-variables have got high factor loadings and two were: first, *'not being able to efficiently using the crop residue biomass'*, and the second, *'by growing same crops according to farmers' choice (without concern for natural resources) may result in stagnation or decline in crop yields'*. This factor is given a suitable new name as ***'Neglect of crop residue incorporation in farm fields'***.

This factor assumes great significance in the context of agro-ecological principles of recycling wastes into the agro-ecosystem, which enables restoration and recuperation processes of regeneration of the agro-ecosystem.

By nature, farming systems have some in-built mechanisms of interactions and bio-resource flows between farm components (recycling of crop residues and manure, effective use of biomass, complementarities between plants, and level of natural pest control. When this crucial aspect of crop residue incorporation is ignored and neglected, the agro-ecosystems suffer losses and degenerate over a period of time and result in contributing to agro-ecological crisis.

Incorporation of crop residues back into crop fields has its own benefits in the long run. As the organic biomass in the soil gets enticed, the formation of humus and subsequent chemical reactions would help enhance the soil fertility levels especially that of organic carbon content of the soils. With this incorporation, soil micro-flora and fauna would be biologically active in soil and thereby the soil structure is maintained.

Results of Factor analysis of causes of agro-ecological crisis related to other important causes

Among the causes related to other important causes, only five were found to be perceived as more important based on the mean scores of severities of causes, as given in table 4.1.11. Only those were taken which had a mean score of more than 2.5 (out of a maximum score of 3) for factor analysis.

Table 4.1.11: Mean ranks of severity perceived by farmer respondents on the other important causes of agro-ecological crisis *viz,* market prices, agroforestry, nature of ecological balance n=120

s. No.	Other important causes	Mean	SD	More severe	Severe	Less severe
1.	Cutting down trees on the field bunds cutting down trees of forests in the neighboring areas.	2.85	0.358	102 (85.0)	18 (15.0)	0.00
2.	Reduction in total rainfall due to cutting down and removal of forests	2.95	0.218	114 (95.0)	6 (5.0)	0.00
3.	The prices at which framers sell their crop produce are not decide by themselves but by the buyers	2.83	0.374	100 (83.3)	20 (16.7)	0.00
4.	The prices at which farmers buy their inputs for agriculture are decided by the sellers and not by the farmers.	2.83	0.374	100 (83.3)	20 (16.7)	0.00
5.	Occurrence of imbalance in nature of proportion of harmful and beneficial insects and other animal populations.	2.62	0.675	87 (72.5)	20 (16.7)	13 (10.8)

Now these five other important causes of agro-ecological crisis, were factor analysed and the final factor loadings are given in table 4.1.12.

Table 4.1.12: Factor loadings of other important causes of agro-ecological crisis

other important causes of agro-ecological crisis	Factors	
	1	2
The prices at which farmers sell their crops produce are not decided by themselves but by buyers.	**0.916**	**-0.019**
The price at which farmers buy their inputs for agriculture are decided by the sellers and not by themselves	**0.906**	**0.041**
Cutting down trees on the field bunds cutting down trees of forests in the neighboring areas.	**-0.226**	**-0.748**
Occurrence of imbalance in nature of proportion of harmful and beneficial insects and other animal populations.	**-0.199**	**0.781**

From among five, only four have been taken for factor analysis, because one factors had insignificant eigen value. The results in the table above indicate the high factor loadings on each of the four other important causes of agro-ecological crisis. These four causes were grouped through factor analysis in three factors. Based on the causes (variables) loaded on the factor, a new name is given to each factor. Here for the two factors the following names are given.

Factor 1: Non-supportive prices and exploitative market forces

Factor 2: Destabilizing ecological balance in nature

Under factor 1, two cause-variables have got high factor loadings and two were: first, *'the prices at which farmers sell their crops produce are not decided by themselves but by buyers'*, and the second, *'the price at which farmers buy their inputs for agriculture are decided by the sellers and not by themselves'*. Both of these causes relate to exploitative market forces and so this factor is named as *'n**on-supportive prices and exploitative market forces'***

This is strange fact that farmers get exploited at both ends. They buy inputs in retail from input dealers and retail shops at high retail prices and not from wholesale markets at cheaper wholesale prices. In the same manner, they get exploited by wholesale merchants and traders in whole sale markets where they go to sell their crop produce. Here too, sellers decide the price at which to buy from farmers. These prices are not supportive and the market forces are highly exploitative. All the struggle that a farmer undergoes to cultivate a good crop facing vagaries of monsoon and sweating in fields goes in vain. This is one of the most important causes of distress among farmers and agro-ecological crisis. The agro-economic sub-system, a part of agro-ecosystem of farmers was perceived as non-supportive and exploitative by these dryland farmers.

Under factor 2, two cause-variables have got high factor loadings and two were: first, 'cutting down trees on the field bunds cutting down trees of forests in the neighbouring areas' and the second, *'reduction in total rainfall due to cutting down and removal of forests'*. / Both these causes relate to health of agro-ecosystems, especially of agro-forestry and maintaining ecological balance of pests and predators in Nature, especially in agro-ecosystems of crop fields and so this factor is named as ***'destabilizing ecological balance in nature'***

Thus, all the causes of agro-ecological crisis faced by farmers were analysed and the results have succinctly brought the major causes of the agro-ecological crisis. In fact, afro-ecology, if not taken care of at every step may become vulnerable and gradually may get destroyed. The agro-ecological conditions prevailing in crop fields with open well, field ponds, water tanks, large water reservoirs have gradually been neglected and allowed to die slowly, with silting up of open wells, ponds, tanks resulting poor water storage capacity. Hence over flowing got resulted in leakages and wastages. The water conservation structures like check dams and ponds have been neglected resulting poor percolation into the soil. With increased run off water causing soil erosion has resulted in loss of fertile top soil and along with it the essential and micro-nutrients. With complete neglect of agro-ecosystems, the problems got aggravated and compounded and completely destroyed natural resources of agro-ecosystems of dryland regions. The most essential resources got depleted: the rain water, soil fertility and micro-nutrients. Hence, the corrective measures started with understanding the hydrological cycle, ways of water harvesting, saving and

Discussion on the results of analysis of causes of agro-ecological crisis

A list of causes was prepared through focused group discussion, categorized into different sets of causes related to erratic rainfall, causes related to depleting ground water, causes related to depleting soil moisture, causes related to declining soil fertility, and those related to conservative agronomic practices and other causes related to adverse market prices, deteriorating agroforestry and agro-ecological balance in Nature. Then farmers' perception of severity of these causes was sought on a three-point continuum of more severe, severe and less severe were analysed.

First the causes were screened by deleting the causes which had mean scores less than 2.5 from this most important causes, two to three factors were derived from each set of causes through factor analysis. These factors were given a new name as the major cause being represented by the causes.

Finally, the major *cause-factors* that emerged were fourteen reduced through factor analysis of 31 causes perceived as *most important* from the initial list of 56 causes collected from focused group discussion. They are:

Factor 1:	Early withdrawal of monsoons
Factor 2:	Lack of contingency crop-water planning
Factor 3:	Long dry spells leading to drought
Factor 4:	Neglect of pro-active intervention
Factor 5:	Over exploitation of ground water resources without any replenishment
Factor 6:	Soil moisture stress due to lack of field ponds
Factor 7:	Depletion of soil moisture
Factor 8:	Loss in soil structure due to monoculture and chemicals leading to nutrient imbalances in soil
Factor 9:	Loss of fertile top soil due to erosion
Factor 10:	Ill effects of agro-chemicals on soil structure
Factor 11:	Destruction of agro-ecological aspects of crop fields
Factor 12:	Neglect of crop residue incorporation in farm fields
Factor 13:	Non-supportive and exploitative market prices and market forces
Factor 14:	Destabilizing ecological balance in nature

A cursory look into the causes of agro-ecological crisis listed above would reveal that these causes were essentially due to *'man-made errors'* to *Mother Nature* and complete neglect of any pro-active ameliorative measures for recuperative and regenerative farming systems.

It is the greed and unthoughtful interventions of man that led to destruction of precarious agro-ecosystems in dryland farming systems. complete neglect of pro-active interventions, and timely actions of water harvesting have further worsened the situation that the agro-ecosystem got destroyed beyond repair jeopardizing the very survival and livelihoods of dryland farmers and their families.

All the causes are again intercalated and further aggravated leading to agro-ecological crisis in dryland agro-ecosystems.

4.2 Profile characteristics of farmers' respondents

All the respondents of this study are dryland farmers and members of water sharing groups. However, they may vary in their socio-personal characteristics. Hence, the socio-personal, socio-economic and socio-psychological characteristics of the respondents are presented here.

Membership in water sharing groups: To begin with, it has been found that all the respondent farmers were members of water sharing associations and their distribution across the villages is given in Table 4.2.1 below.

Table 4.2.1: Distribution of respondents from different selected mandals, villages and water sharing groups in Ananthapur district n=120

Villages in Three Mandals of Ananthapur	Name of Water Sharing Group	Bore well Owners	Non-Owners of Bore well	Total
Gandlapenta Mandal				
1. Karnamwaripalli	Srinivasa Ummadi Neeti Yajamanya Sangham	4	12	16
2. Kumarwandlapalli	Kolugunti Ummadi Neeti Yajamanya Sangham	2	10	12
3. Narasappagaripalli	Mallikaada Ummadi Neeti Yajamanya Sangham	2	9	11
4. Kamathampalli	Khadri Susthira Bhugarbha jala Yaajamaanya Sangham	4	19	23
Kadiri Mandal				
1. Patnam	Ganga Bhawani Ummadi Neeti Yajamanya Sangham	2	12	14
Nallacheruvu Mandal				
1. Padllewaldlapalli	Chinnamarapu Ummadi Neeti Yajamanya Sangham	2	14	16
2. Bodnepalli	Udumbanda Ummadi Neeti Yajamanya Sangham	2	16	18
3. Devireddypalli	Takkillagadda Raithu Sangham	2	8	10
Total	**Eight Societies**	**20**	**100**	**120**

As can be seen from the results, from among three mandals, eight water sharing societies were found, one in each village. Interesting fact was that from among the 120 farmers, only 20 farmers owned bore well and 100 farmer respondents were not owning any bore wells. This shows that the all the farmers came together to form water sharing groups and thereby get mutual benefits. Twenty bore well owning farmers have vowed to provide protective irrigation to all 100 farmers when rains may fail and crops are in dire need of a live saving irrigation.

Age: The age of the respondents was recorded in completed years and the data were analysed and the results are presented in Table 4.2.2

Table 4.2.2: Distribution of farmer respondents on their age

Age of Respondents	**N=120**	
Mean	47.44	
Standard Deviation	1.17	
Range	26 - 75	
Frequency Distribution	**Frequency**	**Percent**
Young (< 35 years)	23	19.20
Middle aged Between 36 & 50 years	47	39.16
Old (>51 years)	50	41.64
Total	**120**	**100.00**

It can be seen from the results in the Table 4.2.2, the mean age of farmer respondents was 47.44 years. The standard deviation was 1.17; indicating the consistency of respondents on their age. The frequency distribution appears to be skewed towards the old age of respondents. About 41.64 percent of respondents were older and the 39.16 percent were middle aged. The mean was also representing middle aged respondents. Very few were young (19.2 percent) farmers.

Sex: Sex of respondents was categorized on nominal level as male and female. Although only 6.7 percent of the respondents were women members, in general most of the women were found to take active role in water sharing group's meetings and activities.

Table 4.2.3: Distribution of farmer respondents on sex

Gender	**Frequency**	**Percent**
Men	112	93.3
Women	8	6.7
Total	120	100.0

Educational Status: Formal education plays a significant role in comprehension of the basic principles involved in sustainable agriculture. Here the educational status of farmer respondents was recorded and analysed. The results are presented in Table 4.2.4.

Table 4.2.4: Distribution of farmer respondents on Educational Status

Category	Code	Frequency	Percent
Illiterate	0	34	28.3
Primary	1	42	35.0
High School	2	31	25.8
Intermediate	3	2	1.7
Degree	4	2	1.7
Diploma	5	9	7.5
Total		**120**	**100.0**

As can be seen from the results, 35.0 percent of the farmer respondents were educated up to primary level, while nearly 26 percent completed high school education. And only10 percent studied beyond. About 28 percent farmers were illiterates.

Family type: The family type of respondents was categorized on nominal level as nuclear and joint family. The results are presented in table 4.2.5

Table 4.2.5: Distribution of farmer respondents on family type

Family type	Code	Frequency	percent
Nuclear	1	44	36.66
Joint	2	76	63.3
Total		**120**	**100.0**

As can be seen from the results about 63 percent of farmer respondents lived in joint families. This is a normal feature in dryland areas, where in large number of family labour is used in cultivating crops. So here too, joint families provided family labour.

***Family size**:* Family size was measured in terms of number of people living in the family. The results are given in Table 4.2.6. As evident from the results, nearly 72 percent of farmer respondents lived in medium families of 4 t0 6 members.

Table 4.2.6: Distribution of farmer respondents on family size

No.	Family Size	Size	Frequency	percent
1	<3 members	Small	33	27.5
2	4-6 members	Medium	86	71.7
3	>7 members	Large	1	.8
	Total		**120**	**100.0**

Farming experience: Experience in farming was recorded in total number of years that the farmer was practicing farming as a vocation. The farmers were categorized and their frequency distribution is presented in Table 4.2.7.

Table 4.2.7: Distribution of farmer respondents on farming experience

Sl. No.	Experience in cultivation	Code	Frequency	percent
1.	> 10year	1	14	11.7
2	10-20years	2	29	11.8
3	20-30 years	3	32	35.1
4	30-40 years	4	24	31.7
5	>40 years	5	21	10.7
	Total		**120**	**100**

As can be seen from the results in the Table 4.2.7, the frequency distribution appears to be following normal distribution. About 35 percent of the farmers had 20-30 years of farming experience and 31.7 percent had 30-40 years of farming experience. The result that about 77 percent farmers having more than 20 years of farming experience can be seen as beneficial to the water sharing groups because their vast experience would guide the group's functioning effectively.

Irrigated land: The data on land holdings were analysed and the results are presented in table 4.2.8**.** As can be seen from the results, about 60 percent were small farmers. Nearly 11 percent were marginal farmers possessing irrigated land of less than one hectare. Another 27.6 percent were semi-medium farmers possessing 2-4 hectares of irrigated drylands. Only 10 percent were medium farmers.

Table 4.2.8: Distribution of farmer respondents on irrigated land

Sl. No.	Farmers' category	Range in ha	Frequency	Percent
1	Marginal farmers	< 1	13	10.8
2	Small farmers	1 - 2	72	60.0
3	Semi-medium farmers	2 - 4	23	27.4
4	Medium farmers	> 4	12	10.0
Total			**120**	**100**

Dryland: The dryland owned and cultivated has also been recorded and the data were analysed to know the dryland owned as well as cultivated by farmers. The results are given in Table 4.2.9. As can be seen from the results, about 56.7 percent farmers were small, with land possession of 1 - 2 ha. About 33 percent were semi-medium farmers, with 2 – 3 hectares of dryland cultivated as only rainfed.

Table 4.2.9: Distribution of farmer respondents on dryland

Sl. No.	Farmers category	Range in ha	Frequency	Percent
1	Marginal farmers	< 1	7	5.8
2	Small farmers	1 - 2	68	56.7
3	Semi-medium farmers	2 - 4	41	33.3
4	Medium farmers	> 4	4	4.2
Total			**120**	**100**

About 56 percent of the respondents were small farmers possessing 1-2 hectares of rainfed drylands. About 90 percent of them were found to cultivate crops in drylands only at the mercy of rains.

Orchard land: The orchard land owned was recorded and analysed to know the ownership of orchard land by the farmers. The results are given in Table 4.2.10.

Table 4.2.10: Distribution of farmer respondents on orchard land

Sl. no.	Farmers category	Range in ha	Frequency	Percent
1	Marginal farmers	< 1	107	89.2
2	Small farmers	1 - 2	9	7.5
3	Semi-medium farmers	2 - 4	3	2.5
4	Medium farmers	> 4	1	.8
Total			**120**	**100**

About 89 percent of farmer respondents owned orchard land of less than one hectare. Orchards with mango trees, although small, were owned by all the farmers.

Total annual income: It was measured in the actual terms as income in rupees per year. The sources of income were field crops: ground nut, sorghum, pigeon pea, tomatoes, etc. Most of the farmers get considerable income from livestock including cows, goats, sheep and poultry. The results are given in Table 4.2.11,

As can be seen from the results in the Table 4.2.11, mean income of farmer respondents was Rs.84750 rupees and the standard deviation was 35490, which indicates wide variation in the incomes of these farmer respondents. In fact, the incomes ranged from as low as Rs. 30,000 to as high as Rs.3, 60,000 per annum.

Table 4.2.11: Distribution of farmer respondents on Total Annual Income

Total income of Respondents (Rs.)	**N=120**	
Mean	84,750	
Standard Deviation	35,490	
Range	30,000 – 3, 60,000	
Frequency Distribution	**Frequency**	**Percent**
Very low (30,000 – 50,000)	10	8.33
Low (51,000 - 70,000)	46	38.33
Middle (71,000 - 90,000)	31	25.83
High (91000-1,11,000)	16	13.33
Moderately high (1,11,000 – 1,30,000)	12	10.00
Very High >1,31,000)	5	4.17
Total	**120**	**100**

About 38 percent of farmers were earning annual incomes between Rs. 51,000 and Rs. 70,000, while nearly 26 percent were earning incomes between Rs. 71,000 and Rs. 90,000. Thus nearly 72 percent of these farmers were earning less than one lakh rupees per annum. Only 27 percent of them were earning more than a lakh of rupees as annual income.

Frequency of Contact with Personal Localite Channels: The frequency of contact with various localite channels (neighbours, friends and relatives and local leaders) was recorded using a schedule and the data were analysed and the results are given in Table 4.2.12.

Table 4.2.12: Distribution of farmer respondents on Frequency of Contact with Personal Localite Channels

Personal Localite channels	**Frequency of Contact / Exposure**			
	Most often	**Often**	**Sometimes**	**Never**
1. Neighbours	34 (28.33)	86 (70.00)	0	0
2. Friends / Relatives	10 (8.33)	110 (91.67)	0	0
3. Opinion Leaders	0	10 (8.33)	20 (16.67)	90 (75.00)

It can be seen from the results, the neighbours, friends and relatives were most sought after personal localite channels of communication. About 86 percent of respondents *often* contacted neighbours, while 34 percent of them contacted neighbours *most often* for communicating purposes. With respect to contacting friends and relatives, about 91 percent of respondents contacted them often. Only 25 percent of the farmer respondents contacted sometimes or often with local opinion leaders. Thus neighbours, friends and relatives were the personal localite channels of contact *often* preferred by the farmers

Frequency of Contact with Cosmopolite Channels: The frequency of contact with various cosmopolite communication channels was recorded using a schedule and the data were analysed and the results are given in Table 4.2.13.

Table 4.2.13: Distribution of farmer respondents on Frequency of Contact with Cosmopolite Channels

Cosmopolite channels	Frequency of Contact / Exposure			
	Most often	Often	Sometimes	Never
1. V.L.W.	0	2 (1.6)	0	118 (98.3)
2. A.D.O	5 (4.2)	74 61.7	27 (22.5)	14 (11.7)
3. B.D.O.	20 (16.7)	66 (55.0)	7 (5.8)	27 (22.5)
4. Cooperative official	2 (1.7)	6 (5.0)	0	108 (90.0)
5. Expert from research	2 (1.7)	6 (5.0)	0	112 (93.3)
6. ATMA	0	15 (12.5)	22 (18.3)	83 (69.2)
7. KVK	2 (1.7)	0	29 (24.2)	89 (74.2)
8. NGO	84 (70.0)	33 (27.5)	0	3 (2.5)
9. Community Resource Persons	56 (46.7)	32 (26.7)	32 (26.7)	0

Among various cosmopolite channels, farmer respondents were found to contact '*often*' the A.D.O., B.D.O., mostly for purpose of getting approvals of the water sharing group's plans and project works for subsidy. V.L.W., officials from cooperatives, experts from research organisations, K.V.K., and ATMA were never met by most of the respondents. However, staff of NGO and community resource persons (CRPs) were contacted '*most often*'. The reason for contacting more often these local people was these two sets of persons were the real grassroots level personnel who had persuaded them to form into water sharing groups. In addition, these people have appraised the farmers of the current critical scenario of water shortages, mistakes done earlier and taught them all the water management innovations.

Frequency of Contact with Mass Communication Channels: The frequency of use of various mass communication sources was recorded using a schedule and the data were analysed and the results are given in Table 4.2.14.

Table 4.2.14: Distribution of farmer respondents on Frequency of Contact with Mass Communication Channels

Mass Communication Channels	Frequency of Contact / Exposure			
	Most often (4)	Often (3)	Sometimes (2)	Never (0)
1. Newspaper	33 (27.5)	5	1 (0.8)	81 (67.5)
2. Radio	0	0	1 (0.8)	119 (99.2)
3. T.V.	62 (51.4)	23 (19.2)	0	35 (29.2)
4. Pamphlet/Bulletin etc.	11 (9.2)	7 (5.8)	29 (24.2)	73 (60.8)
5. *Krishi Mela*/Exhibitions	20 (16.7)	41 (35.2)	2 (1.7)	57 (47.5)
6. Group Meetings	81 (67.5)	7 (5.8)	0	32 (26.7)

As evident from the results on contact with mass communication channels, majority of the farmers were found to be never reading newspapers, not listening to radio and not reading any pamphlets or bulletins. However, they were found to be watching television 'most often'. Some of them were found to be visiting exhibitions and *kisna melas*. However, with respect to group meetings at village and Mandal levels, majority of farmer respondents were found to be attending 'most often' as the meetings were dealt with water related issues, problems and solutions.

Socio-psychological Characteristics of Farmer Respondents

Three variables under this category were chosen for this study: goal commitment, social capital and respondent's adherence to social norms.

Goal commitment: Goal commitment is the most important socio-psychological variable of the study. In this study, commitment of the farmer respondents towards the goal of water sharing groups was studied using a scale developed by Singh (1998). The scale consisted of 6 questions and the possible answers were scored on a three-point continuum of agreement or disagreement, with scores of 2, 1, and 0. The results are given in Table 4.2.15.

Table 4.2.15: Distribution of farmer respondents on Goal Commitment

Goal commitment of Respondents		**N=120**
Mean	6.24	
Standard Deviation	1.365	
Range	4 - 8	
Frequency Distribution	Frequency	Percent
Low Medium High	51 28 41	42.5 23.7 34.2
Total	**120**	**100.00**

As can be seen from the results in the Table 4.2.15, mean goal commitment of farmer respondents was 6.24. The standard deviation was 1.365; which indicates consistency among the respondents on their goal commitment. The frequency distribution appears to be slightly skewed towards low goal commitment scores of the group. About 42 percent of respondents possessed low level of goal commitment, while 34 percent of them possessed high level of goal commitment.

Social Capital: "Social capital is founded upon shared beliefs, norms and values depending upon trust existing between the actors involved" For measuring social capital, three components *i.e.,* faith, norms and social interactions among the members of a group. This was measured using a schedule developed for the study. The results of data analysis are given in. Table 4.2.16.

Table 4.2.16: Distribution of farmer respondents on Social Capital

Social capital Respondents		**N=120**
Mean	66.69	
Standard Deviation	6.105	
Range	53 - 83	
Frequency Distribution	Frequency	Percent
Very Low	1	0.8
Low	16	13.33
Medium	83	69.17
High	11	9.18
Very High	9	7.6
Total	**120**	**100.00**

It can be seen from the results in the Table, mean social capital of farmer respondents was 66.69. The standard deviation was 6.105 indicating wide variation (from 53 to 83) among the respondents on their social capital scores. The frequency distribution appears to fallow normal distribution, although slightly skewed towards higher scores. About 69 percent of respondents possessed moderate levels of social capital. About 16 percent of them were having high level of social capital, while another 14 percent of them had low levels of social capital.

Social Norms: The water sharing groups were formed with an understanding that all the member farmers would comply with the norms set up by the water sharing group. Here the compliance of respondents with the social norms was measured

Compliance to social norms refers to the degree to which a farmer adheres to group-held beliefs and values and the degree to which his or her community or society approves his or her behaviour. A total of 9 statements were developed to measure the given variable in a five-point continuum of agreement or disagreement. The maximum possible score was 45 and the minimum was 9. The data were analysed and the results are given in Table 4.2.17.

It can be seen from the results that mean score of adherence to social norms of farmer respondents was 27.73. The standard deviation was 1.998, which indicates consistency among the respondents on their degree of adherence to social norms. The frequency distribution appears to be slightly skewed towards the low social norms category of respondents.

Table 4.2.17: Distribution of farmer respondents on Social Norms

Compliance Social Norms of Respondents		**N=120**
Mean	27.73	
Standard Deviation	1.998	
Range	24 - 31	
Frequency Distribution	**Frequency**	**Percent**
Low	13	10.8
Medium	83	69.16
High	24	20.0
Total	**120**	**100.00**

About 69 percent of respondents were moderately adhering to social norms. About 20 percent farmers' level of adherence to social norms was high. However, about 10 percent were found to be low on adherence to social norms.

Discussion

The sample of respondents were dryland farmers and are members of water sharing groups. Out of 120 farmer respondents, 100 were not owning any bore well, and only 20 farmers owned bore wells. All the farmers were sharing rain water for growing irrigated crops. About 40 percent of farmers were middle aged and another 40 percent were old. Only 25 percent attended high school, while 35 percent could attend only primary school. Another 28 percent of them were illiterate. About 42 percent of farmers were practicing dryland farming for 30-40 years. They have survived many years in drylands and possessed ways of coping with vagaries of monsoon.

About 60 percent of the respondents were small farmers possessing and cultivating 1-2 hectares of irrigated lands. About 56 percent of them were small farmers with rainfed drylands. Almost all of them possessed small orchards with mango tress. The average annual income was Rs. 85000, while 64 percent of them had annual incomes ranging between fifty and ninety thousands of rupees. About 63 percent of them were living in medium sized joint families. Joint family system was one of the key characteristics of farming families in drylands. Large joint families provide a considerable amount of family labour required for dryland farming systems.

With respect to their contact with localite channels, neighbours friends and relatives were often contacted for information. Among the cosmopolite channels, their contact was limited to *'very often'* contact with only NGO activists and the community resource persons. With respect to their contact with mass communication channels, television and group meetings were *'often'* contacted.

Among the socio-psychological characteristics of farmers, goal commitment of the farmer respondents was at moderate level. Social capital among the water sharing farmers was moderate to high and their adherence to social norms was also at moderate level.

Thus it can be concluded that the profile of farmers appears to be at medium levels on all the socio-personal variables of the study.

4.3 Water Management Innovations in Sustainable Agriculture

In order to address the second objective of this study: *'to document and analyse the water harvesting, water sharing and water management practices in sustainable agriculture'*, a narrative approach was followed to record the process of innovation generation of these water harvesting, sharing and management innovations by the stakeholders (farmers, NGO activists and government officials). One case study on institutional innovation of water sharing group was also written by using qualitative from in-depth interviews.

The innovations of water harvesting, sharing, using and managing within an agro-ecosystem are recorded and presented here and a critique is also written on the uniqueness of these innovations along with their merits and demerits.

Innovation Development Process

An old saying can be quoted here: *'Necessity is the Mother of Invention!'* This is the starting point of innovation development. As all the farmers have had faced severe cases of water crisis, crop losses and were victims of psychological distress, they began to understand their plight and the actively participated in the discussions held by NGO activists in the group meetings in the villages. They could gather all the lost wisdom of farming with open wells and farm ponds, and the way they took care of check dams and other water conservation structures. The solutions started emerging and getting refined

Man has been inventing new things based on what is needed at the time. Need is the first step in innovation development process. Farmers too have evolved innovations and new practices only to solve an immediate problem.

In this study, dryland farmers for have evolved few innovations on water management since water is most essential component of the agricultural livelihood of dryland farmers.

Non-governmental organisations working in the villages of the dryland areas have helped the farmers to face on the problems, the causes and processes of degradation of their agro-ecosystems. During the meetings, some farmers started narrating the way water was stored in water reservoirs, the way the soil and water conservation structures were built, maintained well. They have also narrated the cases of sheer neglect of these water conservation measures over a period of time that led to current crisis.

Many farmers have admitted that they have wasted lot of water to flood irrigation, growing water-hungry crops and depleted their own aquifers. Competitively digging of bore wells has not only depleted whatever water in left in the ground but resulted in loss of money invented in dried up bore wells.

Water Management Innovations

A. Water harvesting: Innovations practiced by farmers

1. Recharge pits (material-stones, sand layer)
2. Slug test (water table measuring test)
3. Soaking pits
4. De-silting (farm ponds, water tanks, reservoirs, deep open well)
5. Stone layering (stone pellets)
6. Deep trenches across slope

B. Water saving: Innovations practiced by farmers

1. Renovated farm pond (water harvested after renovation)
2. Renovated bund of water body (water harvested after renovation)
3. Surface water saving
4. Ground water saving

C. Micro-irrigation: Innovations practiced by farmers

1. Drip irrigation
2. Sprinkler irrigation

D. Conservation Agronomic practices: Innovations practiced by farmers

1. Soil mulching
2. Intercultural operation (sowing in line)
3. Mixed cropping
4. Intercropping

E. Water Sharing Institutional Innovations

Plate II

Initial formation of sangham

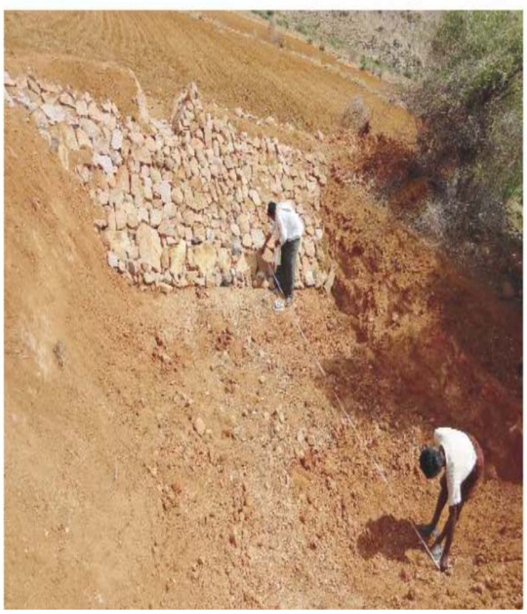
Sangham discussing action plans

Office of the sangham in kamthampalli of Gandlepenta district

Kadri Susthira Bhugarbha jala Yaajamaanya Sangham at Kamathampalli

Plate III

Water level measurement in borewell by using a water level indicator



Renovated to recharge

Sprinklers under water sharing groups in devereddy palli

Plate IV

Different materials filled in the recharge pit viz. stones, neylon net, gravel

Plate V

A pit around the existing bore well is filled with charcoal filler material

A pit around the existing bore well is filled with stone pellet filler material

Small slot made on the casing pipe to allow rainwater to enter into borewell

Recharge structure to agriculture well

Innovative borewell recharge technique

Plate VI

Construction of a recharge structure around existing bore well

Bore well recharge structure for functional agriculture wells

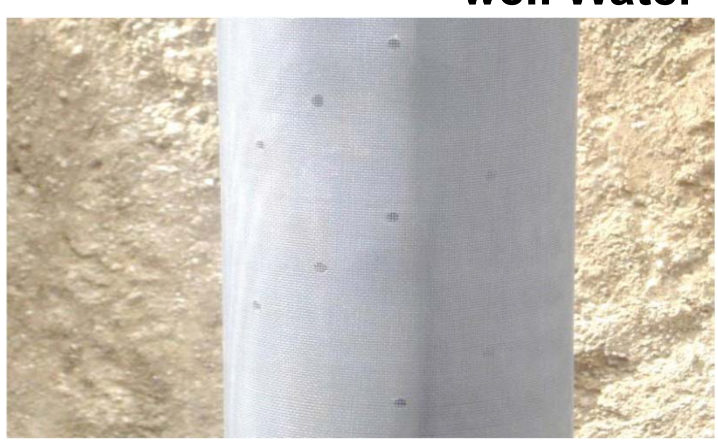
Rainwater harvesting through direct bore well recharge

Plate VII

A pit around the existing bore well is filled with filter material

A pit around the existing bore well is filled with filter material

Renovated bund of a Small holes made on the casing pipe to allow rainwater to enter the bore well Water



A completed recharge structure

Plate XI

Dry bore wells

Borewells recharge technique

Recharge pit

Casing piepe

Plate X

De-silting

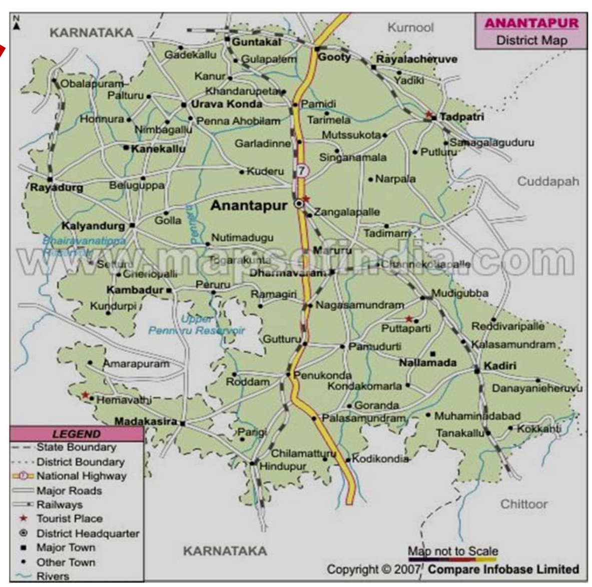
Application of sand in agricultural land

Renovated farm pond

Water harvested after renovation

Renovation of traditional water harvesting structure

Selected district of Andhra Pradesh: Ananthapur



Anantapur district

Fig. 3.1 Maps showing the study area of the research investigation

Water Harvesting and Saving Innovations

These practices solve the serious problems related to fast depletion of ground water resources and deterioration of its quality in the dryland agriculture. The majority of farmers depend mainly on bore wells for irrigation purposes. Due to increase in well density and over-exploitation of groundwater through bore wells, many functional wells were found to be giving poor yields and some were turning dry. The farmers, the NGOs have been applying many water harvesting technologies such as restoration of traditional water bodies, gully control, construction of check dams, percolation tanks, Recharge pits (with layers of stones, sand, soil), Slug test (water table measuring test), Soaking pits, De-silting, Stone layering (with stone pellets), Deep trenches across slopes, etc., for recharging groundwater.

Notions that farmers held earlier

There was a mindset among the people that if one's bore well was not yielding sufficient water, his/her alternative option was to drill a new bore well. But most of the times, this kind of approach ended up in big financial losses to the farmers and even suicides.

Recharge pits: Innovative recharge technique is a relatively new technique which is used for directly recharging the functional bore wells and/or abandoned bore wells. Instead of drilling new bore wells in water scarce regions, direct recharging of poorly yielding bore wells or bore wells in depleted groundwater zones yields better results. The main output from this simple technology is immediate improvement of water levels in the bore wells and improved water quality. A recharge pit dug around the bore-well depends upon the dimension of borewell.

Slug test (water table measuring test): As has been explained by farmers of Ananthapur district, it is a test done for measuring of water table. The device used is known as water level indicator. The process of measuring the water table includes dropping an electronic based device into the bore well and when it goes inside the bore-well and touches the layer of water present, it would start giving beep sound. A meter on the indicator represents water level present in the bore well at that time. Based upon the water level farmers go for either drip irrigation or sprinkler irrigation.

Soaking pits: By using soaking pits, rain water, without getting wasted as run off, slowly percolates into the soil and gets gathered in the ground water aquifers and thereby increasing our ground water resources.

De-silting: De-silting is the process of removing silt deposited from the water storage structures: farm ponds, water tanks and large water reservoirs, deep open wells so that all water bodies get renewed.

In fact, over a period of time, the soil, silt and sand coming with run-off rain water gets deposited at the bottom of the water bodies and reduces the storage capacity of the tank. In addition, the silt deposited at the bottom of the water bodies plugs all the holes in the tank and does not allow any water to percolate into deeper layers of the ground. If the water in water bodies percolates into deeper layers of soil, ground water accumulation occurs, thereby recharging ground water aquifers. Another benefit of de-silting can be seen in the way farmers apply the se-silted soil in their own fields for good soil enrichment, as silt is found to be enhancing soil structure and soil fertility in drylands.

Stone layering (with stone pellets): Stone layering is a process laying stones at the bottom of the water bodies, after de-silting is done. This is done by using stone pellets for ground water recharge. Stone layering is also done on the sloping bunds of tanks, ponds and reservoirs as well for checking tank bund breaks and avoiding erosion of sloping soil bunds of tanks.

Dried up big deep open wells are also repaired by digging out the silt deposited at the bottom and covered with stone pellets for increasing percolation and water holding capacity.

Deep trenches (across slopes): Farmers practicing agriculture in the catchment areas where run off (water) is very high due to uneven soil topography, face twin problems of losing run-rain water at high speeds and also the fertile top soil, which gets eroded in the process. Hence, digging soaking pits and deep trenches across the slope are suggested to solve these problems. By doing so, rain water storage in underground layers gets naturally enhanced and not wasted as run off causing soil erosion.

Water budgeting

Water Budgeting was accepted as an innovation among all the farmer respondents. Here crop-water contingency plans were made for all farmers. Depending on the rain water harvested and the ground water available in the bore well (as measured on first day of every month in the water sharing groups), decisions were made on the amount of water required for all crops in the group, and the crop growth stage, and whether this water is adequate enough for sprinkler irrigation or drip irrigation method of distribution. Thus judicious decision making allows for water sharing equitably among all group members. *'Decision by consultation, discussion and consensus'* was followed in all group meetings.

Water budgeting concept was geared towards instilling an understanding of how water aquifers get charged, its judicious use and long term availability, following the principles of equity and water requirements for all group members. Farmers were made aware of the hydrological cycle and their dependencies on it. Rainfall data provided by Automated Weather Stations (AWSs) installed in villages was used. Community based water management involve surface and ground water monitoring, water availability estimation, water conservation and productivity enhancement, appropriate crop planning and farmers field schools.

Since dryland regions depend on groundwater in the post monsoons, communities were capacitated to monitor their groundwater levels using a water level indicator. Bi-monthly data collected captures the groundwater fluctuation and is publicly displayed. Based on this information, crop plans were made (prior to the Rabi sowing, taking care to secure sufficient water for livestock and domestic purposes in summer). Efficient irrigation methods (drips, sprinklers, micro irrigation systems) were being adopted.

Conservation Agronomic Innovations

For arable soils, the most effective conservation practices for reducing surface evaporation were those that provide some degree of surface cover for the soil. A cover can be best provided by mulches or by tillage practices that leave plant residues on the soil surface.

A mulch is any material placed on a soil surface for the purpose of reducing evaporation or controlling weeds. Mulches act as barriers to movement of moisture out of the soil. They can be either natural (e.g. straw, wood chips, peat) or man-made (e.g. transparent or opaque plastic sheeting). Mulches can also enhance soil temperature, depending on the type of mulch being used. In addition to reducing evaporation, vegetative mulches can reduce the spread of soil borne diseases, reduce weed growth, reduce soil erosion, and provide nutrients and organic matter and aid in infiltration. Mulches improve infiltration by protecting the soil surface from the impact of raindrops and eliminate soil crusting. Mulches can however, be expensive and labour intensive to obtain, transport and apply to the soil. Mulching is usually more practical for high value crops such as vegetables.

Specially prepared plastics can also control evaporative loss. Black plastic can also effectively control weeds. These types of mulches are often applied by machinery and there are holes or slits present for plants to grow through. These mulches are commonly used for vegetables and small fruit crops. The use of plastic mulches has some disadvantages. The formation of a barrier on the surface of the soil decreases ET, but also acts as a barrier to infiltration of additional water from rainfall. There are also problems associated with the removal of plastic mulches at the end of the growing season. It is difficult to completely remove the mulch and debris can build up after several years, interfering with water movement and cultivation.

There are a number of conservation methods to reduce excessive soil water loss. Most provide additional advantages such as building soil structure, improving organic matter or weed control. Soil moisture conservation may be the most efficient and economical way of increasing net returns over the long term.

Some of the agro-ecological principles behind soil moisture conservation were:

- Plants do not need water but they need a little moisture in rhizosphere zone of plants.
- So drip irrigation is sufficient to maintain adequate soil moisture levels.
- Soil moisture is essential for ion exchange process of nutrient availability to root system and uptake of nutrients.
- Soil moisture allows for humus presence in soil, which allows for chemical reactions inside the soil for making nutrients available to plants for uptake.
- Hence soil moisture levels, humus and organic carbon all are essential to maintain soil fertility.
- If soil moisture dries up, the soil chemistry slows and stops. Soil nutrient uptake too stops.

- In the absence of adequate soil moisture around root zone of plants, plants suffer severe soil moisture stress and begin to wilt, wither and die.

Water Saving Innovations: Micro irrigation Systems in water use

Micro-irrigation includes sprinklers and drip irrigation systems. Depending on the water available in the tube well, the decisions were made either to use a sprinkler or a drip irrigation system for providing critical life-saving irrigations to the field crops of water sharing groups' members.

Institutional Innovations: Water User Groups (WUGs)

The concept of social institutions through Water User Groups was promoted in all villages of the Panchayat with the objectives of educating community on the need to conserve water and to promote the concept of water sharing. These groups consisted of bore well owners and owners of farms receiving water from the bore well.

The farmers were oriented on the need to share water with other farmers. They were reminded that water scarcity was already an issue of concern in the district and were further informed that water levels in their bore wells would go down if newer bore wells were dug in their neighbouring farms. The better option would be to part with some of their water so that more farmers could be benefited. Many farmers were initially unwilling to share water, as they would not be benefited in any way by doing so.

The NGO functionaries told them that micro-irrigation systems (sprinklers and drips) were being given to them at 75 percent subsidy and that the water receivers and the organisations would jointly invest the remaining 25 percent if they agreed to part with some of their water. Few farmers duly came forward to sign Memoranda of Understanding. The other farmers were convinced with the agenda over time.

Training sessions on water budgeting were organised for farmers and each year to build their capacities to make optimal use of water. They were given extensive inputs on the preparation of water budgets. Data were collected on rainfall levels, land cover, crops, livestock and population. Water needs of households, livestock and crops were assessed and compared with the actual usage of water. They were informed that utilization of 70 percent or lesser of existing water resources implied that they were in the *safe zone*. The information in the budget could be used as a basis to plan for the next agricultural year.

There was not much positive response from most bore well owners and they were unwilling to share scarce water resources with others. Very few people turned up at the meeting held. Participation by farmers that did not own bore wells was particularly poor, as they were skeptical of a positive outcome. They were not only unsupportive of this agenda but actually began discouraging the other farmers. Special meetings were held with these farmers to educate them on the importance of cooperation amongst them and well owners.

Water sharing: Dryland farmers faced with an uncertainty of declining water table, drying up of the aquifer in times of a drought year when rains fail to recharge the water aquifer and raise water table. Yet they were not worried, because under the social regulation programme (SRP), water sharing is now made possible. Social regulation is an innovative concept in sharing water among dryland farmers. They were able to provide life-saving irrigation to their groundnut crop and could reap in a better harvest. Their ability to come together and adhere to the agreed upon norms was again the crucial factor for their success. Major crops grown are groundnut and red gram. In the citrus gardens, crops like groundnut, sunflower and vegetables are grown in the inter spaces. Since these are all drylands, farmers resort to mixed cropping of groundnut + red gram + castor, cowpea + green gram and Jowar + cowpea.

A water sharing programme was developed by mutual consent of the farmers of the village. The farmers whose bore wells are filled with water, they can share their water with neighbouring farmers provided they adhere to some five conditions laid down by the group of farmers. These conditions were:

1. The participants in the social regulation programme (SRP) should not dip up any new bore wells in their fields. They need to share water available in the current live bore wells.
2. No one should grow paddy, which requires more water. All the participating farmers have to grow only an irrigated dry crop.
3. All the farmers have to help collect the rain water through water harvesting systems and enhance the recharging of the dead bore wells.

4. Everyone has to adopt micro-irrigation systems like drip and sprinkler irrigation systems, for which subsidies (50 percent) and financial help (25 percent) from local NGO would be made available.
5. All the participating farmers of SRP (social regulation programme) need invariably practice NPM (non-pesticidal management) methods and practices.

Once the farmers have agreed upon these five conditions, they have strictly followed them and they were able to get a good crop of groundnut and no one reported any crop losses due to lack of water. Water was shared among the farmers without any troubles or fights. Since new bore wells were not dug up, and since water was not wasted, and rain water was harvested properly by all farmers, recharging of lower aquifers was made possible and they were able to get water throughout the crop season. All the villagers were happy for being able to come together and solve their water scarcity problems amicable through collective action and social regulation.

Water Sharing Norms to be followed by the society are pooling up of bore wells through a common pipeline network for sharing Water to be shared among all irrespective of having the ownership of bore well. Crop plans based on availability of water in agreement with members, Reduction of area under paddy, sharing the water to protect the kharif crop of non-bore well farmers. Ensuring the acreage of bore well owner and creating general fund for maintenance of pipeline, repairs, etc.

Case Study

The case study approach was specially used in the study as this method allows to record qualitative data, processes involved in evolving innovations for dryland farmers that have transformed their ways of farming, their lives and living standards. Case study involved in-depth interviews of the key informants of water user groups. The case study is

Case No. 1: Farmers joined hands for mutual survival and prosperity – The case of Kummarvandlapalli

Kummarvandlapalli is a small village of about 55 households cultivating groundnut, red gram (pigeon pea) and jowar (sorghum). Being a dryland area, farmers rely heavily on the rains for their livelihoods. If the rains, are good, all farmers reap bumper harvest and lead a prosperous life. If rains fall, some farmers usually provide one or two life-saving irrigations from their bore well to grow enough food for their families. If farmers did not own any bore-well they will end up with dried crops and face starvation. About 40-50 years ago, farmers used to get adequate rainfall as the forest cover, and the climate condition were normal and agro-ecosystem were healthy and doing well in ecological terms. But due to severe climate change happening around the world, the climatic condition of dryland region has become quite erratic and adverse causing stress and misery to the villagers.

In the last 15-20 years digging bore wells and extracting ground water over the years has depleted ground water resources and the water table has gone down year by year and farmers went for deeper boring increasing investment. Farmers who owned bore wells have started growing paddy and sugarcane, which are water gurgling crops. On seeing the success of bore wells owned farmers, other resourceful farmers too have dug up more tube wells. With this competitive digging, the aquifer, started drying up ignorant farmers too have wasted lot of water.

Thus on one side, the tube wells were getting dried up and were left abandoned. Those farmers who owned tube wells had other problems like wastage of water through flood irrigation, lack of pipelines for distribution no water to crop fields. Leakage and seepage losses have forced farmers to irrigate lesser area of crop fields. The farmers who did not own bore wells were forced depend only on rains. During the seasons, when rains failed, the crop produce was less leading to shortage of food for the family. Income were quite fluctuating at the mercy of rainfall. Thus the problems of dryland regions have got aggregated and led to an agrarian crisis. The average investment per acre of land was about Rs. 11700/- the average value of the crop produce per acre of land was about Rs. 18800/-

The average incomes of farmers used to be about Rs. 7100/- per acre of land. The investments for irrigated land used to be about Rs 11700/- and the produce out of one acre of land used to worth of a value of Rs. 18800/- but in the case of farmers growing rainfed corps and not owing any tube well to get still lesser income.

Interventions

The scenario in the village was fast deteriorating. The farmers who did not own tube wells have almost decided to quit farming as rains have become erratic in onset, distribution, withdrawal, and erratic with down pours and long dryspells at wrong times.

The farmers who owned tube wells have started realizing that the competitive digging bore wells and pumping out water for irrigation by individuals would soon end up in depletion of ground water resources, lowering of water table and drying up of aquifer zones in the fields. All the farmers have come together and started discussing to find solutions to their water woes as they feared that very soon in the future all the tube wells in the villages may dry up and results in acute shortage of water, and may cause distress and misery to all villagers. All the farmers have started worrying for their own survival and realized that they need to thank in new ways and evolve sustainable solutions to address this water scarcity issues earnestly. Thus came the thought that they need to join hands, help each other by sharing ground water to sustain their crops and their lives. Thus sharing ground water and evolving appropriate mechanisms and procedures to share water has become a 'do or die' option for all villagers.

All these farmers' discourses and discussions were monitored by local NGOs called '*Annadata'* which is a member of and guided by WASSON (watershed support services and action by network) groups. NGOs working at state level. Another NGOs working at the state level, CWS (CENTRE FOR WORLD SOLIDARITY) was also working.

Farmers were appraised of in various group meetings that they need to understand and make thumb rules of the fallowing ever truthful ground realities:

1. Water is always scarce and need to be used judiciously in a conservative manner.
2. Rainwater is the god sent source of water for all villagers in dryland areas and we need to conserve every drop of rain.
3. Water is a common property, especially that falls from skies and that gets stored in ground water reserve. Everyone has equal right on ground water.
4. Competitive digging of tube wells and pumping out excessive water for growing crops with water demand is not only a wastage with but also suicidal in the long run.

With these ground values well ingrained in the minds of all villagers, farmers have organised themselves into a group by putting reserve funds as capital in a bank account and registered their societies.

Water user group

A farmers' group was formed with 25 famers with 15 farmers owning eight bore wells and few farmers not having any bore wells and this group was named *'Kolugunti Ummadi Neeti Yajamanya Sangham'* (Kolugunti Joint Water Management Society). This water users group formulated some guidelines and instructions for smooth networking of farmers and functioning of the group.

The rules for functioning of the society are laid down as under:

1. All the farmer members of the group are treated as equal irrespective of the water management society.
2. A joint bank account should be opened in the names of representatives of the water management society
3. Contribution of share capital should be equal from all the farmer members whether they own or not any bore wells.
4. For efficiently running the water sharing network and using the micro-irrigation system for all members, repair and maintenance costs should be collected on the basis of acres of land owned by the members at the rate of Rs. 100 per acre per month. This money is handled by one farmer who has been unanimously chosen by the members of the water sharing society of the village. During the critical irrigation stages in crops, this common fund shall be used for repair and maintenance of bore wells and micro irrigation system.
5. Are under irrigation among the farmers need to be fixed every season depending upon the availability of water in the bore well which is measured on the last day of every month. Area under irrigation should not be increased.
6. In critically irrigated areas, water from bore wells should be provided for at least three crop-growth stages out of the four stages: sowing time, flowering stage, pod development (for ground nut crop) and at harvesting time.
7. At the beginning of every crop season, after measuring the amount ground water (using a long measuring tape) in the bore well crop-water budgeting should be done through discussion and decision making in a participatory approach.
8. Only micro-irrigation system should be used by all members through pipe lines, drip and sprinkler system, in order to conserve water and not to waste it at all.

9. No new tube wells should be dug for 10 years without the permission of water sharing society.
10. All the member farmers of water sharing group should take active part in the meetings, discussions and efficient functioning of the water sharing network.
11. Among the members of the water sharing group- Kolugunti Joint Water Management Society, there were 92 percent marginal farmers out of which 56 percent were sub-marginal (with 1 acre of land) farmers and the rest 36 percent were marginal farmers (with 2 acre of land).

When the uncertainty of water availability is removed from their lives through assurance got from all members that lifesaving irrigation for their crops, farmers vowed to revive their agro-ecosystem and learn and use all the water management practices.

Through government support, water pipelines were laid across all the fields of the member farmers with 75 percent subsidy. Thus micro-irrigation system was laid out to use water conservatively. Next for collecting rain water soil conservation structures were repaired. With respect to conservation agronomic practices all the farmers were asked to do regular weeding, apply soil mulching to reduce loss of valuable soil moisture.

Water sharing groups conducted meetings of their group's members regularly every month to discuss the new ways of water conservation and increasing ground water reserves. Gradually the water levels increased, cropping pattern changed and farmers have become alert and awakened.

Impact of social regulation on water sharing

Once the farmers have agreed upon these five conditions, they have strictly followed them and they were able to get a good crop of groundnut and no one reported any crop losses due to lack of water. Water was shared among the farmers without any troubles or fights. Since new borewells were not dug up, and since water was not wasted, and rain water was harvested properly by all farmers, recharging of lower aquifers was made possible and they were able to get water throughout the crop season. All the villagers were happy for being able to come together and solve their water scarcity problems amicable through collective action and social regulation.

Impact on Cropping Pattern and returns from farming

Prior to ground water sharing groups, these dryland farmers used to grow only ground nut as a rainfed crop, because most of them do not have any irrigation facility.

But after the formation and successfully running of water sharing group in the village, a new scenario emerged in which there is assured supply of protective irrigation water, through micro-irrigation systems. They started growing new crops including pigeon pea, sorghum, tomato and mango plantation in addition to growing groundnut. Some farmers have started growing mulberry, paddy, castor, chrysanthemum and micro-irrigated their mango plantations. Their incomes have risen and the value of their crop produce can be seen in Table 4.3.1

Table 4.3.1: Impact of water sharing group on economic returns of crops earned by farmers after initiation of water budgeting and water sharing

S. No	Crops and cropping pattern	Investment (in Rs.)	Value of Produce (in Rs.)	Profit (in Rs)
1.	Pigeon pea (Red gram)	5080	13,600	8,520
2.	Mulberry	19,400	38,400	19,000
3.	Groundnut, Pigeon pea, Sorghum (Jowar)	9,540	23,550	14,010
4.	Groundnut, Sorghum, Tomato	9,720	64,100	54,380
5.	Paddy, Groundnut, Chrysanthemum	12,820	18,840	6,020
6.	Groundnut, Pigeon pea, Sorghum, Castor, Mango plantation	10,230	22,800	12,570
7.	Mulberry, Groundnut, Pigeon pea, Sorghum	15,280	38,900	23,620
8.	Paddy, Mango plantations	10,900	25,500	14,600
9.	Groundnut, Pigeon pea, Sorghum, Mango Plantations	5,770	11780	6,010
10.	Groundnut, Pigeon pea, Sorghum, Castor	12,290	26,000	13,710

Now the water sharing group was still working and continue to serve the group's member farmers in a sustained manner. Farmers' hopes have got livened and future plans of more collective actions were envisaged.

Reflections

1. Farmers living in the village Kumaravandlapalli had seen the vagaries of monsoon, crop failure and over exploitation of ground water resources, psychological distress and misery. They began discussions and thought collectively to find any solutions.
2. Intervention of the NGO *Annadata* happened at the most opportune time and their staff started mobilizing people for group actions. At first farmers were skeptical, hesitant and reluctant to join hands. Through several meetings and discussions, farmers were appraised of the changes happening in the village due to global climate change and rains becoming quire unpredictable and erratic.
3. But once the water sharing group got initiated results got realised in the first crop season itself with assured crop harvests for every member family. Farmers could get lifesaving irrigation at critical stages of crop. They were saved from worries and misery and were quite happy as all the farmers could fetch good returns from farming.
4. With adequate storage of water and assurance from the water sharing society they have gradually moved onto better paying and yet water saving crop choices to get better income.
5. Farmers have started appreciating the value of rain water, promoted water harvesting in the village through collecting water in tanks, increasing percolation of rain water through digging deep trenches across the slope of their lands, summer ploughing to keep the fields ready for water absorption and percolation reducing run off and erosion of top fertile soil.
6. All the farmers have adopted all the necessary water saving practices like water harvesting, water storage, recharging aquifers, soil moisture conservation through agronomic practices like inter-culture, mulching, weeding, soil fertility enhancement through crop residue incorporation, application of FYM and organic matter.

4.4 Level of knowledge of agro-ecological bases of water management innovations

The level of knowledge can be measured as level and accuracy of information possessed by the respondents on the agro ecological bases (roots / principles) of water management innovations of sustainable dryland agriculture. It was measured trough the knowledge index developed for the study. The responses of farmers were taken in the form of close ended questions and responses were coded as 1 for correct answer and zero for wrong answer. The index was measured as the percentage of obtained scores of correct answers over total obtainable scores for each respondent.

Table 4.4.1: Distribution of farmer respondents on Knowledge Index of Respondents on water management innovations

Knowledge Index of Respondents	**n=120**	
Mean	90.67	
Standard Deviation	3.06	
Range	80.77 – 96.15	
Frequency Distribution	**Frequency**	**Percent**
Low (<87.61)	12	14.40
Medium (87.61 - 93.73)	10	12.00
High (> 93.73)	76	63.33
Total	**120**	**100.00**

It can be seen from the results in the Table 4.4.1, mean knowledge index score of farmer respondents was 90.67. This means that the farmers on an average had very high level of knowledge on water sharing processes. The standard deviation was 3.06 indicating very high consistency among the sample of farmers. The scores ranged from 80.77 to 96.15 out of a total of 100. Majority (63.33 %) of farmers found to possess high level of knowledge about the agro-ecological reasons behind the contemporary water management innovations. The frequency distribution of farmers on their level of knowledge appeared to be highly skewed towards higher scores of knowledge on agro-ecological bases of water management innovations.

The graph of normal distribution shown below clearly represented the high level of knowledge among farmers. Majority of farmers, being the members of water sharing groups had been well exposed to all the details of the agro-ecological rationale behind water management innovations. It also appears that all of them had imbibed and learnt thoroughly the key agro-ecological concepts and principles behind rain water harvesting, water sharing and water management innovations.

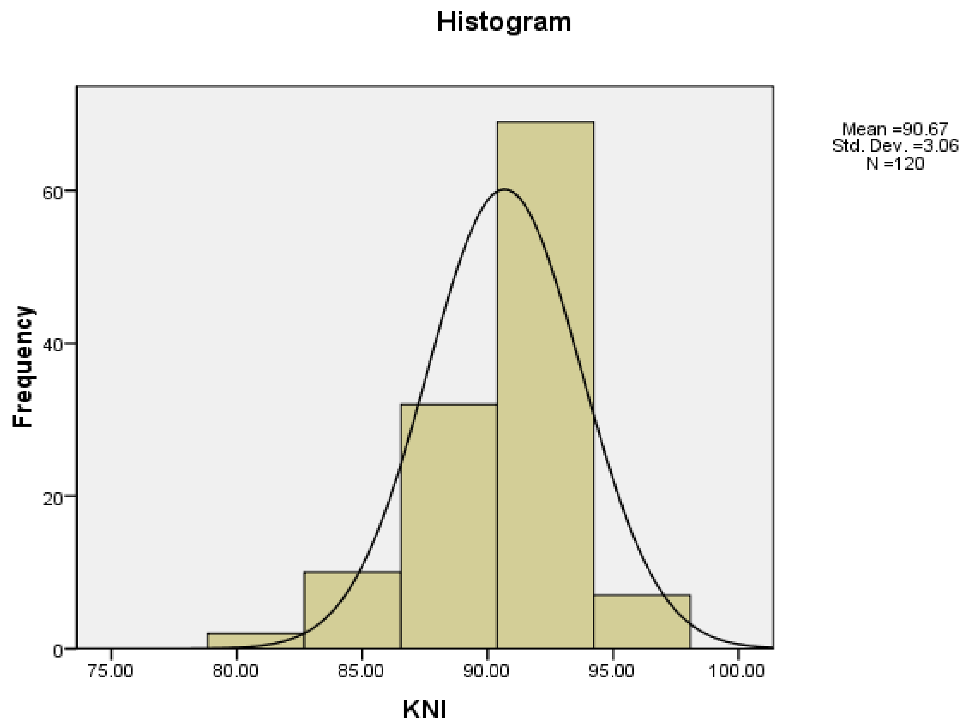


Fig-4.4.1 Knowledge Index of Respondents on water management innovations

Having seen the overall score of knowledge on all the five water management innovations, an attempt was made to assess the level of knowledge separately for all the five water management innovations, *viz.*, rain water harvesting innovations, water saving innovations, micro-irrigation innovations, conservation agronomic innovations and water sharing institutional innovations.

***Level of knowledge of rain water harvesting*: ** The level of knowledge of rain water harvesting practices can be measured as level and accuracy of information on the agro ecological bases of rain water harvesting practices including percolation pits, soaking pits, desilting of water reservoirs, farm ponds,

As can be explained from the results, the mean of knowledge level of farmer respondents on water harvesting was 12.78. The standard deviation was 0.61. Out of 14 items on knowledge test about 65.8 percent farmers were having high level of knowledge about 13 of the knowledge items of water harvesting practices.

Table 4.4.2: Distribution of farmer respondents on level of knowledge of rain water harvesting (WH)

Knowledge of Water Harvesting innovations		**n=120**
Mean	12.78	
Standard Deviation	0.61	
Range	11-14	
Knowledge items	Frequency	Percent
11 out of 14 items	3	2.5
12 out of 14 items	29	24.2
13 out of 14 items	79	65.8
14 out of 14 items	9	7.5
Total	120	100.00

Majority of farmers were found to possess more knowledge on what benefits would accrue if the rainfall run off is showed down, let it percolate and rainwater harvested.

Level of knowledge of water saving practices: The level of knowledge water saving practices can be measured as level of and accuracy of information on the agro ecological bases of water saving practices of dryland sustainable agriculture for example they are having decent knowledge about water saving by farming water sharing groups, they used to plan cropping system for whole year for proper water budgeting.

All the farmers know fully well: "*for judicious use of ground water resources, all the farmers used to form jointly a society of water users group. Farmers' need to choose only such crops that need very few irrigations. They need to conserve water. They need to formulate an agreement for providing conservation irrigation only when it is necessary to save the crop. All the farmers need to discuss and decide by consensus a few terms and conditions for running the water user group. All farmers need to adhere to these terms and conditions compulsorily without any fail. They need to make plans for cropping for the whole year through proper water budgeting procedures."*

Farmers were found to express their understanding of the meaning and usefulness of joint ground water management, water sharing groups, water budgeting and contingent crop planning for water conservation.

Level of knowledge of micro-irrigation practices: The level of knowledge micro-irrigation can be measured as level of and accuracy of information on the agro-ecological bases of micro-irrigation of dryland sustainable agriculture. They were fully knowledgeable about water saving through micro-irrigation systems of sprinklers and drip and water use efficiency range from 85 to 98 percent. They also understand the worth of precious ground water and not to waste it anymore.

Level of knowledge of agronomic practices: The level of knowledge agronomic practices can be measured as level of and accuracy of information on the agro-ecological bases of agronomic practices of dryland sustainable agriculture. The various practices include giving life-saving irrigation at critical stages of crop growth, spacing, inter cropping, mulching thereby reducing soil moisture loss, contingent crop planning.

Farmers exhibited full levels of knowledge of agro-ecological bases of agronomic practices for soil moisture conservation and enhancing soil fertility.

Correlates of Level of Knowledge of Water Management Innovations

An attempt is made to know the correlates of level of knowledge of agro-ecological bases of contemporary water management innovations was done For this, some selected relevant factors were studied and their possible association with the level of knowledge of the contemporary water management innovations were put to empirical testing.

In this section, an effort has been made to find out the possible association between socio-personal, socio-psychological and communication variables concerning the perception level of knowledge of the contemporary water management innovations.

Table 4.4.3 shows the association between the socio-personal, socio-psychological and communication variables with their level of knowledge.

As can be seen from the table, only two variables, namely, goal commitment and frequency of use of cosmopolite channels were found to be positively and significantly associated with the extent level of knowledge. They were significant at 0.01 level of probability. Frequency of contact with NGO activists has helped increase their level of knowledge. One’s own goal commitment too was associated positively and significantly with one’s level of knowledge of these innovations.

Table 4.4.3: Correlation coefficients of Level of knowledge of agro-ecological bases of water management innovations

Sl. no.	Independent variable	Correlation coefficients
1.	Age	-0.078
2.	Education	-0.107
3.	Farming experience	-0.071
4.	Land size	-0.203*
5.	Total income	-0.364**
6.	Goal commitment	0.449**
7.	Social norms	0.002
8.	Social capital	-0.152
9.	Contact with cosmopolite channels	0.238**

***** Significant at 0.01 level of probability***

But land size and total annual income were negatively associated with level of knowledge of water management innovations. Thus t can be concluded that younger farmers with smaller land holdings possessed higher level of knowledge.

Other socio-personal variable like, age, educational status, farming experience, and social capital were negatively associated with extent of adoption of water management innovations. However, the social norms were not significantly associated with level of knowledge correlated.

Prediction of level of knowledge of some selected water management practices

The correlation analysis would merely give an idea about the association of independent variables with the dependent variable. In order to assess the contribution of each independent variable to the prediction of dependent variable, the data were adopted for regression analysis. In this study, ten independent variables were fitted in the multiple regression equation. The findings are presented in the table 4.4.4.

It may be seen from the table 4.4.4 that all selected variables explained significantly to the extent of only 38.5 percent of variation in the level of knowledge of selected water management innovation by farmers. 'F" ratio was found to be significant at 11, 108 degree of freedom. The statistical analysis thus indicated that all the selected variables taken together explained a moderately significant amount of variation in the level of knowledge of farmers on water management innovations.

Table 4.4.4: Multiple Regression Analysis of Level of knowledge of water management innovations

Sl. No.	**Socio-personal characteristics of farmers**	**Unstandardized Coefficients Partial 'b'**	**t-value**	**Sig.**
	(Constant)	103.544	16.656	.000
1.	Age	-.050	-1.017	.311
2.	Education status	-.024	-.440	.661
3.	Farming experience	.035	.818	.415
4.	Land size	-.285	-1.539	.127
5.	Total income	-1.953E-5	-2.570**	.012
6.	Goal commitment	1.184	4.400**	.000
7.	Social Norms	-.463	-3.026*	.003
8.	Social Capital	-.062	-1.391	.167
9.	Contact with personal localite channels	.363	.343	.732
10.	Contact with extension personnel cosmopolite channels	-.706	-.904	.368
11.	Contact with Mass communication channels	.659	.644	.521

** Significant at 0.05 level of probability* *** Significant at 0.05 level of probability*

R^2 =0.385 F Ratio at 11 and 108 degrees of freedom = 6.141**

Out of all the selected variables fitted in the multiple regression analysis three variables: total annual income, goal commitment, and social norms contributed significantly to the prediction of level of knowledge of farmers on water management innovations.

As farmers' goal commitment was found to be contributing significantly. As the farmers had high goal commitment towards ensuring their livelihood security through water harvesting, saving and sharing among themselves, their knowledge levels too increased. Adherence to social norms was another major contributor to the prediction of level of knowledge of water management innovations. This finding was quite apt here as social regulation and adhering social norms is at the core of water sharing innovation.

Thus it can be concluded that the level of knowledge of agro-ecological bases of contemporary water management innovations was very high among farmers.

4.5: Extent of adoption of farmers on the selected water management practices

The level of adoption of different water management technologies were analysed through an arbitrary scale developed for the purpose of that contains selected water management technological and institutional innovations in water management practices and responses were scored as per the scoring system given in the chapter on Research methodology. The index was developed by dividing obtained scores to obtainable scores multiply by hundred.

Table 4.5.1: Distribution of farmer respondents on Extent of Adoption of water management innovations

Extent of Adoption of Water management innovations	**n=120**	
Mean	78.63	
Standard Deviation	8.07	
Range	55.21 – 90.62	
Frequency Distribution	**Frequency**	**Percent**
Very Low (<62.29)	2	1.7
Low (62.29 – 70.36)	14	11.67
Medium (70.36 - 86.5)	73	60.83
High (86.5 – 94.57.04)	31	25.83
Very High (>94.57)	0	0.0
Total	**120**	**100.00**

It can be seen from the results in the Table 4.5.1, the mean score of extent of adoption of farmer respondents was 78.93. The standard deviation was 8.07. Majority of the farmers were adopting different water management innovations 78 percent of the total innovations. Majority (60.83 percent) of farmers were adopting 70 – 86 percent of water management innovations as can be seen from their percentage scores on adoption index. The graph of normal curve was also representing normal distribution.

Extent of Adoption of all different water management innovations

As can be seen from the results on scores of adoption index on all the water management innovations ranged very widely, an attempt was made to see whether the extent of adoption varied on any of the component innovations of water management.

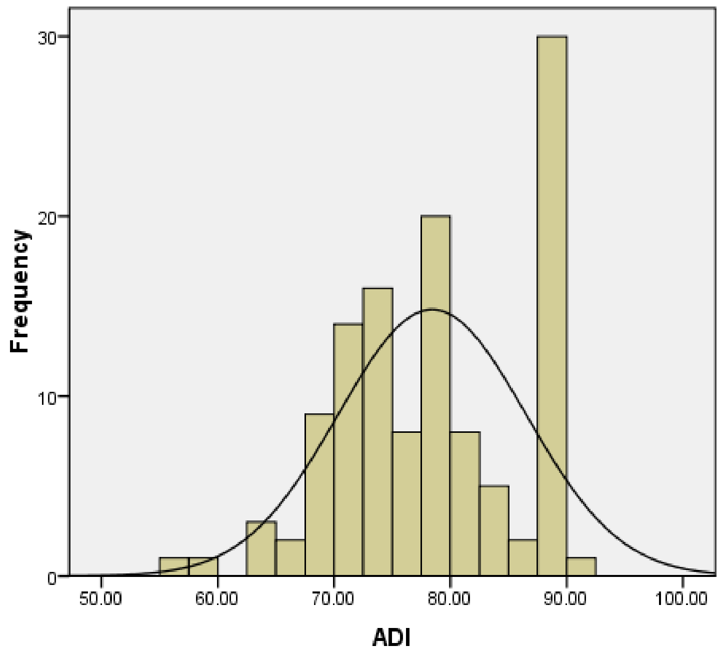


Fig-4.5.1 Extent of Adoption of all different water management innovations

Extent of adoption of water harvesting: The level of adoption of water harvesting can be operationalized as extent of accepting, adopting and practicing water harvesting practices of dryland sustainable agriculture. These practices adopted by farmers after having complete knowledge of agro-ecological bases behind water harvesting practices. These practices were: restoration of traditional water bodies, gully control, construction of check dams, percolation tanks, recharge pit (with stones, sand layer), slug test (water table measuring test), soaking pits, de-silting, stoning (stone pellet), deep trenches, etc.

Table 4.5.2 Distribution of farmer respondents on extent of adoption of water harvesting innovations

Extent of adoption of water harvesting Innovations of respondents	**n=120**	
Mean	30.85	
Standard Deviation	5.578	
Range	15 -41	
Scores on extent of adoption	Frequency	Percent
Very Low (<20)	2	1.8
Low (between 20-25)	14	11.7
Moderate (between 25-30)	50	41.4
High (between 30-35)	24	20.0
Very High (>35)	30	25.1
Total	120	100.00

Extent of adoption of water saving: The extent of adoption of water saving innovations can be operationalized as extent of accepting, adopting and practicing water saving practices of dryland sustainable agriculture. These practices adopted by farmers after having full knowledge of agro-ecological bases behind water saving practices *viz.*, renovated farm pond (water harvested after renovation), renovated bunds of water bodies (water harvested after renovation), water saving through using sprinklers and drip systems and finally and saving ground water resources.

Table 4.5.3: Distribution of farmer respondents on the extent of adoption Water Saving Innovations

Extent of adoption of Water Saving innovations	**n=120**	
Mean	15.75	
Standard Deviation	1.33	
Range	12 -18	
Scores on extent of adoption	Frequency	Percent
Very Low (13)	4	3.4
Low (14)	12	9.9
Moderate (15)	42	34.7
Moderately High (16)	26	21.5
High (17)	22	18.2
Very High (18)	14	11.6
Total	120	100.00

Extent of adoption of micro-irrigation: The level of adoption of micro-irrigation can be operationalized as extent of accepting, adopting and practicing micro-irrigation practices of dryland sustainable agriculture. These practices adopted by farmers after having full knowledge of agro-ecological bases micro-irrigation as drip irrigation and sprinkler irrigation. The results are given in Table 4.5.4.

Table 4.5.4: Distribution of farmer respondents on extent of adoption of Micro Irrigation

Extent of adoption of Micro Irrigation	**n=120**	
Mean	14.20	
Standard Deviation	1.69	
Range	9 -18	
Scores on extent of adoption	Frequency	Percent
Low (between 9-12)	16	13.3
Medium (between 12-15)	81	67.5
High (between 15-18)	23	19.2
Total	120	100.00

Mean score of extent of adoption of farmers on micro-irrigation was 14.20.

The standard deviation was 1.69, indicating consistency among the farmers on the extent of adoption. The frequencies of adoption scores of appeared to be falling into a normal distribution, although slightly skewed towards higher side. All the farmers were adopting micro-irrigation systems to save water and not waste away in flood irrigation. About 67.5 of farmers were adopting micro-irrigation up to moderate levels.

Extent of adoption of conservation agronomic practices: The level of adoption of agronomic practices can be operationalized as extent of accepting, adopting and practicing micro-irrigation and soil moisture conservation agronomic practices namely soil mulching, intercultural operations (sowing in line), mixed cropping and intercropping.

Table 4.5.5: Distribution of farmer respondents on extent of adoption of Conservative Agronomic Practices

Extent of adoption of Conservative Agronomic Practices	**n=120**	
Mean	11.84	
Standard Deviation	0.55	
Range	9 -18	
Scores of Extent of adoption	**Frequency**	**Percent**
Low (<9)	6	5.0
Medium (10-11)	5	4.2
High (>12)	109	90.8
Total	120	100.00

The mean score of extent of adoption of conservation agronomic practices was 11.84. Standard deviation was0.55 indicating very high level of consistency. About 90.8 percent of farmers were adopting up to high extent the conservation agronomic practices..

Association between extent of adoption and independent variables

Acceptance or rejection of innovations is not entirely dependent upon the inbuilt qualities and limitations of the innovations itself but also certain other factors which directly or indirectly influence the behavior of individual farmers. Thus, some selected relevant factors were studied and their possible association with the adoption of the contemporary water management innovations were put to empirical testing.

In this section, an effort has been made to find out the possible association between socio-personal, socio-psychological and communication variables concerning the perception and also the attribute of innovation and the extent of adoption of the contemporary water management innovations.

Table 4.5.6 shows the association between the socio-personal, socio-psychological and communication variable with their extent of adoption.

Table 4.5.6: Correlation analysis between extent of adoption of water management innovations and some selected socio-personal and socio-psychological variables.

Sl. No.	Socio-personal and socio-psychological characteristics	Correlation coefficients
1.	Age	-0.140
2.	Education status	0.042
3.	Farming experience	-0.247**
4.	Land size	-0.082
5.	Total income	-0.071
6.	Goal commitment	0.396**
7.	Social norms	0.455**
8.	Social capital	-0.137
9.	Contact with communication channels	0.267**
10.	Level of knowledge	-0.023

***significant at 0.01 level of probability*

As revealed from table 4.5.6 only two variables, namely, social norms and social capital were found to be positively and significantly associated with the extent of adoption. They were significant at 0.01 level of probability. Other socio-personal variable like, educational status, frequency of use of communication source were not significantly associated with extent of adoption of water management innovations. However, age, social capital and level of knowledge, land size, total income were negatively correlated.

The correlation analysis was done in this study, only twelve independent variables were fitted in the multiple regression equation. The findings are presented in the table 4.5.7

Table 4.5.7: Multiple Regression Analysis with selected socio-personal, socio-psychological, and communication variable with Extent of adoption of water management innovations

n=120

Sl. No.	Independent variables	Unstandardized Coefficients Partial 'b'	t-value	Sig.
1	(Constant)	79.475	2.506	.014
2	Age	.041	.310	.757
3	Educational status	.093	.646	.520
4	FE	-.112	-.964	.337
5	Land size	-1.010	-1.999*	.048
6	Total income	4.151E-7	.020	.984
7	Goal commitment	2.124	2.693**	.008
8	Social norms	1.211	2.811**	.006
9	Social capital	.093	.762	.448
10	Contact with localite channels	-2.775	-.969	.335
11	Contact with cosmopolite channels	4.504	2.126*	.036
12	Contact with mass media	-2.060	-.744	.459
13	Level of knowledge	-.539	-2.074*	.040

** Significant at 0.05 level of probability* *** Significant at 0.05 level of probability*

R^2 =0.362 F Ratio at 12 and 107 degrees of freedom = 5.059**

It may be seen from the table 4.5.7 that all selected variables explained to the extent of 36.2 percent of variation in the extent of adoption of water management innovation by farmers. 'F" ratio was found to be significant at 12, 107 degrees of freedom. The statistical analysis thus indicated that all the selected variables taken together explained a moderately significant amount of variation in the extent of adoption of farmers.

Out of all the selected variables fitted in the multiple regression analysis few variables, namely, land size, goal commitment, social norms, contact with extension cosmopolite channels, and level of knowledge contributed significantly to the prediction of adoption behaviour of farmers.

It is interesting to note that farmers' goal commitment, farmers' adherence to social norms, contact with NGO activists and their level of knowledge were good predictors of the extent of adoption of contemporary water management innovations.

4.6 Constraints in diffusing water management innovations in similar dryland agro-ecosystems

Primarily, dryland agro-ecosystems in all states of India were generally a neglected lot. During the years of agricultural development and Green Revolution, undue emphasis on irrigated agriculture and food security of cereal food grains, the drylands were not given adequate support. When regional differences began increasing the gap between drylands and irrigated areas too began widening. Continued neglect of any development initiatives and lack of policy on efficient and judicious use of ground water resources, farmers in drylands were left to fend for themselves and the problems of water scarcity loomed large and resulted in agro-ecological crisis. Now there are several district which became drought-prone and need ameliorative actions in water harvesting, storing, saving and sharing among dryland farmers.

Water Management Innovations

In this study, it has been mentioned that in the previous section, that farmer respondents have ardently adopted all the innovations related to water management in drylands, i.e., water harvesting, water budgeting, water sharing and water saving through using micro-irrigation systems, and adopting soil moisture conservation agronomic practices. Case study has also provided evidence that farmers get ample benefits in forming water sharing groups for assured crop yields.

In such dryland regions, in order to diffuse these water management innovations among farmers in similar dryland agro-ecosystems, the questions that may arise include: What constraints would come in the way to achieve this? To answer this question, opinions were sought from experts and their consensus was achieved through Delphi technique.

Delphi methodology was employed with a panel of 30 experts, scientists and extension functionaries in the field of agriculture the questionnaire for the first round of Delphi was developed by this group through reviewing existing literature on project reports. Questionnaires for second round were developed from the responses of first round of Delphi using constant comparative method. Subsequently, the questionnaire for round III was developed using the responses from the round II.

Furthermore, consensus was said to be high when quartile deviation was less than or equal to 0.5 and IQR less than or equal to 1, medium when quartile deviation was in between 0.5 and 1 and IQR greater than 1 but less than 2 and low consensus if quartile deviation is more than 1 and IQR more than 2. The levels were: **High** in which the *median* value is 4 and above, while **Medium** in which the *median* value is 3 and **Low** when *median* value is less than 3. Only items having high and medium consensus with high importance were retained for the study. The above procedure was used for all sets of constraints and the finally arrived list of constraints are given in Tables here and discussed. Here all four categories of constraints are presented.

Technological Constraints

The results technique on technological constraints are given in Table 4.6.1.

Table 4.6.1: Technological Constraints coming in the way of diffusing water management innovations in similar dryland agro-ecosystems

n=23

No.	Technological constraints	Median value	Q1	Q3	IQR	QD	Remark
1	Lack of ground level area specific information on ground water status at village level and matching data from remote sensing satellites	3	3	5	2	1	LH
2	No research data on efficacy of complete package application of all innovations of harvesting, conserving, sharing and micro-irrigating large crop fields	5	4	5	1	.5	HH
3	Lack of research on water supply devices and efficacy leading to innovative and affordable technologies	5	4	5	1	.5	HH
4	No research on rain water harvesting and rain water use efficiency by agricultural scientists	4	4	5	1	.5	HH
5	No research on social institutions, community mobilisation for managing common property resources	4	4	5	1	.5	HH

****HH**-high consensus with high importance, **MH**-medium consensus with high importance, **LH**-low consensus with high importance.*

As can be seen, the most important constraints turned out to be lack of research rain water harvesting and rain water use efficiency by agricultural scientists and No research on social institutions, community mobilization for managing common property resources. In fact, these water management innovations demand participation by all the farmers as harvesting rain water requires group actions by all in a concerted manner. Similarly, forming community based organisations (CBOs) is essential for managing these common properties of ground water resources. In addition, many of the water related innovations were at the level of individual adoption. But innovations need to be generated for community adoption on a large scale, for ground water management.

Socio-political Constraints

Since ground water resources are available for the whole society in a village, the socio-political dynamics play a crucial role in equitable access to ground water resources. These constraints are presented in Table 4.6.2.

Table 4.6.2: Socio-political Constraints coming in the way of diffusing water management innovations in similar dryland agro-ecosystems n=23

No.	Socio-Political constraints	Median value	Q1	Q3	IQR	QD	Remark
1	Erosion of traditional wisdom, indigenous knowledge, social values, social capital in societies of dryland villages	5	4	5	1	.5	HH
2	Social exclusion of resource poor farmers on lines of *dalit*, caste and backwardness	4	4	4	0	.5	HH
3	Lack of encouragement of community water bodies with support of local administration.	5	4	5	1	.5	HH
4	Neglect of existing soil and water conservation structures and their regular maintenance	4	3	4	2	1	HM
5	Lack of interest in promoting water percolation pits, soaking pits and farm ponds by Gram Panchayats and block administration	5	4	5	1	.5	HH
6	Socio-political dynamics of dominance and oppression on sharing common property resources of pasture lands, water bodies and ground water resources	4	3	4	1	.5	HH

***HH**-high consensus with high importance, **HM**-high consensus with medium importance,* Over the years, farmers in dryland villages have lost their vast store of traditional wisdom of contingency crop planning, indigenous technical knowledge of mulching, and other means of survival in arid climates. They have also neglected the existing soil and water conservation structures like check dams. Local administrative bodies like Gram Panchayats too did not give any encouragement to maintenance of community water bodies and for promoting water percolation pits, soaking pits and farm ponds. Socio-political dynamics of dominance and oppression have resulted in social exclusion of poor and *dalits* on sharing common property resources of villages. These constraints were considered important for diffusing water management innovations.

Socio-psychological Constraints

The socio-psychological constraints are given in Table 4.6.3.

Table 4.6.3: Socio- Psychological Constraints coming in the way of diffusing water management innovations in similar dryland agro-ecosystems

n=23

No.	Socio-Psychological constraints	Median value	Q1	Q3	IQR	QD	Remark
1	Lack of knowledge and practical experience in practicing scientifically water management practices, crop-water budgeting and understanding hydrological cycle.	4	4	5	1	.5	HH
2	Non-cooperation of bore well owners for water sharing with other farmers.	4	4	5	1	.5	HH
3	Lack of conviction in the innovations of water harvesting, saving and sharing as these practices seem *very strangely new.*	4	4	5	1	.5	HH
5	Lack of initiative and hope of success in farming and running water sharing group as social institutions.	4	3	4	1	.5	HH
6	Doubts on accountability and responsibility of water sharing group for care and maintenance of water storage structures and distribution pipelines	5	5	5	0	0	HH

***HH**-high consensus with high importance,*

At the individual level, i.e., at socio-psychological level, the constraints like individual ignorance and fears play a role as constraints, which comprise the sociopsyche of the villagers. Lack of knowledge on the crucial details of water harvesting and micro-irrigation techniques and lack of conviction on the efficacy of these water management innovations pose as great constraints in dealing with motivating farmers for adoption of these new innovations on water management. Doubts on the issues of social responsibility and accountability due to their past experiences of lack of faith also act as constraints. Non-cooperation of bore well owners and lack of initiative among young farmers in forming water sharing groups were other constraints perceived by the experts, scientists and extension functionaries and NGO activists.

Administrative and Policy Constraints

Constraints related to administration and policy issues are given in Table 4.6.4.

Table 4.6.4: Administrative and policy Constraints coming in the way of diffusing water management innovations in similar dryland agro-ecosystems n=23

No.	Administrative and policy constraints	Median value	Q1	Q3	IQR	QD	Remark
1	Lackadaisical (apathetic) approach of policy makers towards management of valuable ground water resources of the country.	5	5	5	0	0	HH
2	Lack of innovative social regulation programmes and suitable agency for construction and maintenance of community level water harvesting infrastructure and sharing systems.	4	3	4	1	.5	HH
3	No government initiative for provision of robust technology, infrastructure and research and development support to rainfed systems	3	3	4	2	1	MH
4	Lack of mixed approach of penalty and incentives for community (as well as at individual level) for water harvesting sharing, and saving.	4	4	4	0	0	HH
5	Very difficult to mobilize community for participatory ground water management and for formation of water users' association.	5	4	5	1	.5	HH

***HH**-high consensus with high importance, **MH**-medium consensus with high importance, **LH**- low consensus with high importance.*

In designing and implementing innovative programmes of water sharing groups and water harvesting and using through micro-irrigation techniques, few administrative constraints may arise. These constraints need attention of extension functionaries.

The administrative constraints were: lack of innovative social regulation programmes and suitable agencies for construction and maintenance of community level water harvesting infrastructure in the dryland villages and lack of mixed approach of penalty and incentives for community (as well as at individual level) for water harvesting sharing, and saving. In addition, it was found to be very difficult to mobilize community for participatory ground water management and for formation of water users' associations in villages. At the policy level, the apathetic approach of policy makers towards management of valuable ground water resources was another constraint. No government initiative was taken for provision of robust technology, infrastructure and research and development support to rainfed systems.

At the outset, the major constraints were: lack of research information on rain water use efficiency, lack of focus on research on community mobilization of managing common property resources of ground water. The socio-political constraints were social exclusion of poor farmers and lack of attention for maintenance of water harvesting measures at Gram Panchayat level. The issues of generating conviction among farmers on the efficacy of water saving technologies and water sharing institutions were socio-psychological constraints. Lack of Government support for innovative social regulation programmes of water sharing and saving was another constraint.

4.7 Suggestions for Extension Strategies for diffusing water management innovations in similar dryland agro-ecosystems

In this study, it has been mentioned that in the previous section, that farmer respondents have ardently adopted all the innovations related to water management in drylands, i.e., water harvesting, water budgeting, water sharing and water saving through using micro-irrigation systems, and adopting soil moisture conservation agronomic practices. Case study has also provided evidence that farmers get ample benefits in forming water sharing groups for assured crop yields.

In such dryland regions, in order to diffuse these water management innovations among farmers in similar dryland agro-ecosystems, the questions that may arise include: 'What suggestions may have emerged as extension strategies for diffusing these water management innovations among dryland farmers in other similar areas?'. To answer this question, opinions were sought from experts and their consensus was achieved through Delphi technique.

Delphi methodology was employed with a panel of 30 experts, scientists and extension functionaries in the field of agriculture The questionnaire for the first round of Delphi was developed by this group through reviewing existing literature on project reports. Questionnaires for second round were developed from the responses of first round of Delphi using constant comparative method. Subsequently, the questionnaire for round III was developed using the responses from the round II.

Furthermore, consensus was said to be high when quartile deviation was less than or equal to 0.5 and IQR less than or equal to 1, medium when quartile deviation was in between 0.5 and 1 and IQR greater than 1 but less than 2 and low consensus if quartile deviation is more than 1 and IQR more than 2. The levels were: **High** in which the *median* value is 4 and above, while **Medium** in which the *median* value is 3 and **Low** when *median* value is less than 3. Only items having high and medium consensus with high importance were retained for the study. The above procedure was used for all sets of suggestions and the finally arrived list of suggestions are given in Tables here and discussed. Here all four categories of suggestions are presented.

The suggestions are presented here in five categories: technological innovations of conservation agronomy, extension and communication strategies, agricultural education and administrative measures and policy advocacy measures.

Suggestions for Innovations Development Strategies

In the dryland agro-ecosystem what are the suggestions in the form of research in agronomy, soil science and water technology for promotion of better water management innovations among the farmers in similar dryland agro-ecosystems were taken and listed out based on the opinion of the agronomists and water technologists.

Table 4.7.1: Innovation development strategies through research by the water specialists n=23

No	Innovation development strategies	Median value	Q1	Q3	IQR	QD	Remarks
1	Convergence approach is needed to conduct mega project of longitudinal research studies needed for assessing rain water harvesting and rain water use efficiency on villages and watersheds	5	4	5	1	.5	HH
2	Social scientists and management experts need to evolve new research based data on designing, running social institutions for social learning on rain water use.	4	3	4	1	.5	HH
3	Agronomic research is needed on low cost soil moisture conservation innovations, spacing, mulching, mixed cropping, inter-cropping and contingency crop planning.	5	4	5	1	.5	HH
4	Developing IFS (Integrated Farming Systems) model including crops, animals, and trees for efficient utilization of all on-farm resources and generating agro-ecological solutions to farming systems.	4	4	4	0	0	HH
5	Agro-ecological research is needed to generate useful information on basic research on all aspects of selected eco-systems. This basic scientific information is needed to teach farmers.	4	4	5	1	.5	HH

***HH**-high consensus with high importance,*

As can be seen in the table above, the most important suggestions for innovation development strategies included: (i) Need for convergence approach in conducting a mega project of longitudinal research studies for assessing rain water harvesting and rain water use efficiency on villages and watersheds. (ii) Need for research based data on designing, running social institutions for social learning on rain water use by social scientists and management experts, (iii) Need for agronomic research on low cost soil moisture conservation innovations, spacing, mulching, mixed cropping, inter-cropping and contingency crop planning, etc., for dryland agriculture, (iv) Developing IFS (Integrated Farming Systems) model including crops, animals, trees for efficient utilization of all on-farm resources and generating agro-ecological solutions to farming systems.. In all these research programmes for innovation development for achieving sustainable agricultural research in dryland areas was the need for agro-ecological research to generate useful information on basic research on all aspects of selected eco-systems. Such agro-ecological basic scientific information would be useful to teach dryland farmers.

Suggestions on Extension and communication strategies

Extension and communication strategies suggested by the panel of experts were listed out to diffuse water management innovations in similar agro-ecosystems.

Table 4.7.2: Extension and communication strategies as suggested by the experts

n=23

No	Extension and communication strategies	Median value	Q1	Q3	IQR	QD	Remarks
1	Conducting series of training course for all stakeholders to re-orient for dryland agro-ecosystems.	4	4	5	1	.5	HH
2	Developing package of practices on water management innovations and developing training manuals and training kits. Extension literature on agro-ecological principles.	4	4	5	1	.5	HH
3	Developing extension literature on agro-ecological rationale behind contemporary water management innovations.	5	4.5	5	.5	.25	HH
4	Promoting adaptation strategies for farmers to cope with increasing climate variability and climate change.	4	4	5	1	.5	HH
5	Conducting a series of travel workshops in the drought-hit villages and creating awareness and action plans for motivating and mobilizing farmers for community level rain water harvesting and sharing	4	4	5	1	.5	HH
6	Empowering people for social inclusion and equitable distribution of benefits from community managed common property resources like rain water, surface water and ground water.	4	4	5	1	.5	HH

HH*-high consensus with high importance*

As can be seen from the table above, the suggestions for developing extension and communication strategies were: (i) Conducting series of training course for all stakeholders to re-orient for dryland agro-ecosystems, (ii) Developing package of practices on water management innovations and developing training manuals and training kits. Extension literature on agro-ecological principles, (iii) Developing extension literature on agro-ecological rationale behind contemporary water management innovations, (iv) Conducting a series of travel workshops in the drought-hit villages and creating awareness and action plans for motivating and mobilizing farmers for community level rain water harvesting and sharing, and finally, (v) Empowering people for social inclusion and equitable distribution of benefits from community managed common property resources like rain water, surface water and ground water.

Suggestions on Agricultural Education

Contents and methodology of teaching for graduates and post graduates need to be changed for preparing agricultural graduates for dealing with all the critical issues involved in dryland agriculture. These suggestions are given in Table 4.7.3.

Table 4.7.3: Agricultural education strategies as suggested by the water specialists **n=23**

Sl. No	Agricultural education Strategies	Median value	Q1	Q3	IQR	QD	Remark
1	Special course on agro-ecology concepts and principles need to be taught at graduate level to appraise students the principles of cyclical complementarities in agro-ecosystems	4	3	4	1	.5	HH
2	Conducting study tours of farmers to the farms of innovative farmers showing profitable production under deficit irrigation. This will encourage conviction among dryland farmers.	4	3	4	1	.5	HH
3	Re-orienting scientists and students of agriculture to new approach of ecological farming through refresher courses for innovation development in sustainable agriculture.	4	4	5	1	.5	HH
4	Encouraging inter-disciplinary research by agronomists, agricultural engineers, water technologists and physiologists to evolve sound and sustainable technologies based on agro-ecological principles.	5	4	5	1	.5	HH

HH*-high consensus with high importance.*

As can be seen from the table above, the suggestions for engaging scientists and students in the discourse on agro-ecology for sustainable agriculture were listed as: (i) Special course on agro-ecology concepts and principles need to be taught at graduate level to appraise students the principles of cyclical complementarities in agro-ecosystems, (iii) Conducting study tours of farmers to the farms of innovative farmers showing profitable production under deficit irrigation. This will encourage conviction among dryland farmers, (iii) Re-orienting scientists and students of agriculture to new approach of ecological farming through refresher courses for innovation development in sustainable agriculture, and finally, (iv) Encouraging inter-disciplinary research by agronomists, agricultural engineers, water technologists and physiologists to evolve sound and sustainable technologies based on agro-ecological principles.

Suggestions on Administrative measures and Strategies

The items were listed as suggested by the administrative measure and innovative program needs to be developed to address the dryland agro-ecosystem in a novel way for restoring the confidence of farming communities in dryland agro-ecosystem areas.

Table 4.7.4: Administrative and Policy measures as suggested by the water specialist **n=23**

Sl. No	Administrative and Policy measures	Median value	Q1	Q3	IQR	QD	REMARK
1	Policy framework need to be develop for arid and semi-arid zones for judicious ground water management.	5	5	5	0	0	HH
2	Administrative guidelines need to be evolved for rain water harvesting aquifer recharge and ground water use for all drought-hit districts and strictly adhered to.	4	3	4	1	.5	HH
3	Innovative projects and schemes need to be devised with rewards, subsidies, incentives and penalties and additional budget for rain water harvesting, aquifer recharging and judicious use of ground water through micro-irrigation system.	4	3	4	1	.5	HH
4	KVKs in drought-hit districts and in arid and semi-arid areas need to be developed as model training unit for training farmers and extension functionaries and all aspects of eater harvesting, saving and sharing through sprinklers and drip irrigation systems.	4	4	4	0	0	HH
5	Group extension methodologies need to be developed at block level through convergence of all line departments for mobilizing dryland farmers for efficient rain water, and ground water management.	5	4.5	5	.5	.25	HH

***HH**-high consensus with high importance.*

As can be seen from the table above, the suggestions for administrative and policy measures for diffusing water management innovations among farmers in similar agro-ecosystems are listed as below: (i) Policy framework need to be develop for arid and semi-arid zones for judicious ground water management, (ii) Administrative guidelines need to be evolved for rain water harvesting aquifer recharge and ground water use for all drought-hit districts, (iii) Innovative projects and schemes need to be devised with rewards, subsidies, incentives and penalties and additional budget for rain water harvesting, aquifer recharging and judicious use of ground water through micro-irrigation system, (iv) KVKs in drought-hit districts and in arid and semi-arid areas need to be developed as model training unit for training farmers and extension functionaries and all aspects of eater harvesting, saving and sharing through sprinklers and drip irrigation systems, and (v) Group extension methodologies need to be developed at block level through convergence of all line departments for mobilizing dryland farmers for efficient rain water, and ground water management.

At the outset, the most significant suggestions included:

Going through all the issues considered, the most important suggestions for extension strategies can be listed as below:

1. Social scientists and management experts need to evolve new research based data on designing, running social institutions for social learning on rain water use.
2. Conducting a series of travel workshops in the drought-hit villages and creating awareness and action plans for motivating and mobilizing farmers for community level rain water harvesting and sharing.
3. Conducting study tours of farmers to the farms of innovative farmers showing profitable production under deficit irrigation, for encouraging conviction among dryland farmers
4. Group extension methodologies need to be developed at block level through convergence of all line departments for mobilizing dryland farmers for efficient rain water, and ground water management.
5. KVKs in drought-hit districts and in arid and semi-arid areas need to be developed as model training unit for training farmers and extension functionaries and all aspects of eater harvesting, saving and sharing through sprinklers and drip irrigation systems.

CHAPTER -V

SUMMARY AND CONCLUSIONS

Dryland regions experienced severe cases of agro-ecological crisis due to erratic rainfall patterns and depleting ground water resources. Rain water harvesting, storing, saving and sharing by farmers of dryland agro-ecosystem assumes great significance in surviving water crisis that is looming large in arid and semiarid regions of India. Innovations related to judicious use of scarce water resources were evolved by the farmers and refined by the few non-formal researchers and NGOs activists. These water management innovations are being practiced by large number of farmers in drylands with promising results. These innovations are driven by scientific problem-solving approaches and agro-ecological concepts and principles. These new non-formal innovations needed to be studied for their agro-ecological rationale for diffusing the contemporary water management innovations in arid and semi-arid regions.

These innovations have been evolved through the traditional wisdom and indigenous technical knowledge evolved by farmers over long years of their experiences of survival in the particular agro-ecosystems. Although these are essentially indigenous in nature, these have been tested and refined by few interested researchers, informal water technologists and non-government agency's water experts and farmers and hence can be termed ***'Contemporary water management innovations'***. The scientific explanations behind the agro-ecological components of contemporary water management innovations need to be understood thoroughly by the farmers. Hence, in order to understand the different contemporary water management innovations being practiced by farmers of dryland agro-ecosystem, a research investigation is planned with the following objectives.

1. To analyse the causes of agro-ecological crises faced by farmers of dryland agro-ecosystem.

2. To document and analyse the water harvesting, water sharing and water management practices in sustainable agriculture.

3. To assess the level of knowledge of agro-ecological bases of water management practices in dryland agro-ecosystem and analyse their correlates.

4. To measure the extent of adoption of farmers on the selected water management practices and analyse their correlates.

5. To analyse the constraints and suggest extension strategies for diffusing water management practices in similar agro-ecological conditions.

This study was conducted in eight villages of three mandals in Ananthapur district of Andhra Pradesh. The villages were selected purposively because of the presence of functional water sharing groups. A sample of 120 farmers were selected random from these villages. Focused group discussion, personal interview, case study and Delphi technique were used for data collection and analysis. A sample of 30 comprising mixed group of scientists, NGOs activities and other experts were sought to enlists constraints and suggestions in diffusing these, contemporary water management innovations in similar agro-ecological conditions.

Salient findings of the study

4.1 Causes of agro-ecological crisis

Among the different sets of causes related to erratic rainfall, depleting ground water, depleting soil moisture, declining soil fertility, conservative agronomic practices and other causes of adverse market prices, deteriorating agroforestry and agro-ecological balance in Nature, the final list of fourteen major causes of agro-ecological crisis perceived by farmers as most severe and most important, were derived through data reduction process of factor analysis.

They are: (i) *Early withdrawal of monsoons (ii) Lack of contingency crop-water planning, (iii) Long dry spells leading to drought, (iv) Over exploitation of ground water resources without any replenishment, (v) Neglect of pro-active intervention*

(vi)Depletion of soil moisture, (vii) Soil moisture stress leading to poor nutrient uptake from dried up soil, (viii) Monoculture depleting soils leading to imbalances in soil fertility, (ix) Loss of fertile top soil due to erosion, (x) Ill effects of agro-chemicals on

soil structure, (xi) Destruction of agro-ecological aspects of crop fields, (xi) Dwindling yield stability due to cultivating commercial crops, (xiii) Destabilizing ecological balance in nature and (xiv) Non-supportive and exploitative market prices and market forces. All the causes are again intercalated and further aggravated leading to agro-ecological crisis in dryland agro-ecosystems.

It is the greed and unthoughtful interventions of man that led to destruction of precarious agro-ecosystems in dryland farming systems. Complete neglect of pro-active interventions, and timely actions of water harvesting have further worsened the situation that the agro-ecosystem got destroyed beyond repair jeopardizing the very survival and livelihoods of dryland farmers and their families.

4.2 Profile characteristics of the farmers

About 100 farmer respondents were not owning any bore wells. Only 20 respondents had bore wells and were sharing ground water through micro-irrigation in the sample villages. This shows that the all the farmers came together to form water sharing groups and thereby get mutual benefits. Twenty bore well owning farmers have vowed to provide protective irrigation to all 100 farmers when rains may fail and crops are in dire need of a live saving irrigation. The profile characteristics were:

i. Majority of the farmers (39.16 %) were middle aged.
ii. Most of the farmers (60.8%) were educated between primary and higher education levels.
iii. Majority of farmers (63.3%) lived in joint families
iv. Majority of farmers (71.7%) lived in medium sized families.
v. Majority of farmers (66.8%) had more than 20 years of farming experience.
vi. Majority of farmers (60%) were small farmers possessing irrigated land.
vii. Majority of farmers (56.7%) were small farmers possessing dryland land.
viii. Majority of farmers (89.2%) had small orchards of less than one hectare.

ix. Majority of Farmers (64%) were earning moderate levels of annual income between 51 thousand and 90 thousand rupees.

x. 51.66 percent of the respondents were small farmers

xi. Majority of farmers (91.67%) had frequent contact with friends and relative in the localite channels

xii. Majority of farmers (70%) most often contacted NGO activists for information among cosmopolite channels

xiii. Majority of farmers (67.5%) attended group meetings of NGO activists.

xiv. Majority of farmers (42.5%) were low on the goal commitment

xv. Majority (69.17%) the farmers were moderate on social capital

xvi. Majority (69.16%) of farmers were moderate on adherence to social norms.

4.3 Case study of Water Management Institutional Innovation

The water management innovations were recorded and documented are: water harvesting innovations, water saving innovations, soil fertility innovations, and conservation agronomic practices, and water sharing institutions. A case study analysis revealed the way the water sharing group of farmers were able to grow crops through the use of social regulatory measures in water sharing groups, micro-irrigation and conservation agronomic practices and were able to enhance their incomes.

The major reflection of the case analysis was that all the farmers in the water users group had a strong belief in their group effort and were thoroughly convinced about the efficacy of rain water harvesting, storing and sharing for the benefits of all the dryland farmers. They seem to be highly empowered.

Other reflections were:

1. Intervention of the NGO *Annadata* happened at the most opportune time and their staff started mobilizing people for group actions. At first farmers were skeptical, hesitant and reluctant to join hands. Through several meetings and discussions, farmers were appraised of the changes happening in the village due to global climate change and rains becoming quire unpredictable and erratic.

2. But once the water sharing group got initiated results got realised in the first crop season itself with assured crop harvests for every member's family. Farmers could get lifesaving irrigation at critical stages of crop. They were saved from worries and misery and were quite happy as all the farmers could fetch good returns from farming.

3. Farmers have started appreciating the value of rain water, promoted water harvesting in the village through collecting water in tanks, increasing percolation of rain water through digging deep trenches across the slope of their lands, summer ploughing to keep the fields ready for water absorption and percolation, reducing run off and erosion of top fertile soil.

Section 4.4 Level of knowledge of agro-ecological bases of water management Innovations

All the farmers shared the agro-ecological principles and rationale behind the community participation and community management of common property resources of rain water, through rain water harvesting, saving, sharing and using judiciously through micro-irrigation systems. All the farmers have comprehensively understood the agro-ecology behind hydrological cycle of water harvesting and water saving for future contingencies. The knowledge levels of agro-ecological principles and hydrological cycle were very high among the majority of farmers.

i) Majority of farmers (65.8) had very high level of knowledge on water harvesting innovations and the rationale behind them

ii) Since all the farmers were members of water sharing groups, all of them had very high levels of knowledge of agro-ecological rationale behind the water saving innovations, micro-irrigation innovations and soil moisture conservation agronomic practices for growing the irrigated dry crops.

iii) Majority of farmers (65.8%) possessed high levels of knowledge on water harvesting innovations and their agro-ecological rationale.

iv) Almost all the farmers possessed full knowledge on water saving, micro-irrigation and conservation agronomic practices for soil moisture conservation in their crops.

v) Among the correlates, goal commitment and contact with extension cosmopolite channels were significantly associated with level of knowledge of water management innovations.

vi) Goal commitment and social norms contributed significantly to the prediction of level of knowledge of farmers.

Section 4.5: Extent of adoption of farmers on the selected water management practices

About 60.83 percent of farmers had high (70% - 86%) extent of adoption of all the water management innovations. With respect to water harvesting innovations, about 65.8 percent of farmers had adopted 12 of the 14 different practices, indicating a very high extent of adoption among farmers.

(i) Majority of farmers (45.1%) were adopting water harvesting innovations from moderate to high levels.

vii) Among the correlates, farming experience, goal commitment social norms, contact with extension cosmopolite channels and level of knowledge were significantly associated with extent of adoption of water management innovations.

viii) Goal commitment, social norms and level of knowledge contributed significantly to the prediction of extent of adoption of farmers.

Water sharing groups were another most important institutional innovations farmers need to work together for large scale adoption by all farmers for rain water harvesting, saving and sharing through community mobilization and sustained participation. Water sharing groups get legitimized sanction for group survival and livelihood security in complex risk-prone dry land agro-ecosystems.

Section 4.6 Constraints coming in the way of diffusing Water Management Innovations in similar agro-ecological conditions

Constraints coming in the way of in diffusion of water management practices in similar dryland agro-eco-system were:

1. The formal research organizations in agriculture and water science and technology do not have the inclination and drive to take up large scale

longitudinal research studies to evolve new technologies on ran water harvesting and rain water use efficiency.

2. No research based information is available on rain water harvesting, rain water use through micro-irrigation among members of water user groups.
3. No government support for research programme for large scale rain water harvesting, ground water aquifer recharge and water sharing groups of farmers.
4. Socio-political dynamics of dominance social exclusion of resource-poor and *dalits* may not allow for formation of water sharing group of farmers.
5. Neglect of traditional wisdom, and existing water conservation structures had caused erosion of indigenous knowledge and social capital of villages
6. Lack of conviction of farmers in the efficacy of water management innovations and lack of initiative and faith in people's participation in forming water user groups and their accountability.
7. Non-co-operation of bore well owners and other people to work together for the social benefit all villagers.
8. Lack of policy framework for managing ground water resources and lack of innovative social regulation programme for judicious use of rain water and ground water resources.
9. District administration did not have or designed new guidelines on reward and punishment for encouraging community level water harvesting and sharing.

4.7 Suggestions for extension strategies for diffusing Water Management Innovations in similar agro-ecological conditions

Suggestions for innovation development. Extension and communication and for administrative and policy strategies were given as below:

1. Social scientists and management experts need to evolve new research based data on designing, running social institutions for social learning on rain water use.
2. Convergence approach is needed to conduct mega project of longitudinal research agro-ecological studies needed for assessing rain water harvesting and rain water use efficiency on villages and watersheds

3. Conducting a series of travel workshops in the drought-hit villages and creating awareness and action plans for motivating and mobilizing farmers for community level rain water harvesting and sharing.

4. Developing extension literature on agro-ecological rationale behind contemporary water management innovations

5. Special course on agro-ecology concepts and principles need to be taught at graduate level to appraise students the principles of cyclical complementarities in agro-ecosystems

6. Conducting study tours of farmers to the farms of innovative farmers showing profitable production under deficit irrigation, for encouraging conviction among dryland farmers

7. Group extension methodologies need to be developed at block level through convergence of all line departments for mobilizing dryland farmers for efficient rain water, and ground water management.

8. Administrative guidelines need to be evolved for rain water harvesting aquifer recharge and ground water use for all drought-hit districts

9. KVKs in drought-hit districts and in arid and semi-arid areas need to be developed as model training unit for training farmers and extension functionaries and all aspects of eater harvesting, saving and sharing through sprinklers and drip irrigation systems.

Implications of the Study

This study brought out lessons for extension system as such studies revealed the farmers' way of understanding and analysing their problems, assessing their local resources and evolving new solutions to solve their water scarcity problems. The study also highlighted the significance of water user groups and their better functioning due to inclusion of mandatory clauses of strictly adhering to social norms set by the group. Water sharing groups are the results of active government involvement to address session's issues of scarce water resources in dryland areas. The active role of NGO's in mobilizing the farmers understand the real agro-ecological issues involved in water harvesting and sharing.

The contemporary innovations in this study were: a) institutional innovations: Farming groups of water users, Formulating norms, procedures and standardizing the processes for continuous up scaling b) water harvesting innovations: Increasing percolation of rainwater, reducing surface runoff losses, recharging ground water aquifers, water saving technology through micro irrigation through drip as well as sprinklers, and soil moisture conservation agronomic practices. All these practices can be promoted as a full package to other dryland farmers in the country.

Suggestions for Future Research

1. For wider generalization of findings, similar studies could be conducted in other districts and states (in arid and semi-arid regions) as the present study was confined to only one district.
2. A multi- disciplinary research team must explore the prospects of contemporary water management innovations practices and their agro-ecological rationale, as this one is major component of sustainable agriculture.
3. In depth studies may be conducted for water sharing institutional innovations in order to enhance their efficiency and effectiveness among farmers.
4. Content analysis of messages related to contemporary water management practices through print media and programmes in radio and television may be studied.
5. Extension strategies of government and non-government organizations for promotion of contemporary water management practices may be studied for their efficiency.

"An Analytical Study of Agro ecological bases of Contemporary Water Management Innovations in Sustainable Agriculture"

ABSTRACT

Rain water harvesting, storing, saving and sharing by farmers of dryland agro-ecosystem assume great significance in surviving water crisis that is looming large in arid and semiarid regions of India. Innovations related to judicious use of scarce water resources were evolved by farmers and refined by few non-formal researchers and NGOs activists and these are termed ***'contemporary water management innovations'*** which are now being practiced by majority of farmers in drylands. These new non-formal innovations needed to be studied for their agro-ecological bases of contemporary water management innovations and their adoption.

This study was conducted in eight villages of three mandals in Ananthapur district of Andhra Pradesh. The villages were selected purposively because of the presence of functional water sharing groups. A sample of 120 farmers were selected randomly from these villages. Focused group discussions, personal interviews, case study and Delphi technique were used for data collection and analysis. A sample of 30 mixed group of scientists, NGOs activists and other experts were sought to enlist constraints and suggestions in diffusing these contemporary water management innovations in similar agro-ecological conditions. The major findings are: Among the sample of the farmer respondents, only 20 for users owned bore wells and shared with 100 farmers who did not own any bore wells. Water sharing has been accepted and farmers have formed and managing the water sharing institutions in villages.

A critical analysis of causes of agro-ecological crisis was delineated through focused group discussion, personal interview and factor analysis. Among the causes related to erratic rainfall, *early withdrawal of monsoons, lack of contingency crop-water planning,* and *long dry spells leading to drought* were most important. Among the causes related to depleting ground water resources, *neglect of pro-active intervention, over exploitation of ground water resources without any replenishment, soil moisture stress due to lack of field ponds* were most important.

A case study analysis revealed the way the water sharing group of farmers were able to grow crops through the use of social regulatory measures in water sharing groups, micro-irrigation and conservation agronomic practices and were able to enhance their incomes.

All the farmers shared the agro-ecological principles and rationale behind the community participation and community management of common property resources of rain water, through rain water harvesting, saving, sharing and using judiciously through micro-irrigation systems. All the farmers have comprehensively understood the agro-ecology behind hydrological cycle of water harvesting and water saving for future contingencies. As the farmers have had undergone great stress periods during times of agro-ecological crisis, they were all appreciating the value of scarce water resources for their livelihood security.

Constraints in the way of diffusing CWMI in similar agro-ecosystem were found to be community mobilization and convincing farmers for group actions. Suggestions given for diffusing CWMI in similar agro-ecological conditions included convergence of actions from all stakeholders, government and non-government agencies and policy advocacy strategies for promoting water harvesting and sharing among dryland farmers.

The study concluded that contemporary water management innovations were well accepted and integrated into the culture of the dry land farmers as they comprehensively understood the agro-ecological bases for their survival and sustenance in dry land area.

"स्थायी कृषि में समकालीन जल प्रबंधन नवाचारों के कृषि पारिस्थितिकीय आधारों का एक विश्लेषणात्मक अध्ययन"

सारांश

शुष्क भूमि कृषि-पारिस्थितिक प्रणाली के किसानों द्वारा वर्षा-जल संग्रहण, भंडारण, बचत और साझा करना भारत के शुष्क और अर्ध-शुष्क क्षेत्रों में बड़े पैमाने पर उभरते हुए पानी संकट में काफी महत्व रखता है। दुर्लभ जल संसाधनों के न्यायिक उपयोग से संबंधित नवाचारों को किसानों द्वारा विकसित किया गया था जो कुछ गैर-औपचारिक शोधकर्ताओं और गैर सरकारी संगठनों के कार्यकर्ताओं द्वारा परिष्कृत किया गया और जिसे 'समकालीन जल प्रबंधन नवाचार' कहा जाता है। आजकल देश के कुछ शुष्क क्षेत्रों में अधिकांश किसानों द्वारा एसे नवाचार का अभ्यास किया जा रहा है। इन समकालीन जल प्रबंधन नवाचारों को अध्ययन करने की आवश्यकता है जिससे कृषक इस कृषि-पारिस्थितिकीय सिद्धांतों के तार्किक रूप को समझ कर किसान उसे अपना सके।

यह अध्ययन आंध्र प्रदेश के अनंतपुर जिले में तीन मंडलों के आठ गांवों में किया गया था। कार्यात्मक जल साझाकरण समूहों की उपस्थिति के कारण सौदेश्य इन गांवों को चुना गया था। इन गांवों से 120 किसानों का एक नमूना यादृच्छिक रूप से चुना गया था। केन्द्रित समूह चर्चाएं, व्यक्तिगत साक्षात्कार, वृत्तांत और डेल्फी तकनीक का उपयोग द्वारा डेटा संग्रहण किया गया था। वैज्ञानिकों, एनजीओ कार्यकर्ताओं और अन्य विशेषज्ञों के 30 मिश्रित समूह का नमूना इसी तरह के अन्य कृषि-पारिस्थितिक स्थितियों में इन समकालीन जल प्रबंधन नवाचारों को फैलाने में बाधाओं और सुझावों को शामिल करने के लिए किया गया था।

प्रमुख निष्कर्ष : किसान उत्तरदाताओं में, उपयोगकर्ताओं के लिए केवल 20 ही स्वामित्व वाले बोर कुएं हैं जिसे 100 किसानों के साथ साझा किया गया है जिनके पास कोई भी बोर कुएं नहीं है। इन कृषकों द्वारा जल साझाकरण स्वीकार कर लिया गया है और किसानों ने गांवों में जल साझा करने वाले इकायियों का गठन और प्रबंधन किया है।

कृषि-पारिस्थितिकीय संकट के कारणों का एक महत्वपूर्ण विश्लेषण केंद्रित समूह चर्चा, व्यक्तिगत साक्षात्कार और कारक विश्लेषण के माध्यम से चित्रित किया गया था। अनियमित वर्षा से संबंधित कारणों में, मानसून की जल्दी वापसी, आकस्मिक फसल-पानी की बजट योजना की कमी, और सूखे की वजह से लंबे सूखे मंत्र सबसे महत्वपूर्ण थे। भूजल संसाधनों के कमी होने से संबंधित कारणों में से, सक्रिय सकाल हस्तक्षेप की उपेक्षा, बिना किसी पुनर्भरण के भूजल संसाधनों का शोषण, खेतों के पास तालाबों की कमी के कारण मिट्टी नमी की कमी सबसे महत्वपूर्ण था।

एक वृत्तांत विश्लेषण से पता चला कि किसानों के जल साझाकरण समूह जल साझाकरण समूहों, सूक्ष्म सिंचाई और संरक्षण कृषि संबंधी प्रथाओं में सामाजिक नियामक उपायों के उपयोग के माध्यम से फसलों को विकसित करने में सक्षम थे और उनकी आय में वृद्धि करने में सक्षम थे।

सभी किसानों ने वर्षा जल संचयन, बचत, साझाकरण और सूक्ष्म सिंचाई प्रणाली के माध्यम से समझदारी से जल का उपयोग करके वर्षा के पानी के आम संपत्ति संसाधनों के समुदाय भागीदारी और सामुदायिक प्रबंधन के पीछे कृषि-पारिस्थितिक सिद्धांतों और तर्क को साझा किया। सभी किसानों ने वर्षा-पानी की संग्रहण के प्राकृतिक जल-चक्र और भावी आकस्मिकताओं के लिए पानी की बचत के पीछे कृषि-पारिस्थितिकी को व्यापक रूप से समझ लिया है। चूंकि कृषि-पारिस्थितिक संकट के समय किसानों में तनाव रहता था अतः वे सभी अपनी आजीविका सुरक्षा के लिए दुर्लभ जल संसाधनों के मूल्य की सराहना कर रहे थे।

इसी तरह के अन्य कृषि-पारिस्थितिकी प्रदेशों में 'समकालीन जल प्रबंधन नवाचारों' को फैलाने के रास्ते में कृषक समूह संगठन तथा समूह कार्यों के लिए प्रेरित करना और किसानों को इन नवाचारों में विश्वास दिलाना प्रमुख बाधाएं पायी गई । इन बाधाओं को दूर करने के लिए किसानों के बीच जल संचयन और साझा करने के प्रचार के लिए सभी हितधारकों, सरकार और गैर-सरकारी एजेंसियों और नीति वकालत रणनीतियों के कार्यों का अभिसरण शामिल था।

अध्ययन में निष्कर्ष निकाला गया कि समकालीन जल प्रबंधन नवाचार सूखे भूमि किसानों की संस्कृति में अच्छी तरह से स्वीकार्य और एकीकृत किए गए थे क्योंकि वे शुष्क भूमि क्षेत्र में उनके अस्तित्व और जीवित रहने के लिए कृषि-पारिस्थितिक आधारों को व्यापक रूप से समझते थे।

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APPENDIX - I

Interview Schedule for Farmer Respondents

Kindly score the causes perceived by during agro-ecological crisis

S. No.	Rainfall related causes	More severe	Severe	Less severe
1.	Washing away, as waste, of rain water through excessive run off without getting percolated.			
2.	Late on set of monsoons			
3.	Early withdrawal of monsoons a few days after start of rainfall			
4.	Weak monsoon winds in the beginning of the reason resulting in very little rain			
5.	No rain in the mid-crop season leading to water shortages			
6.	Uneven distribution of rainfall with no rain during the most important crop growth stages			
7.	Unpredictable rainfall			
8.	Heavy rainfall sometimes and heavy drought- farmers get anxious and distresses feeling helpless.			
9.	Untimely rainfall- Heavy rains when not necessary and drought spell when rain is required			
10.	Due to many rain- less days, the drought spell gets elongated.			
11.	Rain- water use efficiency being very less or poor			
12.	Lack of facilities for rain water harvesting and storage			
13.	Early withdrawal of winter rains affecting rabi crops			
14.	Not being able to choose appropriate crops when rainfall is very low.			

S. No.	Ground water related causes	More severe	Severe	Less severe
1	Everyone is cultivating crops on their own. There is no cooperation among farmers.			
2	Farmers have pumped out all ground water by competitive digging of bore wells. They have wasted ground water resources. They have also wasted lot of money in digging up bore wells.			

S. No.	Ground water related causes	More severe	Severe	Less severe
3	Life-saving irrigation is not available when necessary during a critical crop growth stage.			
4	Ground water reserves have depleted and aquifers got dried due to excessive pumping out of ground water.			
5	Early withdrawal of monsoons leading to lower quantities of ground water reserves.			
6	Lack of facilities (Water tanks) for storing rain water and allowing for recharging of aquifers under the bore wells.			
7	Rain water not being able to reach deep ground water reserves			
8	Leaving away damage check dams and other water conservation structures without regular maintenance timely repairs.			

S. No.	Soil moisture related causes	More severe	Severe	Less severe
1	Hot winds reduce soil moisture and lets the soil to dry up totally.			
2	Very low relative humidity in fields			
3	Due to excessive weed growth, water uptake by weed and excessive Evapo-transpiration from foliage, soil moisture gets depleted.			
4	Lack of water harvesting and storage structures in the fields			
5	Lack of facilities for slow recharging of soil layers from rainfall run off.			
6	No practice or tradition of application of tank slit and soil in crop fields			
7	Due to heavy destruction or complete removal of green grass cover on the soils, it becomes very difficult to protect and conserve soil moisture of such denuded lands.			
8	Due to depletion of soil moisture, the roots of the crop plants may fail to take up nutrients from dried up soil.			

S. No.	Soil fertility related causes	More severe	severe	Less severe
1	Continuously cultivating crops without application of any farm yard manure and other organic manures.			
2	Los of soil fertility due to leaching of soil nutrients into deep layers of soil			
3	Due to soil erosion, soil nutrients get lost			
4	Loss of soil micro nutrients adversely affection soil fertility			
5	Due to heavy rain water run-off, loss of top soil and plant nutrients			
6	Loss of ammonia of urea fertilizers into atmosphere			
7	Flow of polluted water in crop fields			
8	Indiscriminate use of chemical pesticides			
9	Bulk density of soil gets increases due to heavy application of chemical fertilizers. So the water absorption capacity and holding capacity water in soil gets reduced.			
10	Sometimes the vegetative growth may be good due to balanced use of fertilizers. But the reproduction stage growth period reduced leading to lower yields.			
11	Damage of top soil and structure happens due to heavy rain water run off erosion.			
12	Loss f soil fertility due to fragmentation of lands caused by braking up of joint families and sharing of lands amongst brothers.			

S. No.	Agronomic Practices related causes	More severe	severe	Less severe
1	Growing high-water demand crops like sugarcane and paddy ground water resources get depleted			
2	Ground water reserves get depleted by growing commercial cash crops			
3	By growing continuously same crop year after year, agro-ecosystem of the region and its ecological balance in nature gets destroyed beyond repair.			
4	By growing same crops according to the choice of farmers yield may get stagnated of declined			
5	Not being able to go for mulching with the weed grasses pulled out and covering soil to protect soil from heating up losing soil moisture.			

6	Completely not adopting any of the traditional cultural practices			
7	Not being able to efficiently using the crop residue biomass.			

S. No.	**Agro-Forestry related causes**	**More severe**	**Severe**	**Less severe**
1	Reduction in total rainfall due to cutting down and removal of forests			
2	Cutting down trees on the field bunds cutting down trees of forests in the neighboring areas.			
s. No.	**Market prices related causes**	**More severe**	**Severe**	**Less severe**
1	The prices at which framers sell their crop produce are not decide by themselves but by the buyers			
2	The prices at which farmers buy their inputs for agriculture are decided by the sellers and not by the farmers.			
S. No.	**Nature's Ecological Balance related causes**	**More severe**	**severe**	**Less severe**
1	Occurrence of imbalance in nature of proportion of harmful and beneficial insects and other animal populations.			
2	Incidence of diseases and pests in crops			
3	Low level of adoption of natural control measures of pests and diseases of crops.			

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1. Village: .... **2. Mandal / Block**: .... **3.District: Ananthapur**

4. Name of the respondent: ______________________**5. Sex: Male / Female**. **6. Age:** ....

7. Educational status: Illiterate / Primary ☐ ☐ High School ☐ / College ☐

8. Family type: Nuclear ☐ Joint ☐ 9.Family Size (No. of family members): _________

10. Occupation: Main: ___________ Secondary: ______________ Any other: ___________

11. Farming experience: ___________

12. Size of land holding: ________ guntalu __________ acres

Land category	Owned	Leased in	Leased out
a.Irrigated land			
b.dryland			
c.orchard			

13. Total income: (₹/year)

i. From farming (crops): ....
ii. From livestock rearing: ……………………
iii. From non-farm activity: ....
iv. From other business: ……………………….
v. From deposits of migrant family members: …………………

14. Personal Localite channels: From where do you seek information about agriculture/dairy/goattery/sheep rearing, and related technology information services?

Personal Localite channels		Frequency of use / exposure			
	Do you prefer this channel? Yes / No	**Most often (4)**	**Often (3)**	**Sometimes (2)**	**Never (1)**
1.Neighbours					
2. Friends / Relatives					
3.Opinion Leaders					

15. Extension personnel & Cosmopolite channels: From where do you seek information about agriculture/dairy/goattery/sheep rearing, and related technology information services?

Extension personnel & Cosmopolite channels	Do you prefer this channel? Yes / No	Most often (4)	Often (3)	Sometimes (2)	Never (1)
1. V.L.W.					
2. A.D.O					
3. B.D.O.					
4. Cooperative official					
5. Expert from research					
6. Stockman					
7. ATMA					
8. KVK					
9. NGO					
10. Community Resource Person					

16. Mass Media exposure: From where do you seek information about agriculture/dairy/goattery/sheep rearing, and related technology information services?

Mass Media exposure	**Do you prefer this channel? Yes / No**	**Most often (4)**	**Often (3)**	**Sometimes (2)**	**Never (1)**
1. Newspaper					
2. Radio					
3. T.V.					
4. Pamphlet/Bulletin etc.					
5. *Krishi Mela*/Exhibitions					
6. Group Meetings					
7. Films / videos					
8. Mobile (simple)					
9. Mobile (android) / Smart phone)					
10. Internet					

17. Goal commitment:

1. Do you talk regularly with fellow villagers and project functionaries in order to give your participation?

   Always ☐ Sometimes ☐ Never ☐
2. Do you share your experience with others?

   Always ☐ Sometimes ☐ Never ☐
3. Did you help in the formation of the water sharing group? Yes ☐ No ☐
4. How frequently do you absent yourself in the water sharing group's meetings and discussion?

   Mostly ☐ Sometimes ☐ Never ☐
5. Did you compete for election to any office bearer in the water sharing group or in any farmer's interest group? ☐ Yes ☐ No
6. Do you actively participate in any of the monitoring and evaluation of the programmes? Yes ☐ No ☐

18. Social capital:

A. Social interaction:

A) In this water sharing system, how many persons do you contact and develop inter personal relations and communication

People	**Numbers**	**Frequency of interaction**		
		Frequently/regularly	**Often**	**Rarely**
Fellow farmers				
Bore well owner				
WASSON officials				
Village activists				
Community resource persons				
Mandal level officials				
Water sharing group office bearers				
Village level officials				
Extension functionaries Agricultural				
Extension functionaries Irrigation				
Bore well mechanic				
Others				

B) In this water sharing system, how do you develop inter-personal relations?		
	Yes/No	How
a. As fellow farmers		

b. As beneficiaries of bore well water		
c. Water sharing group member		
d. As member of society		
e. As friend or neighbour		
f. Water technician		
g. NGOs officials		

C) Do you get any additional benefit from the fallowing people?

If yes – from where? a) Tube well owner b) neighbor c) fellow farmer

D) What is the intensity of relation more between you and others?

People	More	Moderate	Less
Fellow farmers			
Bore well owner			
WASSON officials			
Village activists			
Community resource persons			
Mandal level officials			
Water sharing group office bearers			
Village level officials			
Extension functionaries Agricultural			
Extension functionaries Irrigation			
Bore well mechanics			
Others			

E) Whether the mutual relations based on friendship and compatibility? Yes No

F) Did you encounter any enmity or adverse situations among your fellow farmers and others? Yes No

G) How do you resolve the conflicts that may have arisen among the member of water sharing groups?

a. How do you resolve? ____.
b. How do you get rid of? ____.
c. How do you establish relation? ____________________________________.

H. Faith:

Statement	Agree	Undecided	Disagree
1. Due to this water sharing process people have get divided?			
2. The farmer who owns the bore well actually becomes a well wishes for all other farmer?			
3. From the time this foundations was laid for this new system of water sharing, farmers got very good benefits?			
4. Only due to the assurance given by the tube well owner farmers could get their crops irrigated on time?			
5. In this system of water sharing, tube well owner may not be considered faithful, hence many problem may arise?			
6. Sometimes the tube well owner may not provide water to other farmers only to trouble then want only?			
7. We, the farmers have to talk again and again to request the tube well owner to provide as adequate irrigation water for our crops?			
8. We share frequently with others our successful happy experiences among other farmers and thereby spread the feeling of optimization on our society?			
9. We have to helped in talking with other farmers in initiating and managing the planned program of water sharing system in our village?			

I. Norms:

Statements	Always	Often	Never
1. I feel relaxed as I am assured of protective irrigation for all farmers from the bore well owners?			
2. Fellow farmers help me in getting adequate protective irrigation at the right irregularly?			
3. I get good assurance from the bore well owner for irrigation water?			
4. I do not face any problems working with water sharing group's farmers?			
5. Sharing water for protective irrigation for all is running quite well smoothly?			
6. All the farmers in the water sharing group interact frequently either personally or through telephone talks?			
7. No one has cheated me ever in this water sharing system?			

19. Social Norms

No.	Statement	SA	A	U	D	SD
1.	I do not take any decision that go against my religion or my group / community					
2.	I am careful about the approval of my decision by my Neighbours and fellow villagers					
3.	The approval of my behavior by my family, friends, colleagues and fellow farmers is as important as my farm enterprise					
4.	I do not care about what society thinks of me as long as my agri-business is profitable					
5.	I do not care about what others say of my lifestyle					
6.	I take punitive action on those who suggest me ideas which are against social norms even if they are brilliant					
7.	I stopped growing paddy and/or sugarcane on the insistence of my family and friends and my farmers' interest group members					
8.	Starting a personal farm business is generally not appreciated in my society					
9.	Conformity to the norms of the society is more important for me than to pursue my personal / business goals					

Any other Notes:

____

____

____

____

____

Knowledge Test

Farmers' knowledge on water management practices in the areas where rainfed crops are being cultivated, an effort is made here to assess the level of knowledge of farmers on water management practices. Towards this end, a knowledge test was prepared. Kindly give correct answers to the following questions.

Sl. No.	Water management practices	Yes	No
1.	Is it better to provide water to your crops under the saved water irrigation system by releasing water through irrigation channels so that it spreads on its own in the entire field (through flood irrigation)?		
2.	Is it better to provide water to your crops under the saved water irrigation system through sprinklers?		
3.	Is it better to provide water to your crops under the saved water irrigation system through drip irrigation through water pipes?		
4.	What are the key (most important) cultivation stages of ground nut crop to provide irrigation (from saved water)? a. Before sowing b. 7-10 days after sowing c. Flowering stage (50 DAS) d. 70-75 DAS e. Nut growing stage (90 DAS)		
5.	What are the key (most important) cultivation stages of tomato crop to provide irrigation (from saved water)? a. Before transplanting tomato seedlings b. Every 7-10 days c. Flowering stage d. Tomato fruiting (fruit formation and growth) stage		
6	It is not correct (good) to provide flood irrigation to crops by pumping out ground water source through bore pumps for saved water irrigation.		
7	For saved water irrigation, joint water management groups were formed distributing ground water equally among all group member farmers.		
8	By providing irrigation water facility for each farmers' ground nut crops most important crop growth stages, through micro irrigation systems, the ground water resources will be used judiciously the bore wells do not get dried up.		
9	It is good for every farmer to dig his own personal tube well in his own field and grow whatever crops he may wish by exploiting ground water resources in dryland areas.		
10	All our ground water resources have got depleted because all resourceful rich farmers have resorted to competitive digging of bore wells and growing crops.		
11	By using soaking pits, rainwater, without getting wasted as run off, slowly percolates into soil and get gathered in the ground water resources and thereby increasing our ground water resources.		

12.	What actions need to be taken up for increasing the water level of our ground water resources? The silt deposited in big water bodies needs to be renewed and layers of stones have to be put up. Thus, more water gets scored as percolation increases?		
13	Small tanks near the crop fields need to be repaired for strong tank bunds and stone layering needs to be done so that tank bunds do not break.		
14	Dried up big deep open wells need to be repaired by digging out the silt deposits at the bottom and covered with stone pellets for increasing percolation and capacity of holding more water.		
15	In areas where run off (water) is very high soaking pits need to be dug up; deep trenches across the slope need to be dug up. By doing so, rain water can be allowed to get soaked and percolated into soil to increase water storage in underground layers and also not wasted as run off causing soil erosion.		
16	For judicious use of ground water resources, all the farmers used to form jointly a society water users group. Farmers' need to choose only such crops that need very few irrigations. They need to conserve water. They need to formulate an agreement for providing conservation irrigation only when it is necessary to save the crop. All the farmers need to discuss and decide by consensus a few terms and conditions for running the water user group. All farmers need to adhere to these terms and conditions compulsorily without any fail. They need to make plans for cropping for the whole year through proper water budgeting procedures.		
17	If we want to judiciously (& efficiently) use ground water resources (which are depleting day by day) farmers need to take joint action for increasing ground water resources. They need to adopt new practices like sprinklers and drip irrigation system that conserve water. Thereby they would increase the area under irrigated crops and enhance the water use efficiency of ground water resources.		
18	What benefits would accrue if the rainfall run off is showed down and stopped? Rain water gets soaked into the soil and ground water resource will increase. The water so conserved is utilized in irrigating crops whenever is required. This water rain water gets into the recycling process and re-use cycle.		
19	In uplands the rain water run off takes away with great force the fertile top soil of crop lands. This soil loss by rainfall water run off erosion can be stopped.		
20	By stopping or reducing the speed of run off of the rain water flow, the flooding conditions can be avoided and the inundation of low level lands and crop fields can be avoided.		
21	If the rain water can be collected and saved/stored at the place where rain falls, the purity and safety of water can be ensured. We can protect the rain water from being polluted with harmful chemical fertilizers and pesticides of the crop fields. Thus the water tanks will get filled with pure fresh water that is safe for drinking by animals and human beings.		

22	Wastage of rain water run off can be stopped and stored in tanks and wells. Such stored water can be used for giving lifesaving irrigation during long dry spells and acute drought. Such a facility is possible if rain water run-off is stopped or slowed down.		
23	By increasing soaking or percolation of rain water the water table of open wells and bore wells can be increased.		
24	In uplands, catchment area can be increased through digging soaking pits, deep trenches across slope and so rain water percolation can be increased. By doing so the speed of run-off and the subsequent water erosion and soil loss can be reduced. Other losses can be reduced.		
25.	Ground nut sowing needs to be done in closer lines thereby reducing soil moisture evaporation loss. Close spacing covers the soils and acts as a live soil mulch. By line sowing all types of intercultural operations need to be taken up easily.		
26.	Mixed cropping and inter-cropping may be practiced in ground nut cultivation by growing such crops like cowpea, pigeonpea, jowar, mungbean, urdbean, castor, gogunta, bajra and korra (Italian millet or foxtail millet). By resorting to intercropping, even if a few crops fail due to drought and long dry spells, other crops will survive and provide some yields. By growing and millets, some food grains may be available as food for family. If the yields are good, the surplus can provide extra income. Contingency planning is practiced in dryland conditions.		

Extent of adoption schedule:

Please state the extent of adoption of the following contemporary water management Innovations and institutional innovations among farmers.

S. No.	Item	Full Adoption	Partial adoption	Non-adoption
a.	**Water harvesting practices**			
1.	Have you adopted restoration of traditional water bodies technology?			
2.	Have applied control gully erosion to restore water bodies?			
3.	Have you constructed check dams to retain water in the fields?			
4.	Are you using percolation tank for ground water recharge?			
5.	Are you using slug test for constructing water harvesting structure?			
6.	Have you prepared recharge pit by using different materials viz, stones, sand layer, neylon net, gravel etc.			
7.	Have you adopted digging soaking pits for ground water recharge?			
8.	Are you practicing de-silting for ground water recharge as well as restoration of water in the pond?			
9.	Have you adopted stoning by using stone pellet to recharge ground water?			
10.	Have you adopted digging deep trenches to increased catchment area for rainwater percolation?			
11.	Have you used small slots in casing pipe to allow the rain water to enter into the borewells?			
12.	Have you adopted Small tanks near the crops fields for strong tank bunds?			
b.	**Water saving technology**			
13.	Are you using renovated Traditional form pond for water harvesting?			
14.	Have you adopted institutional innovations like water sharing groups for Joint water management?			
15.	Have you adopted surface water saving and ground water technique for water harvesting?			
c.	**Micro-irrigation practices**			
16.	Have adopted sprinkler irrigation methods for water saving?			

17.	Have adopted drip irrigation methods for water use efficiency based on slug test?			
d.	**Agronomic conservation practices.**			
18.	Are you giving irrigation at the critical stages of crops?			
19.	Have you adopted close line spacing for crops as live mulch?			
20.	Have you adopted intercropping and mixed cropping?			
21.	Have you adopted contingent crop planning?			
22.	Have you adopted growing irrigated dry crop to save soil moisture?			
23.	Are you using destroyed weed as soil mulch?			
24.	Are you using pruned biomass as soil mulch?			
25.	Are you using anti-transpirant for soil moisture conservation?			
26.	Are you applying FYM, and other suitable manure in the field to enhance soil moisture conservation?			
27.	Are you practicing contour farming to check erosion as well as to conserve soil moisture?			
28.	Are you practicing strip cropping with soil water conserving crops along the contour?			
29.	Are you practicing sub soiling for water conservation?			
30.	Have you adopted the basin listing along the slope?			
31.	Have you adopted soil mulching with different material like plastic or any other natural material?			
32.	Have you adopted conservation tillage viz, deep tillage with fine harrowing?			

APPENDIS - II

All Tables of Factor Analysis of Causes of Agro-ecological crisis

Causes of agro-ecological crisis related to Rainfall

Communalities

	Initial	Extraction
RF2	1.000	.434
RF3	1.000	.915
RF4	1.000	.920
RF5	1.000	.724
RF12	1.000	.770
RF13	1.000	.721
RF14	1.000	.720

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.023	28.903	28.903	2.023	28.903	28.903	1.953	27.898	27.898
2	1.965	28.071	56.975	1.965	28.071	56.975	1.847	26.380	54.278
3	1.217	17.383	74.358	1.217	17.383	74.358	1.406	20.080	74.358
4	.848	12.119	86.477						
5	.505	7.216	93.693						
6	.317	4.534	98.227						
7	.124	1.773	100.000						

Extraction Method: Principal Component Analysis.

Rotated Component Matrix[a]

	Component		
	1	2	3
RF2	-.164	.147	.621
RF3	.955	.001	-.058
RF4	.957	.062	-.006
RF5	-.133	-.051	-.839
RF12	-.181	.801	.310
RF13	.086	.813	.230
RF14	-.200	-.718	.405

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 4 iterations.

Causes of agro-ecological crisis related to Ground water

Communalities

	Initial	Extraction
GW2	1.000	.800
GW3	1.000	.750
GW5	1.000	.131
GW6	1.000	.654
GW8	1.000	.734

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.916	38.320	38.320	1.916	38.320	38.320	1.865	37.303	37.303
2	1.153	23.051	61.371	1.153	23.051	61.371	1.203	24.068	61.371
3	1.040	20.799	82.170						
4	.460	9.208	91.377						
5	.431	8.623	100.000						

Extraction Method: Principal Component Analysis.

Rotated Component Matrix[a]

	Component	
	1	2
GW2	-.123	.886
GW3	.707	.499
GW5	.073	.354
GW6	.803	.096
GW8	.836	-.188

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Causes of agro-ecological crisis related to soil Moisture

Communalities

	Initial	Extraction
SM1	1.000	.593
SM3	1.000	.553
SM4	1.000	.716
SM8	1.000	.699

Extraction Method: Principal Component Analysis.

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.469	36.737	36.737	1.469	36.737	36.737	1.463	36.581	36.581
2	1.091	27.276	64.012	1.091	27.276	64.012	1.097	27.432	64.012
3	.890	22.257	86.269						
4	.549	13.731	100.000						

Extraction Method: Principal Component Analysis.

Rotated Component Matrix[a]

	Component	
	1	2
SM1	-.178	.749
SM3	-.214	-.712
SM4	.835	.136
SM8	.830	-.102

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Causes of agro-ecological crisis related to Soil Fertility

Communalities

	Initial	Extraction
SF1	1.000	.844
SF2	1.000	.743
SF3	1.000	.794
SF4	1.000	.569
SF8	1.000	.707
SF9	1.000	.700
SF10	1.000	.810

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.098	29.976	29.976	2.098	29.976	29.976	2.057	29.388	29.388
2	1.548	22.107	52.083	1.548	22.107	52.083	1.566	22.374	51.762
3	1.522	21.747	73.830	1.522	21.747	73.830	1.545	22.068	73.830
4	.720	10.280	84.110						
5	.547	7.821	91.931						
6	.383	5.471	97.402						
7	.182	2.598	100.000						

Extraction Method: Principal Component Analysis.

Rotated Component Matrix[a]

	Component		
	1	2	3
SF1	.911	.040	.108
SF2	.626	.501	-.317
SF3	.116	.883	-.029
SF4	-.210	.693	.212
SF8	-.030	.115	.832
SF9	.154	-.008	.823
SF10	.867	-.201	.132

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

Causes of agro-ecological crisis related to Agronomic Practices

Communalities

	Initial	Extraction
AP2	1.000	.836
AP3	1.000	.853
AP4	1.000	.852
AP7	1.000	.891

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.905	47.614	47.614	1.905	47.614	47.614	1.879	46.980	46.980
2	1.528	38.209	85.823	1.528	38.209	85.823	1.554	38.844	85.823
3	.364	9.102	94.926						
4	.203	5.074	100.000						

Extraction Method: Principal Component Analysis.

Rotated Component Matrix[a]

	Component	
	1	2
AP2	.295	.866
AP3	.923	.030
AP4	-.222	.896
AP7	.944	.011

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Other Important Causes of agro-ecological crisis

Communalities

	Initial	Extraction
AGF2	1.000	.610
EB1	1.000	.650
OT1	1.000	.840
OT2	1.000	.822

Extraction Method: Principal Component Analysis.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.752	43.798	43.798	1.752	43.798	43.798	1.750	43.750	43.750
2	1.169	29.231	73.029	1.169	29.231	73.029	1.171	29.279	73.029
3	.782	19.557	92.586						
4	.297	7.414	100.000						

Extraction Method: Principal Component Analysis.

Rotated Component Matrix[a]

	Component	
	1	2
AGF2	-.226	-.748
EB1	-.199	.781
OT1	.916	-.019
OT2	.906	.041

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.