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CONTENTS

RAINFED AGRICULTURE IN INDIA: IMPORTANCE AND PRIORITIES

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Abstract

Indian economy is mainly dependent on agriculture, which contributes 21 per cent of the country's GDP and 60 per cent of the employment. Rainfed agriculture occupies 67 percent net sown area, contributing 44 percent of food grains and supporting 40 percent of the population. In view of the growing demand for food grains in the country, there is a need to increase the productivity of rainfed areas from the current 1 t ha^{-1} to 2 t ha^{-1} in the next two decades. The quality of natural resources in the rainfed ecosystem is gradually declining due to over exploitation. Rainfed areas suffer from bio-physical and socio economic constraints affecting the productivity of crops and livestock. In this context a number of economically viable rainfed technologies have been discussed. These include soil and rainwater conservation measures, efficient crops and cropping systems matching to the growing season, suitable implements for timely sowing and saving of labour, integrated nutrient and pest management (INM and IPM). To provide stability to farm income during drought and to utilize the marginal lands, different alternative land use systems like silvipasture, rainfed horticulture and tree farming systems were evolved and demonstrated on watershed basis. Integration of livestock with arable farming systems and incorporation of indigenous knowledge in farming systems perspective are also discussed. Formation of self help groups, use of innovative extension tools like portable rainfall simulators and focus group discussions to help for quick spread of the rainfed technologies in the farmers' fields are highlighted. The farming systems approach in rainfed agriculture not only helps in addressing income and employment problems but also ensures food security.

Introduction

The Indian economy is mainly dependent on agriculture, which contributes 21percent of country's capital GDP and 60 percent of employment potential. India made rapid strides in food production during last three decades culminating in self-sufficiency and surplus production. However, feeding the ever-increasing population through the next millennium remains an uphill task. The country will have to feed about 1.3 billion people by the year 2020 requiring 5-6 mt of additional feed grains every year. Besides, the problem of poverty and malnutrition have their own implication to national food security. Over 70 percent of Indian population, which is predominantly rural, do not have proper access to food and non-food commodities due to poor employment and infrastructure facilities. This reminds all those concerned with the country's food security of the daunting task ahead in order to ensure access to food to the growing population. Rainfed agriculture occupies 67 percent of net sown area, contributing 44 percent of food grain production and supporting 40 percent of the population. Even after realization of full irrigation potential of the country, 50 percent of net sown area will continue as rainfed (CRIDA, 1997).

At present 95 percent of area under coarse cereals, 91 percent under pulses. 80 percent under oilseeds, 65 percent under cotton and 53 percent under rice is rainfed (Government of India, 1994). Livestock forms an integral part of rainfed ecosystem and two out of every three animals are thriving in these regions. These areas are spread-out throughout the length and breadth of the country with semi-arid to sub-humid environments, shallow textured light soils to deep textured black and alluvial soils with varied effective crop growing periods from 90 to 180 days.

Scenario of food demand and resources

The food grain requirement of the country is 243 mt by the year 2007-08, out of which food demand could be about 104 mt of rice, 84.3 mt of wheat, 34.4 mt of coarse grains and 21.5 mt of pulses, 9.5 mt of oilseeds and 119.5 m t of milk and 110.7 mt of vegetables and for fruits 70.5 mt. The food grain requirements have been projected for 2025 at 308 mt with low growth population of 1286 million. But at higher population growth scenario (1333 million), the projected food grain production is 320 mt by 2025 (Kumar et al,2005).More than the calories, ensuring protein security will become an important issue in view of the predominantly vegetarian habits of the populace and the dwindling availability of vegetable (pulses) proteins whose current supply is about 25 g head^{-1} day^{-1} against the minimum dietary need of about 70 g.

The agriculture production increased from 50 mt to over 200 mt, between 1950-2000, thanks to green revolution. This, however, had its own costs in terms of degradation of land and water resources, loss of plant biodiversity, shift of agricultural land to non-agricultural uses, polluted environment, widening gap between the rich and the poor. Thus, physical access to food was the most important food security challenge in the past but economic and access to food has now become the most important cause of hunger and ecological access to food might become the most important concern in the next millennium owing to the damage now being done to land, water, flora, fauna and atmosphere.

Shrinking of natural resources

The per capita availability of agricultural land in India was 0.46 hectares in 1951 which decreased to 0.15 hectares in 2000 as against the global average of 0.6 ha. Number of persons per hectare of net-cropped area was 3 in 1951, 6.5 in 2000 and is estimated at 8 persons in 2025. This situation of rapidly declining land to man ratio is likely to worsen further owing to competitive demand for food, fibre, fuel, fodder, timber and developmental activities such as urbanization and industrialization, special economic zones, mining, road construction and reservoirs etc.

Constraints of production in rainfed areas

The rainfed lands suffer from a number of biophysical and socio-economic constraints which affect productivity of crops and livestock. These include low and erratic rainfall, land degradation and poor productivity (Abrol and Katyal, 1994), low level of input use and technology adoption, low draft power availability (Mayande and Katyal, 1996), inadequate fodder availability low productive livestock (Singh, 1997), and resource poor farmers and inadequate credit availability.

Strategies for Sustained Food Production in Rainfed Region

Identification of viable rainfed technologies

A number of economically viable rainfed technologies have been developed over the years in the country to address the problems of food production in rainfed agriculture through CRIDA and its network centresfor the last three decades. These technologies have been evolved after refining them in farmers' field through Operational Research Projects, Institute Village Linkage Program (IVLP) and farm science centres. These include simple practices like off-season tillage in rainfed Alfisols and related soils for better moisture conservation and weed control. Farmers in Operational Research Project (ORP) areas of Hyderabad adopted this practice in sorghum and castor and realized yield advantage by 40 percent over traditional practice. Lack of adequate draft power with many small farmers, however, is one of the major constraints to popularize this practice. Custom hiring of tractor is effective solution of farm mechanization on these lands.

Soil and rain water conservation techniques

Efficient conservation of rainwater is the central issue in successful dryland farming. Extensive trials conducted by the soil conservation and dryland research centres have led to the identification of a number of inter-terrace land treatments besides contour and graded bunds (Sharma et al., 1982). These techniques are location specific and the benefits from their adoption are highly variable depending on the rainfall intensity, slope and texture of the soil besides the prevailing crop/cropping system. (Katyal and Das, 1993).

Farmers have not widely adopted mechanical measures like contour bunds, graded bunds, grassing of waterways and construction of farm ponds without the government support due to financial constraints. However, studies at Hyderabad, Bangalore and Anantapur revealed that more than 80 percent farmers follow simple conservation measures like sowing across the slope, opening of dead furrows and key line cultivation. The yield improvement by adoption of soil and water conservation measures vary between 12 and 20 percent which are at times not convincing enough to farmers. However, cumulative effects are significantly visible at some locations. Since such measures help in long-term conservation of resources, these are implemented through the Government of India or the respective State Government sponsored watershed management programmes.

Timely planting of crops

Timely sowing and precision are essential for getting good plant stand, higher yield and optimum utilization of rainfall and reduction in the incidence of pests and diseases. A number of demonstrations have been taken up in farmers fields through ORPs, KVKs and IVLP programmes in different rainfed regions of the country .In case of sorghum and castor in farmers fields of Hyderabad , a fifteen day delay in sowing led to reduction of 300 and 850 kg/ha compared to normal sowing . Inadequate availability of farm implements and draft are major constraints. However, seeding and interculture experiments developed by CRIDA and AICRPDA centres helped in overcoming the constraints to some extent.

Adoption of improved crop varieties

A number of improved varieties and hybrids were evaluated in the farmers fields to identify suitable ones for matching growing periods for inter and sequence rainfed cropping systems. For example, farmers gained additional benefit ranging from Rs. 2000-4000/ha by adopting improved varieties of sorghum, castor and sunflower in Alfisols of Hyderabad.

Efficient crops and cropping systems

To achieve appropriate land use, efficient inters and sequence-cropping systems were recommended based on soil type, rainfall and length of growing seasons. The studies at Hyderabad indicated only 25 percent farmers adopted 2:1 ratio of sorghum-pigeonpea. Whereas 45 percent of farmers adopted the finger millet + pigeonpea system (8:1) ratio in Alfisols of Karnataka and maize + soybean system (2:2) was accepted by Ranchi farmers. Groundnut + pigeonpea (7:1) was widely accepted by the farmers in Rayalseema of Andhra Pradesh. Some of the constraints for wider adoption by the farming communities are preference for fodder genotypes in cereals rather than grains for feed to live stock, lack of suitable farm implements to seed in different ratios, delay in planting of kharif for double cropping systems. These have to be refined under on-farm situations for greater acceptance by the farmers

Farm implements

Proper tillage and precise placement of seed and fertilizers in the moist zone are most critical to for successful crop establishment in drylands. Since the sowing of crops must be completed in a short span of time, use of appropriate implements is necessary to cover large area before the seed zone dries out. Suitable implements have been recommended for various locations to meet this requirement. These are designed to suit the soil type, crop and the draught power availability. In many cases, the existing local implement used by the farmers have been improved to increase their working efficiency (Gupta and Sriram, 1987).

Studies at CRIDA in farmers' fields of Telangana indicated that use of the drill plough for sowing of castor and sorghum crops showed no variation in yields of the crops and plant as compared to farmers practice resulted 1 ½ times more coverage compared to farmers' method of seeding . Two labourers who are required for placement of seed and fertilizer in farmers methodcan be saved with the drill plough. Thus a saving of Rs. 187/ha is possible wit a drill plough compared to the traditional plough and plant system.

Nutrient management

Fertilizer recommendations in rainfed crop production have been made primarily for NPK along with the conjunctive use of chemical, organic and bio-fertilizer (Rao and Das, 1982). Inclusion of legumes in cropping systems can supplement fertilizer N to the extent of about 20 kg N per ha. Conjunctive use of fertilizer N with FYM, croppings of luecaena and gliricidia help in reducing the requirement of fertilizer by 50 percent (Reddy et al., 1996).

Integrated pest management (IPM)

Pests and deceases constitutes a major constraint to increased food production. Crop losses due to pest attack range from 10-30 percent depending on the crop and environment. Complete crop failure may occur in case of serious attack. Indiscriminate use of the pesticides in rainfed crops will lead to harmful side effects such as direct toxically to the applicator or consumer, development of strains or pests resistant to pesticides, resurgence of pest species, outbreak of secondary pesticides, destruction of non-target organisms such as parasites and predators and accumulation of harmful residues of food products. Integrated pest management is one of the alternatives for the chemicals used for pest management. IPM encourages the most comfortable and ecologically sound combination of available pest suppression techniques and to keep the pest population below economic threshold. Easily adaptable and economically viable integrated pest management strategies have been developed for the control of major pest in rainfed crops like cotton and pulses.

Alternate Land use Systems

Despite evolving a number of production technologies, arable cropping in drylands continues to suffer from instability due to aberrant weather. To provide stability to farm income and also utilize the marginal lands for production of fodder, fuel wood and fibre, a number of alternative land use systems were evolved based on location specific experimentation and cafeteria studies (Singh, 1988). In addition to the above general guidelines, specific experiments have been carried out to develop land use practices for different categories of soils across the centres integrating annual crops with the perennial component in order to utilize the off-season rainfall (Katyal et al., 1994). Different alternate land use systems include agri-silviculture, silvi-pasture, agri-horticulture, alley cropping etc.

Integration of live stock with rainfed farming systems

Live stock is treated as a part of farming system in rainfed agriculture in India. The soil, plant, animal cycle is the basis for all feed used by the animals. The livestock in the rainfed regions are weak. Farmers in this area often sell their cattle due to the scarcity of fodder. In India the land holdings are being reduced with increased population pressure. Hence, land not suitable for agriculture has to be diverted for raising fodder need of animals through the appropriate alternate land use system such as improved pasture, silvipasture, hortipasture and tree techniques.

Integration of the technologies through watershed approaches

The concept of watershed is important in efficient management of water resources. As the entire process of agricultural development depends upon the status of water resources, the watershed with distinct hydrological boundary is considered ideal for taking up a development programme. In brief, planning and designing of all soil conservation structures are carried out considering the peak runoff. In this context, the watershed concept is of practical significance. Also, the entire development needs are to be taken up on topographic considerations from ridge to valley.

Resource conservation measures

Details about conservation measures adopted in cultivated lands have been delineated by Katyal et al., (1995) and Sharma and Mishra (1995). Based on the nature and type of barriers and their cost, the conservation measures in arable lands can be divided into three categories: (i) Hardware treatments (ii) Medium software treatments and (iii) Software treatments.

Farming system approach

Of late, it has been increasingly recognized that unlike irrigated areas, it is difficult to develop profitable technologies for heterogeneous agro-ecological and socio-economic conditions of small holders in arid and semi-arid regions (Osten et al., 1989). Since, the problems are complex ,addressing only a component of the farming system, e.g crop variety, fertilizer use or even crop husbandry *per se* is not expected to bring about a significant increase in the productivity as witnessed in irrigated areas. The extension strategy should be such as to match this challenge. The farming systems perspective, dovetailed on watershed approach therefore can be the appropriate management strategy for such regions (Chambers, 1991).

The following steps constitute the farming systems mode for research, both on-station and on-farm (Watershed)

- PRA and assessment of socio-economic conditions of people.
- Identification of ITK (indigenous technical knowledge)
- Collection of available technological knowledge on various components of the farming system – arable farming, animal husbandry, water harvesting, management of wastelands and alternate land use systems etc.
- Focus group (farmers) interaction to identify appropriate technology for different categories of farmers.
- Identification of lead farmers to function as facilitator in technology application and adoption.
- Identification of points of synergy among systems components.
- Structuring of technological components with maximum synergy.
- Phasing of program over the project period

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RAINWATER HARVESTING : ISSUES AND STRATEGIES

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Soil erosion

Soil erosion is the process of loosening soil particles and transporting them from one place to another. Basically, weather agencies like water and wind in motion are responsible for effecting soil erosion by dislodging the soil particles and transporting them.

TYPES OF SOIL EROSION

Soil erosion can be categorized into two types viz., geologic erosion and accelerated erosion.

1. Geologic erosion

It is the erosion, which takes place in undisturbed natural conditions of soil. In undisturbed conditions, and equilibrium is reached between climate and the vegetative cover which protects the soil from erosion. It is slow erosion process and is compensated by the formation of soil under natural weathering process.

2. ACCELERATED EROSION

When the land is put under cultivation, the equilibrium existing between the soil, climate and the vegetative cover is disturbed. As a result, the removal of surface soil due to natural agencies like wind and water takes place at faster rate than that of soil forming process. Such an erosion process is known as accelerated erosion whose rates of soil loss are more than geologic process. It also depletes the fertility of agricultural lands.

Based upon the agency causing erosion, it is classified as water erosion, wind erosion and coastal erosion. Water and wind erosions are more predominant in agricultural lands. Here, water erosion and its types are discussed below as it is more prevalent and damage is severe when compared to other types of erosion.

WATER EROSION

This may further be classified based on the stage of erosion process by flowing water as:

RAINDROP OR SPLASH EROSION

Water in the form of rainfall is responsible for rain drop erosion. The raindrops falling with the considerable velocities strike the soil particles and detach them by impact force as splash. This primary stage is called raindrop or splash erosion.

SHEET EROSION

Subsequent to the splash, a thin layer of top soil is detached and transported by the flowing rain water (runoff) on land surface. This type of soil erosion is known as sheet erosion. Lands subjected to sheet erosion will loose a thin layer of top fertile soil every year.

RILL EROSION

It is the advanced stage of sheet erosion forming finger like rills on land surface. These rills are smoothened every year by farming operations. But, in subsequent years of rill formations, rills slowly increase in their number as well as shape and size affecting crop production.

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GULLY EROSION

It is the advanced stage of rill erosion. When water flows through the unprotected hills the further develop in size and shape and form deep cuts in the form of gullies on land surface or in hills. Gullies so formed if not treated, will expand year after year. Ravines are a form of gullies.

STREAM BANK EROSION

The erosion of stream banks by flowing water is known as stream bank erosion in certain areas where rivers or streams change their course, stream banks are eroded in an accelerated pace. It damages adjoining agricultural lands, highways, roads and bridges.

SLIP EROSION

It is another natural phenomenon like land slides and slips caused due to saturation of steep hills and slopes. This process is referred to as slip erosion. It not only disturbs the natural landscape but also cause damage to highways and add additional sediment load to streams and rivers.

Water erosion control measures

The water erosion control methods can be grouped into two types.

I. Agronomic farming

Contour farming

Contour farming is the practice of cultivating land along the contours laid across the slope of the field. It reduces the flow velocity of water and retards soil erosion. Row crops like maize, sorghum, and pearl millet are well suitable for contour cultivation.

Strip cropping

It involves growing of different crops in alternate strips across the slope of land. They serve as vegetative barriers to control erosion. Strip cropping can be practiced in three ways. They are control strip, field strip and buffer strip cropping.

Contour strip cropping consists of growing alternate strips of erosion permitting and erosion resisting crops along the contours. In field strip cropping, the strips are laid across the slope in uniform width without taking exact contours into consideration. This is useful on uniform slopes with high infiltration rates in buffer strip cropping, permanent strips of grasses are located either in badly eroded areas or in areas that do not fit into a regular rotation. The width of strips of erosion permitting and erosion resisting crops depend upon the factors like slopes, soil texture, rainfall characteristics, type of crops. In general, sleeper the slope, the greater is the width of erosion resisting crop and smaller the width of erosion permitting crop. However, strip cropping is not followed in India on large scale.

Table 1: Crop widths for strip cropping

Slope (%)	Width of erosion permitting crop (m)	Width of erosion resisting crop (m)
1	**50**	**10**
2	**30**	**6**
3	**15**	**5**

Conservation tillage

It is any tillage system, which leaves at least 30% of the soil surface covered with residues after a crop, is planted. It implies that a greater quantity of plant residues would be present at all times during the interval between crops. It may also be any tillage sequence that reduces loss of soil or water relative to conventional tillage, which is a form of non-inversion tillage that retains protective amounts of residue on the surface. Different conservation tillage methods for row crop and small grain agriculture are given in Table 2.

Table 2: Mechanized conservation tillage methods

S. No.	Row crop agriculture	Small grain agriculture
1.	Narrow strip tillage • No tillage • Zero till • Slot plant • Strip rotary tillage	Stubble mulch farming Stirring machines • One way disk • Offset disk • Tandem disk
2.	Ridge planting • Till plant • Planting on ridge	Chisel plows Field cultivators Mulch treaders
3.	Full width-no plow tillage • Fall and/or spring disk • Fall or spring chisel	subsurface tillage • Sweep plows • Rod weeder with semi chisels
4.	Full width-plow tillage • Plow plant • Spring plow-wheel-track plant	Ecofallow Direct drill

II. Engineering or Mechanical Measures

A. Contour bunds

Bunds constructed along the contours or with permissible deviation from contours are called contour bunds. Bunding is preferred over the areas where annual rainfall is <500 mm and soil moisture is limiting for crop production. Mostly, bunds are constructed on the land slopes varying from 2 to 10%. For the lands below 2%, agronomic measures can be adopted for in-situ moisture conservation. Contour bunds are preferred in the permeable soils like alluvial, red and shallow black soils. However, bunds are not preferred in the dry soils or deep black soils.

Design of contour bunds involves fixing vertical interval and horizontal interval between two consecutive bunds, their deviations from actual contour and the cross-section of the bund. Vertical interval (VI) can be calculated by using the formula.

$$VI = (s/a \; + b)$$

Where,

S=land slope, %

a, b= Constants depending upon the soil, and rainfall characteristics. Cropping programme of the area.

Horizontal interval (HI): $\frac{VI}{s} \times 100$

The criterion for spacing of contour bunds is to intercept the water before it attains erosive velocity. This depends on slope, soil, and rainfall, cropping programme and conservation practices adopted. The non-erosive velocities one 0.5 m/s for sandy soils and 0.6 to 0.75 m/s for clay soils. The cross-section of bund can be determined based on the volume of water impounded between on contour bunds, and the seepage line across the bund.

Graded bunds consist of constructing wide and shallow channels across the slope very near to the contour ridge. These channels induce and regulated the excess runoff water and remove the same with non-erosive velocities. Graded bunds are preferred in the areas whose channel rainfall area is >800 mm. The grade of the channel varies from 0.2 to 0.4% depending on soil type.

Bunds with growing of vegetarian along sides and top of the bund to protect from raindrop impact, biotic interference etc are called live bunds. Generally, grasses like khus-khus. Cenchrus ciliaris and legume like gliricidia are preferred for the above purpose.

B. Terracing

i. Broad based terraces

They are also called as ridge terraces or broad bunds. The terrace consists of a channel with a ridge on its lower and whose function is to drain surface runoff or it absorb runoff Thus, these are called drainage or absorption terrace. These can be adopted in slopes < 10%.

ii. Bench terraces

Bench terraces are preferred in the land slopes varying from 10 to 33% on hill slopes the cost is limiting factor in adoption of bench terraces, they are adopted where intensive culture is practiced on hill slopes. Bench terraces consist of constructing step like fields and contours by half cutting and half filling. Original slope is converted into level fields nominating all hazards of soil erosion.

iii. Level or table top bench terraces

Bench terraces with level tops are adopted in the medium rainfall, having deep and highly permeable soils. As there is no slope given to the benches, most of the rainfall falling in the area is to be absorbed by the soil and very little water goes as surface drainage terraces can be used for paddy cultivation where irrigation facility is available.

iv. Inward sloping bench terraces

Terraces with benches sloping inward are adopted in the high rainfall areas where a major portion of the rainfall is to be drained as surface runoff. In such terraces, a suitable at the inward end of each of these terraces is to be provided to remove excess runoff a suitable outlet.

v. Outward sloping bench terraces

Bench terraces with outward sloping are adopted in low rainfall areas with permeable soils. In these terraces, a strong bund with spillway arrangement would suffice remove excess runoff occurring in case of heavy rainfall events. Excess runoff will flow one terrace to another.

vi. Puertorican type bench terraces (California type)

In this type of terrace, the soil is excavated little during every plowing and developing bench terraces by pushing the soil down hill against vegetative barrier laid along contour. Such a terrace is developed over the years above bench terraces.

vii. Stone terraces

They are small embarkments constructed with stones across the hill slopes. These are justified where stones are available in adequate quantities near to the site. These can be used for growing annual crops and perennial tree plantations.

Design of bench terraces

Consists of determining type of bench terrace, terrace spacing, terrace width and terrace cross-section. Selection of bench terrace depends upon the rainfall and soil conditions. Terrace spacing is the vertical interval between two terraces. It depends on the depth of cut. The factors that limit the depth of cut are the soil depth and land slope. The terrace spacing is so selected that depth of cut and fill are balanced. The width of terrace designed such that is enables economic and convenient agricultural operations. As in the case of contour bunds, the vertical interval between terraces can be determined. The width of terrace is calculated from the following formula.

$$VI = \frac{ws}{100-ns}$$

Where,

VI	=	Vertical interval, m
w	=	width of terrace, .m
n	=	batter slope (1/2 : 1 to 1:1)
s	=	land slope, %

Soil and Water Conservation through watershed management

Watershed is a manageable hydrologic unit with common boundary draining runoff from farthest point to a common outlet at the lowest elevation point. The size of watershed can be selected based on the possibilities of developing it with soil and water conservation structures with 3 to 5 years time. Mini or micro watershed can be the basis for planning and execution.

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FARM PONDS: Planning, Design, and Construction

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Rainfall is a basic resource for all the forms of water in semi arid tropics of India. Though the annual average rainfall of the country is 1200 mm, it varies in both space and time affecting the availability of water for different sectors. India uses 80% of the available water in agriculture keeping the remaining 20% for drinking, industry and energy sectors. The growing population puts tremendous pressure on the water resources. The annual per capita water availability has decreased from 5000 m^3 in 1950 to 1300 m^3 in 2010 and projected to decrease further to below 1000 m^3 by 2025 (MOWR,2011). Added to this, the country may face climate change in future predicting more frequent floods, droughts, extreme events of rainfall etc. with increased temperature (IPCC, 2007). The food grain production in India is calculated by irrigated and rainfed areas by 60% and 40% respectively. Most of the pulse and oil seeds production (80%) comes from rainfed areas. Rainfed areas are suffer from severe land degradation and poor socio economic base of farmers.

Several management options are available at the farm scale to increase rainfall use efficiency. Some of these are management of crop residues to improve infiltration and reduce sediment levels, construction of farm ponds for collection of excess rainfall flowing from the farm area, crop rotations and soil amendments (Freebairn *et al.,* 1986). Several researchers have shown that on-farm runoff collection into dugout farm ponds and supplemental irrigation can increase and stabilize the crop production (Krishna *et al.,* 1987). There is abundant scope and opportunity for harvesting excess runoff in the rainfed region in different states of the country (Wani, et al., 2003, Sharma et al, 2009) Among several interventions, farm ponds is the most important one in the integrated water management practices and other natural resource management. Farm ponds would help the farmers for on farm water management by using stored water for tackling the drought or dryspells during the season.

Planning of Farm Pond

Farm pond

Farm Pond is a dug out structure with definite shape and size having proper inlet and outlet structures for collecting the surface runoff flowing from the farm area. It is one of the most important rain water harvesting structure constructed at the lowest portion of the farm area. The stored water must be used for irrigation only. Inadvertently, some people use the farm ponds as ground water recharge structures which is not correct as per the definition. For recharging the ground water, the structures require high capacity and are generally located in the soils having high infiltration rates and are called percolation tanks. Percolation tank is meant for only recharge purpose and not for irrigation. Such structures conceptually differ in their hydrology and physical location. A farm pond must be located within a farm drawing the maximum runoff possible in a given rainfall event. A percolation pond can be dug out in any area where the land is not utilized for agriculture.

Farm ponds have a significant role in rainfed regions where annual rainfall is more than or equal to 500 mm. If average annual rainfall (AAR) varies between 500 to 750 mm, the farm ponds with capacity of 250 to 500 m^3 can be constructed. If AAR is more than 750 mm, the farm ponds with capacity more than 500 m^3 can be planned particularly in black soil regions without lining. It was observed from the field experience and if present rainfall pattern changes; atleast two to three rainfall events producing considerable runoff are possible in a season making farm ponds an attractive proposition. Farm ponds conserve the natural resources like soil and nutrients apart from water and acts as flood control structure by reducing peak flows in the watersheds or given area of catchment.
Depending on the source of water and their location; farm ponds are grouped into four types:
1) Excavated or Dug out ponds
2) Surface ponds
3) Spring or creek fed ponds and
4) Off stream storage ponds.

Soil type
India has 30% alfisols, 35% vertisols and 35% of other soils including alluvial, laterite, etc., in rainfed areas (Virmani, 1991). The distribution of different soils of India is given in. For construction of farm pond, the soils must have low hydraulic conductivity with minimum seepage and percolation so that water can be retained for more time in a farm pond. Soils with a low infiltration rate are most suitable for construction of pond. The black soils have good potential for rain water harvesting without lining as the seepage losses are minimum. The seepage losses are more in sandy soils and their mixed textures and they require lining for storing water for more time. The soils having outcrops and stones must be avoided for digging farm ponds. The soil profile depth must be investigated before digging of the pond. The soils having good depth of >1 m, free of stones, low Ph, Ec and ground water level may be choosen for site selection for farm pond. Peat soils have special problems, since they are usually very acidic in nature and need sufficient liming. Soils rich in limestone create special problems of precipitating phosphate and iron.

Soil depth
The depth of soil is important where rain water harvesting systems are proposed. Deep soils have the capacity to store harvested water for longer duration. Soils having more than 1m are ideal for construction of farm ponds. More the depth of soil, the depth of farm pond will be more and reduces the evaporation losses.

Topography

The topographic features of the farm catchment area may vary from place to place and proposed land for pond construction must have minimum earth excavation so that cost can be reduced with increased storage. Depending up on the capacity of the farm pond, the contour survey is conducted to determine the slope, drainage pattern within farm. However, for small catchments of 1-5 ha land, a reconnaissance is sufficient to identify the location for farm pond. The contour survey can be done by using dumpy level with staff or a total survey station which gives the digital map of the farm with contours. The farm pond must be located within farm itself looking into the slope and drainage flow pattern to the convenience of the farmer.

Drainage / Catchment area

The drainage/catchments area which produces surface runoff for storage in farm ponds is very important from hydrology point of view. The structure must get filled at least once in the season so that the farmers can use the water for critical irrigation during dry spells. The characteristics of a catchment that directly affect the runoff yield are the slope of the area, infiltration of the soil, vegetation, land use and shape of the catchment. These interrelated factors are variable and site-specific. If the drainage area is too small in relation to the pond size, the pond may not adequately fill, or the water level may drop too low during extended periods of hot, dry weather. The high intense rainfall events would cause soil erosion and the runoff carries the silt load into the farm pond. These problems can be solved through proper soil and water conservation treatments. In order to achieve the desired depth and capacity of a pond to be proposed, the inflow must be reasonably free of silt from an eroding catchment. The best protection is adequate erosion control through in situ moisture conservation or land management practices (Ridge and furrow, Broad bed furrow, Compartmental bunds, Contour bund and Graded bund etc). On the drainage contributing area. Land under permanent cover of trees or grasses are the most desirable drainage area. If such land is not available, treat the watershed with proper conservation practices to control erosion before constructing the pond. The catchments must be selected in such a way that, the drainage from farmsteads, feedlots, sewage lines, dumps, industrial and urban sites and other similar areas does not reach the pond.

Design of Farm Pond

Rainfall analysis

Rainfall is one of the most important and critical hydrological input parameter for the design of farm ponds. Its distribution varies both spatially and temporally in semi arid regions of the country. The quantity of surface runoff depends mainly on the rainfall characteristics like intensity, frequency and duration of its occurrence. The high intense rainfall exceeding infiltration capacity of soil can produce more runoff than the event with low intensity for longer duration. Apart from the physical characteristics of the catchment area contributing to produce surface runoff, the rainfall analysis is very critical for optimal economic design of farm pond. But long term data on rainfall intensity is seldom available in the country. A case of seasonal rainfall analysis is presented in this bullettin for the design of farm ponds.

Design rainfall

It is defined as the total amount of rain during the cropping season at or above which the catchment area will provide sufficient runoff to satisfy the crop water requirements. If the actual rainfall in the cropping season is below the design rainfall, there will be moisture stress for crop. If the actual rainfall exceeds the design rainfall, there will be surplus runoff which may cause damage to the structures. The design rainfall is calculated from the probability analysis. It is assigned some probability level of occurrence or exceedance. Suppose the probability of 67% is given to rainfall, it indicates that the seasonal rainfall may occurre or exceed 2 years out of 3 and therefore, the crop water requirements would also be met two years out of three in a crop season. More the probability of the rainfall, it is more reliable for getting assured runoff into the farm ponds.

Probability analysis

A simple graphical method can be used for probability analysis and frequency of occurrence of annual or seasonal rainfall for the design of ponds. There are several analytical methods by selecting a suitable probability distribution function. Weibulls distribution is commonly used for its simplicity and easy to adaptation for such field situations. The first step is to get the seasonal rainfall (June to September) for the cropping season from the area of concern. It is important to obtain long term data for at least 20 years for the probability analysis. Short term data for 5 to 10 years may not be sufficient to represent the realistic rainfall pattern in the region. For the collected seasonal rainfall, each value has to be given ranks based on their amounts arranged in descending order. The occurrence of probability for each of the ranked observation can be calculated from the below equation (Critchley and Siegert, 1991) for the period N=10 to 100.

$$\mathbf{P}\,(\%) = \frac{m - 0.375}{N + 0.25} \times \mathbf{100} \qquad \text{---- (1)}$$

Where,

P = probability in % of the observation of the rank m
m = rank of the observation
N = total number of observations used.

Steps in probability analysis

1) Annual and seasonal rainfall for a period of 20-30 years may be collected from nearby weather station of either govt (or) research station or IMD for selected area.
2) All the above data may be entered into MS excel sheet.
3) Arrange the annual/ seasonal rainfall data in descending order and rank them, having maximum rainfall as 1 and the minimum value with maximum rank.
4) If two rainfall events are equal consecutively, the same rank must be given to both the quantities.
5) Calculate the probability of each rainfall by using the equation 1.
6) Plot the probability vs rainfall on normal probability paper.
7) Determine the rainfall for 50%, 67% and 75% from the plotting curve.

An example for probability analysis of annual and seasonal rainfall for 30 years at Gunegal Research Farm near Ibrahimpatnam of CRIDA representing Southern Telengana is given below. Thirty years (1981-2010) annual and seasonal rainfall at GRF are given in Table 1. From the above calculations, it is observed that the annual rainfall analysis gives more rainfall than the seasonal rainfall at all probabilities. Generally, farm ponds are more likely to be filled during seasonal rainfall than during other periods in a year. Therefore, annual rainfall analysis may give over estimated designs of farm pond than seasonal rainfall. Therefore, seasonal design rainfall is considered for further calculations.

Table.1. Annual and seasonal rainfall at Gunegal Research Farm (1981-2010)

Year	Annual Rainfall, mm	Year	Annual Rainfall, mm
1981	762	1996	590.6
1982	1022.5	1997	710.1
1983	850.5	1998	977.7
1984	534.2	1999	476.3
1985	553.5	2000	523.6
1986	602.3	2001	625.2
1987	911.9	2002	426.6
1988	570.1	2003	869

Year	Seasonal rainfall, mm	Year	Seasonal rainfall, mm
1981	555.4	1996	341.3
1982	621.9	1997	439.1
1983	621.7	1998	731.6
1984	395.9	1999	370.8
1985	399.6	2000	459.9
1986	377.7	2001	490.3
1987	453.7	2002	241.3
1988	485.5	2003	651.9

1989	769.5	2004	764.5	1989	710.9	2004	381.5
1990	1001.9	2005	1154.6	1990	549.8	2005	683.6
1991	883.2	2006	741.5	1991	676.1	2006	515
1992	507.4	2007	880.8	1992	249.9	2007	716
1993	584	2008	763.8	1993	349.2	2008	431.8
1994	790.5	2009	743.2	1994	338.5	2009	496.2
1995	1019.7	2010	780.8	1995	578.9	2010	550.8

On normal probability paper, the plot of annual/seasonal rainfall against corresponding probabilities is drawn as shown in Fig 1(a,b). The finally fitted curve would show the probability of occurrence or exceedance of rainfall value of a specific magnitude. It means that a seasonal rainfall of 500mm with probability of 50% may exceed or equal once in two years of period. With 67% probability, 425mm rainfall may exceed or equal twice in three years period. Similarly, it is three times in 4 years for 75% probability of 375mm seasonal rainfall as seen from the plotted graph (Fig 1(b)). On average, in case of annual rainfall, 760mm, 650mm and 600mm can be expected for 50, 67, and 75% probability respectively Fig 1(a).

Table 2. Rank and Probabilities of annual and seasonal rainfall at GRF

Year	Annual rainfall, mm	m	p (%)	Year	Seasonal rainfall, mm	m	p(%)
2005	1154.6	1	2.1	1998	731.6	1	2.1
1982	1022.5	2	5.4	2007	716	2	5.4
1995	1019.7	3	8.7	1989	710.9	3	8.7
1990	1001.9	4	12.0	2005	683.6	4	12.0
1998	977.7	5	15.3	1991	676.1	5	15.3
1987	911.9	6	18.6	2003	651.9	6	18.6
1991	883.2	7	21.9	1982	621.9	7	21.9
2007	880.8	8	25.2	1983	621.7	8	25.2
2003	869	9	28.5	1995	578.9	9	28.5
1983	850.5	10	31.8	1981	555.4	10	31.8
1994	790.5	11	35.1	2010	550.8	11	35.1
2010	780.8	12	38.4	1990	549.8	12	38.4
1989	769.5	13	41.7	2006	515	13	41.7
2004	764.5	14	45.0	2009	496.2	14	45.0
2008	763.8	15	48.3	2001	490.3	15	48.3
1981	762	16	51.7	1988	485.5	16	51.7
2009	743.2	17	55.0	2000	459.9	17	55.0
2006	741.5	18	58.3	1987	453.7	18	58.3
1997	710.1	19	61.6	1997	439.1	19	61.6
2001	625.2	20	64.9	2008	431.8	20	64.9
1986	602.3	21	68.2	1985	399.6	21	68.2
1996	590.6	22	71.5	1984	395.9	22	71.5
1993	584	23	74.8	2004	381.5	23	74.8

1988	570.1	24	78.1		1986	377.7	24	78.1
1985	553.5	25	81.4		1999	370.8	25	81.4
1984	534.2	26	84.7		1993	349.2	26	84.7
2000	523.6	27	88.0		1996	341.3	27	88.0
1992	507.4	28	91.3		1994	338.5	28	91.3
1999	476.3	29	94.6		1992	249.9	29	94.6
2002	426.6	30	97.9		2002	241.3	30	97.9

The return period T (in years) can easily be determined once the exceedance probability P (%) is known.

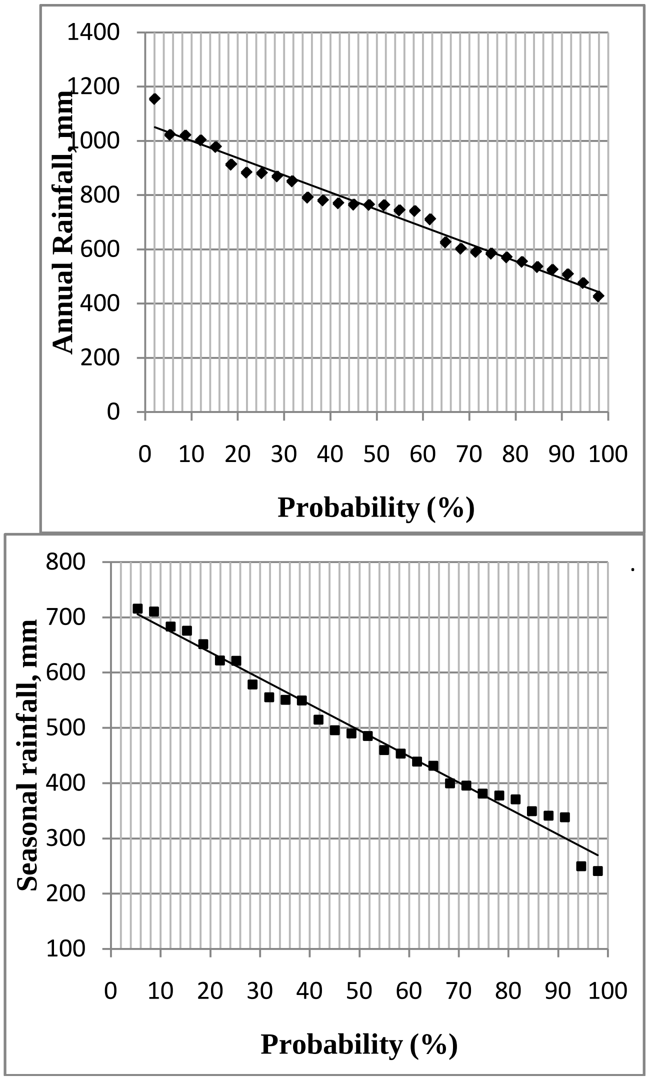
$$\mathbf{T = \frac{100}{P}} \qquad \text{------------------}\mathbf{(2)}$$

From the above example, the return period for annual and seasonal rainfall can be calculated as below:

$$T_{50} = \frac{100}{50} = 2 \text{ years}$$

$$T_{67} = \frac{100}{67} = 1.5 \text{ years}$$

$$T_{75} = \frac{100}{75} = 1.3 \text{ years}$$



(a) Annual **(b) Seasonal**

Figure 1(a,b). Probability plotting for an observed series of annual and seasonal rainfall at GRF

Surface runoff / Water yield

The surface runoff is generated in the catchment area after fulfilling the soil infiltration, interception and local depressions. It depends on the soil physical characteristics, land use characteristics, antecedent soil moisture, topography, shape and size of the catchment besides rainfall characteristics of intensity, frequency and duration.

Rainfall-Runoff relationship

There are several methods to estimate runoff. However, SCS curve number (USDA, 1967) is the most popular for the field engineers of soil and water conservation. It requires minimum data set of daily rainfall data , details of land use and its distribution, hydrologic groups of soils based on infiltration rate of the catchment area and antecedent moisture condition (AMC) of the watershed based on the previous 5 days consecutive total rainfall preceding the rainfall considered.

Catchment and Cultivable Area ratio

The water harvesting systems consist of catchment (collection) and a cultivable (concentration) area. The relationship between the two, in terms of size, determines by what factor the rainfall will be multiplied. For an appropriate design of a system, it is recommended to determine the ratio between catchment (Aca) and cultivable area (Acu) based on information available on runoff coefficients and efficiency factor for the selected location.

The calculation of (Aca): (Acu) ratio is primarily useful for rain water harvesting systems where crops are intended to be grown and it can be related by the equation 2 (Critchley and Siegert, 1991) as given below:

$$\frac{\text{Crop water requirement - Design rainfall}}{\text{Design rainfall} \times \text{Runoff coefficient} \times \text{Efficiency factor}} = \frac{\text{Catchment Area}}{\text{Cultivable Area}} \quad \text{------ (2)}$$

Crop water requirement

Crop water requirement depends on the type of crop and the climate of the location where it is grown. It can be estimated from the climate data by using CROPWAT (FAO, 2011) model.

Design rainfall

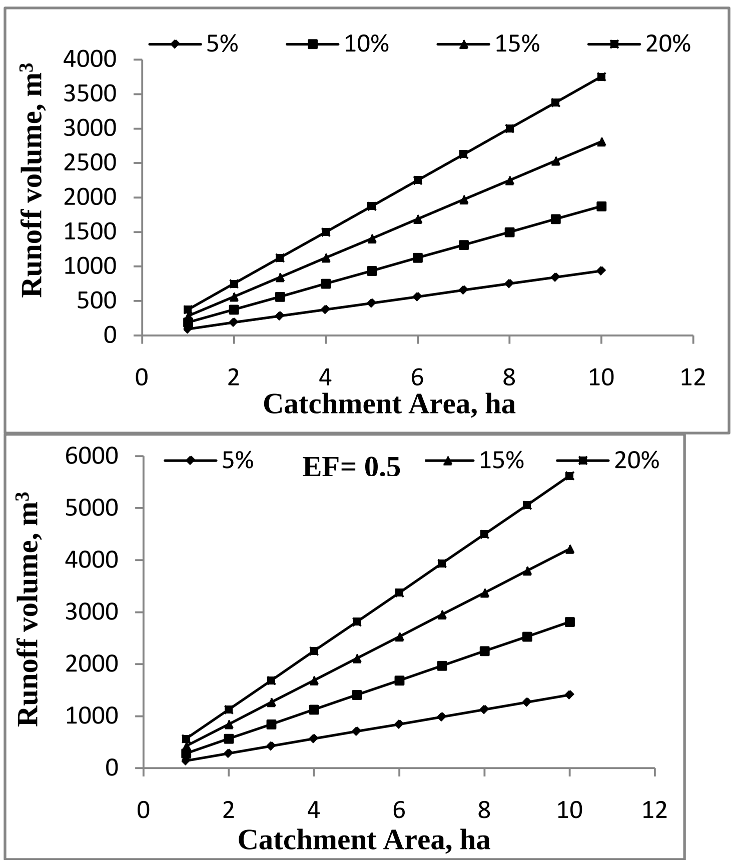
The design rainfall has to be calculated as suggested in section rainfall analysis. A conservative design would be based on a higher probability in order to make the system more reliable and thus to meet the crop water requirement more frequently.

Runoff coefficient

Runoff coefficient is the ratio of rainfall to runoff which flows along the ground. Degree of slope, soil type, vegetative cover, antecedent soil moisture, rainfall intensity, frequency and duration of the rainfall are the major factors which influence the runoff coefficient. The coefficient usually ranges between 10 to 50% (Critchley and Siegert, 1991). A reasonable runoff coefficient must be selected based on the experience and physical characteristics of the catchment. Larger catchments will have low runoff coefficients with varying slopes. Black soils with mini catchments of 1 to 5 ha will have on an average the runoff coefficient of 10 to 20 % with mild to medium slopes (1-10%) (Adhikari et al, 2009). Higher runoff coefficients may be taken for slopes >10%. However, the red soils with high infiltration rates have runoff coefficients varying from 5 to 15% for the mild to medium slopes (1to 10%) and the catchment area varying from 1 to 14 ha for the design of farm ponds in semi arid regions. However, the runoff co efficients are site specific and they must be obtained from the research organizations nearby the area.

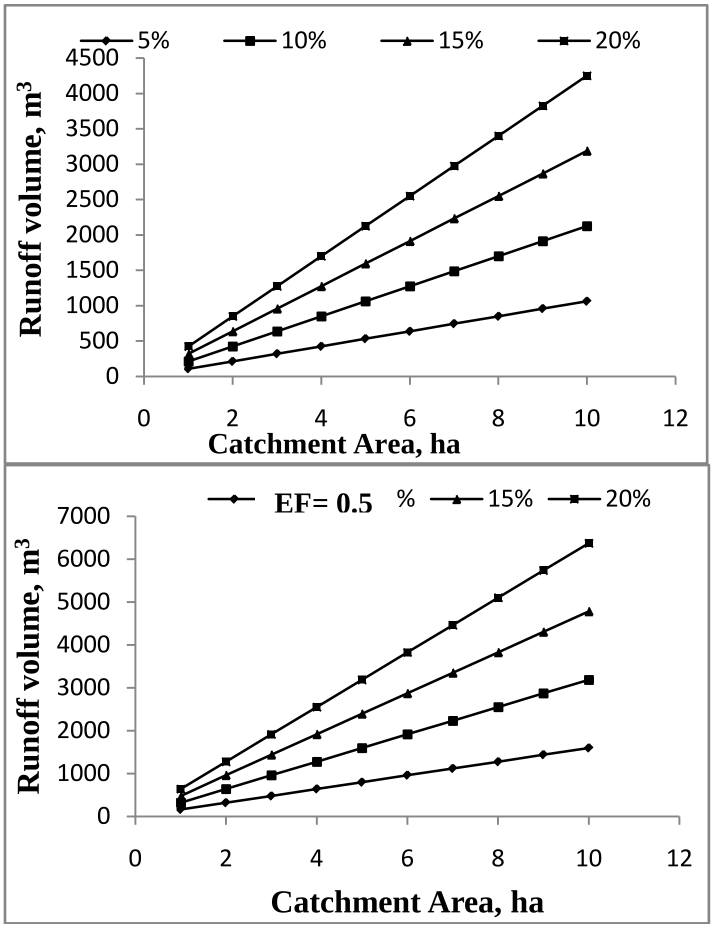
Efficiency factor

This factor takes into account the inefficiency of uneven distribution of the water with in the field as well as losses due to infiltration, surface depressions, evaporation and deep percolation. Where the cultivated area is levelled and smooth, the efficiency is higher. Micro catchment systems have higher efficiency as water is usually less deeply ponded. Selection of the factor is left to the discretion of the designer based on his experience and of the actual technique selected. Normally the factor ranges between 0.5 to 0.75. A factor of 0.5 is selected for larger catchments and 0.75 is taken for micro catchments. The factor decreases with increasing catchment area (Aca). The ratios of catchment to cultivable area for southern Telengana region are calculated for different crops with design seasonal rainfall at probability of 75% with different runoff coefficients varying from 5 to 20% and efficiency factor of 0.5 for alfisols. The design rainfall of 375 mm at 75% probability was used in calculating the Aca : Acu. Based on the above information for different irrigation strategies with farm ponds, the cultivable area (Acu) for different crops can be estimated. For unlined farm ponds, the collected runoff volumes have to be multiplied with a factor of 1.5 for accounting water losses through seepage and evaporation. For linned farm ponds, the volume may be multiplied by the factor of 1.05 to account for only evaporation losses. These volumes have to be considered for the design of farm ponds in a selected catchments.



EF= 0.75

Fig 2(a). Expected runoff volume at design seasonal rainfall of 375mm (75% probability) for varying runoff coefficients, efficiency factor (EF) and catchment area.



b

EF= 0.75

Fig 2(b). Expected runoff volume at design seasonal rainfall 425mm (67% probability) for varying runoff coefficients, efficiency factor (EF) and catchment area.

Pond Design

A well designed pond is a valuable asset for integrated farming system with minimum maintenance cost. Proper construction of a pond must be preceded by proper planning and design. To design a pond, careful study is required with respect to the hydrology of the catchment, rainfall–runoff relationship, and requirement of water, expected seepage and evaporation losses. The main consideration in design is to provide enough water for agricultural operations at minimum cost. The analysis of these parameters will guide to decide the dimension of the ponds. Dimensions in designing a pond are the size, shape of the pond, side slopes and the water control structures (inlet, silt trap and outlet).

The design of a excavated or dugout pond include the determination of specifications for the following: (a) Pond capacity, (b) Shape of pond, (c) Dimensions (depth, top & bottom widths and side slopes), (d) Inlet channels and (e) Emergency spillway or Outlet.

Pond Capacity

The capacity of the dugout pond depends on purpose for which water is needed and by the amount of inflow that can be expected in a given period. The seasonal water yield can be estimated using past historical weather data. The capacity of the pond depends upon the catchment size and factors affecting its water yield. On a conservative estimate, a dependable minimum value of 20% of the seasonal rainfall can be expected to go as runoff in case of black soils and 10% in case of red soils with mild to medium slopes. The pond should be of sufficient capacity to meet the demand of the crops or integrated farming system for which it is constructed. Generally, one or two supplemental irrigations with 50mm or less are planned for irrigating crops from such ponds. Barring summer months, the evaporation rate is fairly constant during the period of storage in the semi-arid regions. However, the seepage rate varies widely due to the variations in the sub-soil strata. A suitable provision should be made for the loss in storage capacity due to silting which is generally kept as 5-10 per cent. In sandy or light texture soils having high infiltration rate (>10cm/hr) will have a water loss of 50-60% in which seepage is predominant (40-50%). In such soils, the pond capacity must be designed for actual requirement of water for irrigation plus the seepage (40-50%) and evaporation losses (5%).

Shape of Pond

Excavated farm ponds may normally be of three shapes, viz; (a) square, (b) rectangular, and c) inverted cone. However, as curved shape offers difficulties in construction, either square or rectangular ponds are normally adopted. Inverted cone ponds with circular cross section are theoretically cheaper, but difficult to construct and manage. Lining of such ponds would require more material for the same capacity of square or rectangular farm ponds. Therefore, the lining of inverted cone farm ponds is costlier.

Dimensions of farm pond

The selection of dimensions for excavated pond depends on the required capacity, soil type, purpose and type of machine available for pond construction. The size of a pond should be relative to the size of the catchment area contributing surface runoff to the site. Ponds with too little catchment will have difficulty in filling up and remaining full during drought conditions. Ponds with too much watershed require expensive water control structures and are difficult to manage. Therefore, determination of optimum dimensions based on hydrological considerations is very important to keep the area loss to an extent of 10 to 12% in a farm catchment.

Depth and side slope of farm ponds

The depth of pond is generally determined by soil depth, kind of material excavated and type of equipment used. The selected pond depth should have a depth equal to or greater than the minimum required for the specific location as depth of pond is most important dimension among the three dimensions. In semi arid regions, the evaporation losses can be reduced by deepening the pond depth for the same volume of water stored as lesser is the area occupied by the pond. However, with increased depth, the seepage losses also increase. Seepage loss can be controlled by application of lining through LDPE/HDPE/Silpaulin plastic film. Water Technology Centre for eastern region reported that, when pond construction is done with labour, any increase in depth beyond 3.5 to 4.0 m becomes uneconomical. It also becomes uneconomical and difficult for lifting devices operated with human and animal power. Hence, a depth of 2.5 to 3.5 m may be suitable in general for the ponds.

The side slope of the pond are decided based on their angle of repose of the material being excavated and this angle of repose varies with type of soil. For the most cases, the side slopes of 1: 1 to 1.5:1 are recommended for practical purpose. Based on practical experience it is recommended that, selected side slopes are generally no steeper than the natural angle of repose of material. The recommended side slopes for different soil are given in Table 3.

Table 3. Suitable side slopes for different soils

Soil type	Slope (horizontal:vertical)
Clay	1:1 to 2:1
Clay loam	1.5:1to 2:1
Sandy loam	2:1to 2.5:1
Sandy	3:1

(Source: FAO, 2011)

The standing of water in a farm pond for a longer duration, may require relatively flatter side slopes to avoid slippage due to saturation. The area of the top and bottom for rectangular, square and inverted cone can be calculated from their dimensions in case of rectangular or square and diameter in case of inverted cone as per. Once the volume, depth and side slope are known, the dimensions of different shape of farm ponds can be calculated using the prismoidal formula.

$$V = \frac{A+4B+C}{6} \times D \qquad \text{------ (3)}$$

Where,
V = volume of excavation (m3)
A = area of excavation at the ground surface (m3)
B = area of excavation at the mid- depth point (D/2) (m3)
C = area of the excavation at the bottom of pond (m3); and
D = average depth of the pond (m).

From the equation (3) the bottom dimensions for rectangular is derived as given below:

$$X = (0.5/C)\left[\sqrt{Z^2D^2(1+C)^2 - 4C\{(4/3)\,Z^2D^2 - V/D\}} - ZD(1+C)\right] \qquad \text{---------- (4)}$$

Where, X, and Y are two sides of the dugout pond (rectangular) at the bottom and C= Y/X. For a square section, C=1, i.e. X=Y, the equation (4) can be simplified as follows:

$$X = \sqrt{Z^2D^2 - (4/3\ Z^2D^2 - V/D\}} - ZD \qquad \text{---- (5)}$$

From the equation (3), [illegible] en [illegible] llows:

$$d_1 = \sqrt{\{(4V/\pi H)-(1/3)Z^2H^2\}} - ZH \qquad \text{- -------- (6)}$$

$$d_3 = (d_1+2ZH) \qquad \text{---- ------ (7)}$$

Construction of Farm Pond

After the site selection and pond dimensions decided, the pond site should be cleared of all stone and woody vegetation. Before construction of farm pond, proper layout should be made for proper construction. Stakes are used to mark the limits of the excavation and spoil placement areas and the depth of the cut from the ground surface to the pond bottom should be indicated on the stakes. Excavation and the placement of the dugout material are the principal items of work required in the construction of pond. Generally, the equipments used for pond construction are tractor pulled wheeled scrappers, draglines and bulldozers. The use of a bulldozer for excavation is usually limited to relatively small ponds due to its inefficiency in transporting the material. In semi arid regions any type of equipment can be used but in high rainfall areas where a ground water table exists in shallow depth, the dragline excavator is most commonly used equipment. The excavated material should be placed as near to the pond and that can be used for making the berm on the pond. After excavating of the earth, compaction of the sub grade and banks should be done thoroughly for proper establishment of the structure.

Earth moving machinery for excavation

The selected site should be free from vegetation, bushes and other obstacles and it should be levelled so that demarcation line of the pond area can be drawn. The design dimensions of proposed pond can be drawn with the help of rope and lines for demarcation can be done with lime powder or making small cuts with spade so that the demarcation lines are visible for equipment operator to enabling to excavate soil form the pond area. Initially digging of pond must be started at the central portion of layout to a designed depth indicated on stakes. There are two types of earth moving machinery like JCB with bucket volume of 0.1 m^3 with short boom and Tata-Hitachi Volvo 200 model with bucket capacity of $1m^3$ with long boom of 4m. When the soil from the bottom of pond is completely removed, put the rope connecting to the corner of bottom area and outer top corner; give the required or desired slope at one corner of pond by cutting the soil. It is often suggested that shaping the pond must be done with cutting rather than filling of soil and this will facilitate better preparation of the sub grade, which is very important for stable pond boundary. The excavation soil should be compacted for its regular shape of trapezoidal bund with bottom width at least 1.5 to 2.5m and top width 0.5m and height of bund as 0.5m. The side slopes may be kept as 1:1. The bunds after compaction to the dimensions may be well grassed for its stability.

Operation and Maintenance of Pond

Proper maintenance of the pond can ensure good life and service as it prevents expensive repair costs. A pond, no matter how well planned and built, must be adequately maintained if its intended purpose are to be realized throughout its expected life. Lack of operation and maintenance has caused severe damage of ponds, and inlet, outlet channels. The pond should be inspected periodically. Care should be taken when heavy rains occur for the damages if any in farm pond. Initially damage may be small, but if neglected it may increase until repair becomes impractical. Any rills on the side slopes of the pond may be filled and any washes are in the inlet spillway must be immediately filled with suitable material with thorough compaction. Care should be taken to keep the water in the pond as clean and unpolluted as possible. Trampling by livestock, particularly dogs and wild life must be prevented.

Fencing

Fencing must be erected around the farm pond to prevent the entry of wildlife, stray dog etc. Fencing provides the protection from the damage and pollution by livestock. In farm field, cost effective vegetative hedges by using Henna, shallow rooted fruit trees, glyricidia etc., may be planned as protection to farm pond. Also, the barbed wire fencing with stones can also be preferred so as to reduce the cost of fencing.

Lining of Farm Pond

Lining of farm pond to control seepage and percolation losses would be helpful in supplemental irrigation at crop critical stages, livestock rearing and domestic water supply. Lining is required in farm pond to control seepage from the wetted surface area. Seepage losses are predominant in case of light texture soils where sand percentile is more as compared to clay and silt particles. Particularly, the farm ponds constructed in red soils require lining for long storage of water in the structures. Black cotton or vertislos or laterite soils do not require lining as the seepage losses are minimum because of more clay content. It is found that water losses through seepage varies from 1.21 to 10.54 cumecs/million sqm from heavy clay loam to porous gravelly soils in the earthen ponds, are the major constraints to its failure. In other words we can say that the drop in depth per day (cm) of ponded water via seepage and evaporation is 10.36 to 90.65 cm from heavy clay to porous gravelly soils. Several material options are available for lining of farm ponds. The locally available material such as bricks and stones are used for hard surface lining of farm ponds. Such linings are constructed by using cement concrete and mortar. Asphaltic materials, paddy husk with cow dung. cement with soil mixture, flay ash mixture, bentonile have been tried to control seepage in farm ponds and their effectiveness are studied at different locations of the country bricks, stones etc.

Advantages of pond lining with plastic film

- Reduction in water losses through percolation and seepage to the maximum extent (95%).
- Availability of water for a longer period of time.
- Lining with plastic film has benefits in porous soils where water retention in ponds and water harvesting tanks is minimal (Red soils).
- Prevents the lower area from the problem of water logging and prevents upward intrusion of salts in to stored water.
- Judicious utilization of stored water for the purpose of storage of drinking water, for fish culture and to provide supplementary irrigation during crop critical stages.
- Economical and effective method of storing water.

Method of laying Polyethylene films in farm ponds

For Laying of Polyethylene films minimum of 500 micron film are best suited for lasting of film and the following procedure are taken into consideration:

- Choose the film as per BIS/ISI mark
- Make the sides of the farm pond clean and smooth by removing vegetation and rills if any on the surface. A herbicide or weedicide may be applied on surface in advance so that there won't be any vegetation or root mass

- Make the trench of dimension 15 x 15 cm at the bottom along the sides for holding the plastic film firmly while laying
- Use minimum of 500 micron sheet or 300-350 gsm cross reinforced silpaulin
- Calculate the film requirement for dugout pond.
- Plastic films manufactured in to panels of standard widths. Therefore convert the film into a single sheet as a desired either mechanically by heat-sealing machine like Hot Air fusion welding machine or manually (by overlapping 15 cm of the edge of two sheet and scrubbed lightly using emery paper or sand paper (120 grade) using bitumen/ Synthetic Rubber adhesive No-998 made by fevicol so that it fit exactly to fit in to the pond.
- Monitor the film in sun light for searching/puncture hole if any, and seal the hole with bitumen/adhesive or by heat – sealing procedure.
- The ends of the film at the surface have to be firmly buried in a trench at the bank of the pond to avoid sagging in the pond with proper anchoring of the sheet in a trench and filling with soil.
- Care should be taken to avoid the wrinkles and film must be pulled at the corner.

Cost economics of construction of farm pond

Generally, the farm ponds are constructed with proper side slopes and inlet, silt trap and outlet structures to a recommended depth of 3 m. Presently, such structures are being done by using manual labour in the scheme of MNREGS implemented throughout the country by Govt. of India. But, they do not meet the design dimensions as required for meeting the crop water requirements and other uses. Therefore, it is recommended to use machinery particularly in hard soils where digging and earth removal becomes difficult by the human labour. Even in loose soils, the machinery is advisable for digging purpose and labor can be employed for making the side bunds and compacting soil. The earth moving machinery is available in the market with different bucket and boom sizes for digging purpose. The size of bucket varies from 0.1 to 1 m^3 capacity with boom lengths varying from 2 to 4 m. A 4 m boom and 1 m3 bucket capcity machine can remove the earth quickly and make the pond with capacity of 500 m^3 within 8 hrs of operation with proper side slopes and transport of the earth for bunding on the sides. The hiring charges with hagh capacity bucket machinery (TATA HITACHI V200 model) ranges from Rs1600-1700 in the market at present rates, which includes transport of the earth. On an average, the cost of digging becomes Rs26/ m^3 of soil in constructing farm pond. For the machinery like JCB, it takes more time atleast 2.5 times more than the bigger machine. Therefore, digging of farm pond must be done on cluster approach identifying the group of farmers for implementing the scheme in watersheds or Govt. schemes in rainfed areas. The details are given in Table4.

Table 4 Construction cost of the different capacities of the lined farm ponds by using machinery

S. No.	Work component	Square	Square	Square	Inverted cone	Inverted cone
1	Dimensions of the pond Top dimensions Bottom dimensions , m×m	20 x 20 11x 11	27.5x27.5 17 x 17	17 x 17 8 x 8	14 dia 5 dia	20 dia 11 dia
2	Depth of pond , m.	3	3.5	3	3	3

3	Side slopes, Z:1	1.5 : 1	1.5 : 1	1.5 : 1	1.5 : 1	1.5 : 1
4	Capacity of the pond, m^3	741	1765	489	229	582
5	Cost for excavation of the soil, Rs.	19266	45890	12714	5954	15132
7	Surface area for lining, m^2	457	849	334	181	358
8	Required dimensions of the plastic sheet, m×m	24 x 24	32 x 32	21 x 21	18 x 18	24 x 24
9	Lining with 500 micron Plastic sheet, Rs.	57,600	1,02,400	44,100	32,400	57,600
10	Construction cost of inlet requirements and spillway, Rs.	10,000	15,000	10,000	10,000	10,000
11	Labour cost for anchoring the lining plastic sheet including trenching, Rs.	11,520	20,480	8,820	6,480	11,520
12	Total cost, Rs.	98,386	1,83,770	75,364	54,834	94,252
13	Cost per unit volume of stored water, Rs./m^3	133	104	154	239	162

The unit cost of expenditure for creating storage of 1m^3 of water decreases as the capacity of farm pond increases. The lining requirement is more in case of inverted cone farm ponds as the dimensions of the film are more for covering the pond surface area as it comes in square dimensions. In other dimensions of farm ponds with regular shape of square and rectangular, the lining requirement is less and easy to do the lining than the inverted cones.

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Rainwater Harvesting: Experiences in Adilabad and Prakasam in Andhra Pradesh and Jalna in Maharashtra

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1.0 Introduction

Rainfed agriculture is inherently dependent on monsoon and so any aberration in the course of monsoon impacts the area, production and productivity. Rainfed agriculture is also characterized by poor and degraded lands and geography of rainfed agriculture and poverty largely overlap. About two billion ha or 15% geographical area of the world is subjected to various forms of land degradation of which erosion by water is the chief contributor followed by wind erosion, chemical degradation and physical degradation (Olderman, 1991). Water erosion is the major source of land degradation in India as well as in the globe (**Table 1**). The total geographical area of India is about 329 million hectare (M ha). Fifty eight per cent of the net sown area (139 M ha) is rainfed, where crop production suffers from rampant land degradation mainly by rainwater.

Soil erosion by rainwater is the major cause of land degradation in India

Table 1. Land degradation – Global & Indian scenario

Type	Global		Indian	
	Extent (Billion ha)	% of total	Extent (Million ha)	% of total
Water erosion	1.10	55.8	148.9	79.3
Wind erosion	0.55	27.9	13.5	7.2
Chemical degradation	0.24	12.2	13.8	7.3
Physical degradation	0.08	4.1	11.6	6.2
Total	1.97	100	187.8	100

(**Olderman, L.R. 1991.** Global extent of soil degradation, ISRIC bi-annual report, ISRIC, Wageningen, The Netherlands, pp:19-30)

Rainwater Management

Out of 400 M ha-m precipitation in the country, 115 M ha-m is lost as runoff resulting in drought in the catchments and floods downstream. Over 5.3 billion tons of top-soil is lost annually resulting in a loss of around 8 million tons of plant nutrient and 3 million tons of food grains. Soil resource base is shrinking at an alarming rate of 0.25 M ha annually due to industrialization and urbanization. The per capita availability of water will touch stress level of 1700 m^3 by 2020. The water resource is dwindling in quantity, quality and equitable availability.

Rainfed areas prone to drought are spread over different agro-ecological regions and river basins. There are 35 basins, 500 sub-catchments and more than 3200 watersheds of various sizes in India. The size of an average watershed works out to be 0.1 M ha. However, presently the convenient working scale or operational unit of a micro-watershed is 5000 ha. A huge investment is envisaged to rehabilitate about 100 M ha of land on watershed basis, which is under various processes of degradation. The GOI continues to accord high priority to rainfed agriculture. Some of the important initiatives are (1) increased public investments on integrated watershed management programs (IWMP), (2) higher institutional credit to agricultural sector, (3) farm insurance and crop diversification and (4) Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), Rashtriya Kishi Vikas Yojana (RKVY), National Horticulture Mission (NHM), etc.

In most rainfed areas, the potential evapotranspiration exceeds rainwater inputs for 8 to 9.5 months in a year resulting in a negative water balance. The effective crop-growing period is 75 to 120 days – just sufficient to grow a single crop. Availability of sufficient soil moisture during the crop growth is a major limitation. In addition, soil degradation is a major cause for low productivity. The torrential character of the seasonal rainfall creates high risk for the cultivated lands. Thus, erosion leaves behind an impoverished soil on one hand and siltation of reservoirs and tanks on the other. Degradation induced source of carbon emissions also contribute to climate change.

Frequent incidence of droughts and floods poses a threat to realization of potential yields as well as to the investments. The twin problem of drought and floods can be addressed by water harvesting at the field and watershed level. Water harvesting is a process of collection of runoff water from treated or untreated land surface to store in an open farm pond or percolation pond or tank for drinking, irrigation or ground water recharging purposes. Efficient utilisation of harvested water in a pond requires an elaborate consideration on selection of soils, runoff inducement, storage, seepage and evaporation losses, water lifting and conveyance devices and their efficiencies. Ground water recharging is a process in which the harvested runoff is allowed to be stored on the surface to recharge groundwater. Three case studies dealing with rainwater harvesting and watershed management are discussed in detail indicating the process and strategies for up-scaling.

2.0 Livelihood Enhancement through Water Harvesting in Vertisols: A Case Study of Adilabad in Andhra Pradesh

Adilabad district in Andhra Pradesh is known for the highest cover under forest (40%) and high rainfall. The district has an average annual rainfall of 1050mm and receives mostly through S-W monsoon (80%). The area has undulating topography and mostly inhabited by *gond* tribe. There is a high potential for rainwater harvesting and recycling. Small dugouts created as farm ponds under MGNREGS didn't motivate the farming community as the volume of water was less and retained for very short period. These ponds were found to be of little use.

An attempt was made to undertake the participatory situation analysis by convincing the farming community to go for large structure with higher depth. A farm pond of about 1000m^3 capacity (17m x 17 m top, 13m x 13m bottom and 4.5m depth) was dug during mid-July 2008 under National Agriculture Innovation Programme (NAIP) on a pilot basis. The farm pond got filled during the first week of August and water was retained even after use till the end of February 2009. The project met the cost of digging while the farmer (Mr. Namdev, Garkampet village, Seethagondi Gram Panchayat in Gudihatnoor mandal of Adilabad) ventured cultivation of tomato on half-acre plot by hiring diesel pumpset for lifting of water and HDPE pipes for conveyance.

The total cost of cultivation of tomatoes in 0.5 acre land was worked out to be Rs. 23,600/-. The picking of tomatoes occupied a lion’s share of total cost of cultivation, which accounted for (34%) followed by watch and ward (25%), transportation (11%), irrigation (10%) and transplantation (8%). The gross returns accrued from 4460 kg production of tomatoes from 27 pickings in 0.5 acre land was found to be Rs. 1,30,450/-. The price ranged from as high as Rs. 40/- per kg to as low as Rs. 15/kg from September to December, 2008. The benefit-cost ratios (BCRs) based on total cost of cultivation of tomatoes and based on total cost of cultivation of tomatoes including cost of pond were calculated as 5.53 and 2.23, respectively (**Table 2**). This indicates that on every rupee investment made on cultivating tomatoes in 0.5 acre land paid a rich dividend of rupees 5.53 on the one side and Rs. 2.23 by covering the cost of pond in one season on the other side revealing higher impact of farm pond. The case study has come out with conclusive evidence of livelihood improvement in terms of five capitals formation namely natural, social, human, financial and physical of the farmer. The response of tribal population who were earlier reluctant is now overwhelming and the technology has been up-scaled to 30 more farmers through participatory demand-driven approach and convergence with MGNREGS within Seethagondi Gram Panchayat and also it is being up-scaled by the agriculture department in the district under RKVY.

Table 2. Impact of farm pond on net returns accrued from production of tomatoes (in 0.5 acre land) during 2008

S. No.	Particulars	Amount (Rs.)
1	Gross returns	1,30,450
2	Total cost of cultivation of crop (a)	23,600
	Cost of digging of pond (b)	35000
3	Net returns accrued from production of tomatoes (1-2a)	107,350
	Net returns accrued after recovering cost of farm pond [1-2 (a+b)]	72,350
4	(a) BCR based on total cost of cultivation of crop	5.53
	(b) BCR based on total cost of cultivation including cost of pond	2.23


Use of farm pond water for cultivation of tomato - Adilabad

3.0 Drought Proofing and Enhanced Productivity through Farm Ponds in Rainfed Southern Light Soils of Andhra Pradesh

South coastal rainfed light soils areas of Andhra Pradesh is prone to both drought and flood and receives rainfall from South-West and North-East Monsoon. The study was initiated to study the feasibility of providing one life saving irrigation to improve the yield of Flue Cured Virginia (FCV) tobacco and other important *rabi* crops to mitigate adverse affect of prolonged dry spells at vegetative phase. Nine farm ponds were made with network of water ways for rainwater disposal as well as harvesting at CTRI Regional Station Kandukur, Prakasam district in Andhra Pradesh. The yield of cured leaf improved between 23 and 31 per cent depending upon the amount and distribution of rainfall during the study period. An additional net income, maximum up to Rs.15940/ha @ Rs. 97 /kg derived with one life saving irrigation over control (rainfed) (**Table 3**). The BC ratio for lined pond varied from 1.0, 1.5 and 2.0 with corresponding life span of farm pond of 10, 20 and 40 years, respectively, (Osman, et. al. unpublished data).

Table 3. Impact of one supplement irrigation on yield and returns of FCV tobacco

Parameters	Year					
	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09
Control (kg/ha	1147	942	1003	983	943	1090
Irrigated (kg/ha)	1416	1238	1249	1213	1183	1311
Additional yield (kg/ha)	269	296	246	230	240	221
Improvement in yield (%)	23	31	25	23	25	20
Rate per kg (Rs.)	34	35	42	54	84	97
Gross returns accrued from irrigation (Rs./ha)	9145	10360	10330	12420	20160	21440
Cost of irrigation (Rs./ha)	2000	2250	2600	3100	5000	5500
Net returns accrued from irrigation (Rs./ha)	7145	8110	7730	9320	15160	15940

The rainwater harvesting and recycling of farm pond technology (lined) developed is found very much suitable for rainfed light soil areas under conditions of providing a life saving irrigation with good quality water as groundwater is unfit for irrigation containing high amount of salts. The technology is suitable for small farmers owing 2 ha of land. The farmers with one supplemental irrigation can realize on average Rs. 10,500/ha as an additional net income. The payback period was estimated as 7 years for lined pond after discounting the cost and returns at 12 percent. As this is one time investment, soft loans are being advocated for construction of these ponds to meet the multiple objectives of rainfed farming viz. harvesting rainwater and capture top soil rich in nutrients for drought proofing, productivity enhancement and income sustainability. Apart from improvement in yield, a positive impact was also noticed on quality of leaf because of good quality of recycled water which is free from chlorides.

Lining f pond and pond filled with rainwater (CTRI Regional Station, Kandukur, Prakasam

4.0 Kadwanchi Watershed – A Success Story from Jalna District in Maharashtra

Krishi Vigyan Kendra, Jalna sponsored by Indian Council of Agricultural Research (ICAR), New Delhi and established by Marathwada Sheti Sahaya Mandal, a Non- Government Voluntary Organization initiated extension activities from 1993 in a village called Kadwanchi situated 18 km away from Jalna town in Maharashtra. Prior to adoption of watershed approach, KVK organized awareness camps and trainings of farmers and rural youth for motivation and conducted front line demonstrations on oilseeds, pulses and other crops. Self-help groups of women were established to initiate the process of women empowerment. Field visits, *kisan melas*, *mahila melavas* were organized to have constant touch with farmers and to get specific feedback on problems of the village. The interaction led to the identification of major constraints like scarcity of water, land degradation and poor soil fertility.

Major Interventions: The watershed implementation started during 1997-98 and was accomplished successfully by 2001-2002. The evaluation of watershed was carried out after a decade during 2011-12 to study sustainability and its impact on livelihoods.

4.1 Soil and Water Conservation Measures

Soil and water conservation measures were undertaken in participatory and scientific manner to the extent possible considering the needs and views of the villagers. Major soil conservation treatments were trenching and bunding with vegetative cover. The physical achievements with the type of work done given in terms of area and drainage line treatment is set out in **Table 4 (a**) and other details of watershed works including current status in **Table 4 (b).**

Trenching: The ridge part of the watershed, which is a hilly terrain was treated with continuous contour trenches (CCT) followed by plantation and grass seeding on the soil mound. Water absorption trenches (WAT) were excavated between CCTs. CCT & WAT checked erosive velocity of water along with increased opportunity time to infiltrate the water resulting in recharging of ground water. Private wastelands were also treated with contour bunding and continuous contour trenches and promoted dryland horticulture.

Bunding: Arable area was treated with peripheral and compartmental bunds, plantation, grass seeding on bunds and spillway to drain out surplus runoff into natural drains. Compartmental and peripheral bunds helped in *in-situ* conservation of rainwater and were found to be acceptable to the community.

Table 4 (a) Treatment and area covered

Sl.No.	Treatment	Sanctioned works	Work completed	Type of work done
(A)	**Area treatment**			
01	Afforestation (ha)	157.7	157.7	Continuous contour trenching, seed sowing and
02	Agroforestry (ha)	251.0	211.0	Farm bunding, dryland horticulture
03	Agro-horticulture (ha)	132.9	132.3	Farm bunding, horticulture plantation
04	Crop cultivation (ha)	1000.00	995.3	Farm bunding, grass seeding on bunds
(B)	**Drainage line treatment**			
01	Gully plugs (m)	3640	4620	Loose rubbles used for construction
02	Gabions (m)	168	54	Constructed using loose rubbles in chain link mesh.
03	Masonry gully plug (check weir), Nos	10	10	Constructed using un-coursed rubble stone masonry (UCR)
04	Check dams, Nos	09	09	Constructed in cement concrete
05	Repair of Nala bund, Nos	09	11	Constructed spill way by UCR

Source: KVK, Jalna

Table 4(b) Details of watershed works done:

Work	Amount spent (Rs. in Lakh)	Measure-ment	People's contribu-tion	Appropri-ateness of structure / design	No. of households benefitted	whether on CPRs/ PPRs	Current status (survival %)
Check dams	36.28	19 No	18 %	Yes	200	CPR	100
CCTs	21.27	368.71 ha	18 %	Yes	50	CPR	80
Tank repair	0.53	09 No	18 %	Yes	20	CPR	100
Plantation	2.98	132 ha	18 %	Yes	90	CPR/PPR	100
Farm Bunding	36.04	1000 ha	18 %	Yes	300	PPR	90
Farm pondS	153 farm ponds by State Dept. of Agriculture under NHM and RKVY. From this about 7.65 lakh cum water storage was created to use during scarcity period for high value crops like grapes, ginger, chilli, etc						

Note: All the works have been executed by Watershed Development Committee excluding farm ponds.
Source: KVK, Jalna

4.2 Impact of watershed programme on agro-ecosystem and livelihoods

4.2.1 Change in land use

Area under rainfed, grazing land, permanent pastures, current and other fallows; and culturable wastelands - all registered decline in post-project scenario. This was converted to irrigated area to the extent of 115% in the post watershed project compared to pre-project period (**Table 5**).

Table 5. Land use pattern before and after watershed programme (ha)

Land use	Before (2001-02)	After (2011-12)	% Change
Cultivated area	1365.95	1517	11.1
Irrigated	572.14	1227	114.5
Rainfed	793.81	290	-63.5
Forest area	-	-	
Grazing land Permanent pastures	102	32	-68.6
Current fallows Other fallows	147.03	62.03	-57.8
Unculturable land	451	451	-
Culturable waste land	147.03	62.03	-57.8
Non-agricultural land	35.54	35.54	-

Source: Focus group discussion

4.2.2 Change in cropping pattern – area and production

Table 6 shows that a substantial increase in area and production of blackgram (29 and 47 fold increase, respectively) followed by chickpea (over 6 and 7 fold increase, respectively), wheat (257% and 315% increase, respectively), cotton (74% and 94%, respectively) and greengram (25% and 75% respectively). Ginger is a new introduction in the post-project period.

Table 6. Change in area and production of different crops

S. No.	Name of crop	Before (2001-02)		After (2011-12)		% Change	
		Area (ha)	Production (q)	Area (ha)	Production (q)	Area	Production
01	Pearl millet	526.41	428.50	303.2	363.6	-42.4	-15.1
02	Black gram	1.4	0.7	42	33.7	2900	4714
03	Green gram	128.31	52.86	161	92.4	25.	74.8
04	Cotton	199.47	125.27	347	242.9	74	93.9
05	Rabi Sorghum	373.95	209.81	361	252.7	-3.5	20.4
06	Wheat	27.70	28.59	99	118.8	257	315.5
07	Chickpea	4.80	2.8	35	24.5	629	762.7
08	Ginger	Nil	Nil	02	25.0	∞	∞

Source: Focus group discussion

4.2.3 Change in area under horticulture

Among the various fruit crops grown, the area under cultivation of grapes registered 20 times increase in the post watershed scenario (**Table 7**). The other fruit crops such as pomegranate, aonla, tamarind and custard apple were the new introduction during the project period. As such the change in overall area under cultivation of fruit plants recorded an increase of 65 times.

Table 7. Change in area under horticultural crops

S. No.	Horticultural crops	Previous (ha)	Present (ha) (h(ha)(ha)	% Change
1	Grapes	3	62.00	1967
2	Pomegranate	N	98.00	∞
3	Aonla	N	11.00	∞
4	Tamarind	N	17.00	∞
5	Custard Apple	N	10.00	∞
	Overall	3	198.0	6500

Source: Focus group discussion

4.2.4 Change in depth of water table

There was appreciable change in ground water level due to treatment of the watershed. The depth of water column increased from 5.5 m during 1997 to 10.97 m in 2002 in the post-monsoon period. During summer season the depth of water standing in well was 3.35m compared to 1.06 m earlier (**Table 8**).

Table 8. Change in depth of water table

S. No.	Year	Rainfall in mm	Depth of water in the well (m) (location No. 3, well no. 6)		
			February	May	October
01	1997	501.50	2.63	1.06	5.50
02	1998	901.00	3.04	1.06	6.09
03	1999	582.00	2.43	1.09	4.09
04	2000	450.00	1.98	1.06	5.09
05	2001	686.00	6.09	3.04	10.67
06	2002	694.00	6.09	3.35	10.97

Source: Focus group discussion

4.2.5 Change in physical assets

There was appreciable increase in the number of tractors, threshers, power sprayers; sprinkler, drips irrigation sets, etc., leading to capital formation in the post-project period in the watershed (**Table 9**).

Table 9. Change in physical assets (Nos.)

S. No.	Particulars	Before	After
1	Tractors	2	40
2	Tractor operated seed drill	Nil	04
3	Threshers	02	18
4	Power sprayers	21	151
5	Chaff cutters	Nil	07
6	Adjustable harrow	Nil	08
7	Vaibhav sickle	Nil	110
8	Sprinkler irrigation set	02	97
9	Drip irrigation set	07	197

Source: Focus Group Discussion

Check dam after increase in height

Semi dug-out farm pond lined with HDPE sheet under NHM

	
Cultivation of bell pepper	**Grape vineyard**

5.0 Conclusion

- The models listed above are replicable in similar areas.
- Active participation of the community in programmes is possible when harvested water is used for high value crops.
- Although farm ponds are costly but saves water and nutrient rich top soil from permanent loss.
- There is a need to have active hand holding mechanism for making any programme a success.

IWMP & IMPACT ASSESSMENT OF WATERSHED

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Introduction:

In a broader sense, watershed management implies rural development with watershed as unit of planning. Apart from management of natural resources such as soil, water, vegetation,human and animal resources related to development of Agriculture, it may encompass areas of infrastructure development such as transport and communication, and even health, energy and education for the overall well being of watershed community. However, in this lecture, discussion is focused briefly on the past and present state of the art and certain emerging issues and challenges of Watershed Management.

Definition:

The geographic area draining to a common outlet point in a drainage line is called the Watershed. The watershed area is always defined with reference to an outlet point in a drainage line. The watershed area increases as we move downstream along a drainage line and it decreases as we move upstream.

Macro and Micro Watersheds:

A very large watershed is called a macro watershed and a very small one is called micro watershed. Micro watershed generally has a single order stream as its drainage line where as a macro watershed has multiple drainage lines of higher order. All India soil and Land use Survey organization has brought out an atlas (1:1million scale) covering 6 major water resource regions, 35 River basins, 112 Catchments, 500 Sub catchments and 3237 Watersheds following a 5 stage delineation approach

Why Watershed:

In drylands, water is the single most limiting factor of crop production. In rainfed areas, rainfall is the only source of water and its efficient utilization is important for successful crop production. Besides, droughts resulting from uncertain rainfall conditions and the consequent water scarcity are common in drylands. Proper rainwater management, conservation, development and judicious utilization of water resources are therefore essential for meeting demands such as water for domestic use, drinking water for cattle, industrial water needs etc. besides water for irrigation. Since watershed is a hydrological entity, water resources planning and its utilization are best attempted by taking watershed as a unit of planning. Rain water management often involves interventions for runoff control and retention such as bunds and vegetative barriers and also water harvesting structures (eg. farm ponds, check dams) and ground water recharge structures (eg. Nala bunds and percolation tanks). All these interventions are designed according to the estimated runoff which in turn depends upon the watershed area above it.

Resource Carrying Capacity Based Use of Natural Resources:

The quantity and quality of the basic natural resources such as climate, soil and water decides the bio-mass production in a watershed and hence the human and cattle population it can sustain. Therefore, while planning resource use, this aspect of watershed should be taken into consideration. A higher population will exert more pressure on the resources of the watershed which can result in over exploitation and consequent degradation of resources.

Demarcation of Watersheds

A watershed is an area draining to a common outlet point bounded by ridge all around and a valley or valleys with in. In small watersheds with well-defined ridges, it may be feasible to physically locate the ridgeline, with reference to a selected outlet point, which can be surveyed and plotted to demarcate the watershed. However, in large watersheds it would be better to take the help of topo-sheets (Survey of India maps) to locate the watersheds. From a study of the contour lines given in topo-sheets it should be possible to locate the ridge and valley lines with reference to any given outlet point in a drainage line and hence the watershed boundary. Remote sensing and GIS can help in delineation of watersheds through Digital Elevation Models.

Watershed Development Programmes:

Many agencies are involved in watershed development programmes in the country. Depending on the objectives with which they are pursuing these programmes, the type of interventions and scale of operations vary. The major programmes of the past and present are:

i) River Valley Projects (RVP)

The primary objective of watershed development of RVPs is to control siltation of major reservoirs. The programme may cover large areas with in the catchment of these reservoirs and priority is given to those watersheds wherein soil erosion is severe and which contribute large quantities of silt into the reservoir. The severity of erosion potential is often estimated by computing the silt yield index for prioritization of the watersheds.

ii) Drought Prone Area Programme (DPAP) & Desert Development Programme (DDP)

In Drought Prone Area Programme, Districts which are identified as drought prone in the country are taken up for development. In this programme emphasis is given to water harvesting and ground water recharge with a view to improve water availability in these areas. Besides, employment generation activities are taken up particularly during drought. DPAP is a programme of the Ministry of Rural Development. Similarly, Desert Development Programmes with emphasis on arresting desertification are taken up in areas where desertification is a problem

iii) National Watershed Development Project for Rainfed Areas (NWDPRA)

The NWDPRA is a project operated by the Department of Agriculture and aims at improving the Dryland Agriculture in rainfed areas mainly through better resource conservation, crop management and farming systems development.

iv) Integrated Wasteland Development Programme (IWDP)

Integrated Wasteland Development Programme, as the name indicates, aims at development of areas classified as wastelands. This programme also adopts a watershed approach. The major activities are afforestation, agro-forestry etc.

Integrated Watershed Management (IWM)

Integrated Watershed Management aims at holistic development of an area through optimal resource utilization by adopting watershed as a unit. Conservation of natural resources such as soil water and vegetation is of paramount importance in watershed programme for maintaining productivity and achieving sustainability.

Objectives:

The major objectives of a watershed programme are:

1. Increased crop production
2. Protection of environment
3. Drought mitigation and improved water availability/Flood control
4. Livelihood security and poverty alleviation

Major Components of IWM

The major components of Integrated Watershed Management are:

1. Soil and Water Management
2. Improved Crop production
3. Alternate Land Use Systems
4. Livestock Managment
5. Pisci-culture
6. Apiculture
7. Other agri-based enterprises
8. Livelihood based farm and off farm activities

Various activities taken up in a watershed under the above components are as follows:

Soil and Water Management:

Soil Conservation Works such as bunding and terracing, vegetative barriers etc in arable lands and contour trenching in non-arable area, loose rock and pucca check dams in water courses for soil conservation and grade stabilization and water harvesting and ground water recharge structures (nala bunds and percolation tanks) are taken up under this component. A number of specialised practices developed by research institutions such as conservation furrow, ridge and furrow, broad bed and furrow etc. have been found to be helpful for in-situ moisture conservation. Mulching is also recommended for soil moisture conservation. Of late, mulch-cum-manuring with organic mulches are being promoted with the twin objectives of moisture conservation and organic matter build-up.

Improved Crop Production:

Improved crop management, practices include improved/high yielding varieties, integrated nutrient management, weed management, integrated pest and disease management and use of improved agricultural implements and machinery.

Alternate Land Use Systems:

In watershed management, it is often desirable to go for alternate land use systems for better resource utilization as well as for improving the income of farmers. Various options are horticulture, agri-horticulture, horti-pastoral, afforestation, agro-forestry, silvi pastoral systems and bio fuel plantations. Of late medicinal and aromatic plants are being promoted for increased returns.

Post-harvest Technologies:

Post-harvest technologies assume great importance for reducing post-harvest losses, value addition of agricultural products and marketing.

Live Stock Management:

Diversified farming systems are often the best way to insure against variation of weather and market. Animal husbandry (Dairy, Poultry, Sheep and Goats, Piggery, emu farming etc,.) provides the best alternative source of income to the farmers, which is more stable.

Others:

Some of the other programmes that can be taken up under watershed programmes are Sericulture (silk worm rearing), Pisci-culture (fish rearing), Apiculture (bee keeping) etc. In the common guidelines-2008, there is provision of 9% of the budget for livelihood activity for asset less persons and 10% for production systems and micro-enterprises

Action Plan Preparation:

Action plans are prepared based upon the need assessment made through Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA) surveys. Detailed programme planning is done under the various components of watershed development such as soil and water management, improved crop management, alternate land use system etc. It may be necessary to carry out further detailed surveys in order to arrive at the exact locations and dimensions of interventions and to estimate benefit/cost ratios of watershed development.

For large watersheds, thematic maps prepared by State Remote Sensing Application Centres can provide basic information about the area on soils, geology, land use etc. It is often desirable to prepare base maps of watersheds with survey numbers on it and show proposed interventions on this map for efficient programme planning, implementation and monitoring.

Impact of Watershed Programme:

An evaluation of Model Watershed Programme implemented by GOI-ICAR-State Departments during 1984-1988 at 47 locations across the country has clearly revealed the beneficial impact of watershed approach in terms of increased water availability (both surface and ground water), increase in productivity of crops, increase in the availability of fodder & fuel and generation of employment in rural (watershed) areas. This has led to the implementation of NWDPRA by the ministry of Agriculture from 1987-88 onwards across the country. Ministry of Rural Development has its programmes such as DPAP, DDP, IWDP etc., based on watershed approach. Now, all the NRM based projects have watershed approach as a common feature.

Lessons Learnt:

Experience with watershed development programmes in the past has revealed that there is a tendency on the part of the farmers to revert back to traditional practices once the governmental support is withdrawn. There was no mechanism for maintenance of common property resources generated under the watershed programme. Therefore constitution of watershed management committees and its proper functioning will ultimately decide the success or failure of watershed management programme. More over, with liberalization, privatization and globalisation that is taking place the world over, and subsidies being withdrawn, technologies have to be competitive and cost effective so that they are adoptable by and profitable to the farmers.

Participatory methods:

For better adoption of technologies, participatory planning and implementation is a must. In participatory methods, the felt needs of the farming communities are given due importance and the action plans are developed by following a Bottom-Up approach rather than a Top-Down approach adopted in the past. Needs are assessed by conducting Rapid Rural Appraisal (RRA) surveys and Participatory Rural Appraisal (PRA) surveys. Officials of Government and NGOs and other agencies involved in watershed development act as Facilitators, and the decisions are taken by the Farmers themselves.

Thrust Areas of Watershed Development

Livelihood security and poverty alleviation

There is a growing realization that any development programme is for the benefit of inhabitants of the watershed at large and in this context, participatory planning and implementation, social equity, gender mainstreaming, poverty alleviation and providing livelihood security are basic consideration in programme planning and implementation. The
Government of India brought out **common guidelines for watershed development projects** in India effective from 1-4-2008 which is applicable to all ministries/ programmes of Government of India (*for details see www.dolr.nic.in/ common guidelines-2008. Pdf)*

Farming systems development:

We must realise that uncertain rainfall conditions and drought is a fact to be lived with and crop losses and even complete crop failures are to be expected. Therefore, it may be necessary to adopt cropping systems that are more resilient to drought. We must also look to diversify options of animal husbandry and other allied agricultural enterprises in order to have alternate sources of income under such circumstances.

Ground water recharge.

Due to the rapid growth in population and urbanization, there is acute shortage in the availability of water in many areas. In many places, water table is going down at an alarming rate due to excessive abstraction through constantly deepening bore wells both in rural and urban areas. It is therefore necessary to take immediate steps to enhance ground water recharge in order to replenish this fast depleting precious resource.

Inter basin water transfer

At the national level, we must realise that temporal and spatial variability in the availability of water is a fact. It is common scene that when one part of the country reels under drought, floods hit another region. There are well-endowed regions where water is in excess. The ultimate solution to the problem of water scarcity lies in inter basin water transfer. For eg., feasibility studies of linking the different river systems of India is currently under way and hopefully some of these schemes might have to be taken up sooner than later to meet the water needs of drylands.

Following is a list of areas needing attention of those involved in watershed research and development:

1. Low cost technologies for soil and water conservation
2. Monitoring of Ground water status and ground water recharge Mechanisms.
3. Crops and cropping systems which promote resource conservation and fetch higher returns such as Medicinal and Aromatic Plants, floriculture, horticulture.
4. Farming Systems Development and increasing role of livestock to provide stable income and returns to farmers.
5. Post Harvest Technologies for preventing losses, processing and value addition.
6. Institutional mechanisms for market intelligence and marketing.
7. Water and Air quality assessment and amelioration measures for pollution control.
8. Institutional mechanisms for meeting situations arising out of uncertain rainfall Condition/drought.

Emerging Issues:

Imparting livelihood security, poverty reduction, employment generation, social equity and gender mainstreaming in rural areas are key-concerns in any development programme. Climate Change and its mitigation and adaptation Strategies are receiving worldwide attention and hence interventions promoting such efforts need to be incorporated in Watershed Management Programmes. We need to promote interventions of Clean Development Mechanisms, Organic Farming, Conservation Agriculture, Non-pesticidal methods of Pest control etc. for arresting degradation of resources and to make our environment a safe place to live on. There is need for increased use of modern technologies such as Geographic Information Systems and Remote Sensing for enhancing our efficiency of planning, implementation and monitoring of Watershed Development Programmes.

GIS & RS APPLICATION IN PLANNING OF RAINWATER HARVESTING STRUCTURES IN WATERSHED AREAS

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Introduction

Rainfed agro-ecological regions (AER) which encompass the semi-arid tropics (SAT) and hot dry and moist sub-humid regions of India includes over 95.09 m ha (28.98%) under the semi-arid climate and 3.19 m ha or 1 % of the land area under the transitional climate. Watershed-based development has been accepted as the template for agricultural development and economic planning of this region. In peninsular India average annual rainfall is 500 mm (300-800 mm), which occurs in 45-50 rainy days. Over 50% of this rainfall occurs by way of thunderstorm that lasts for a few hours. Considering such a rainfall pattern, it is essential to harvest, store and use rainwater for undertaking agriculture and other allied activities for the rest of the year. Intensive rainfall events induce severe soil erosion in bare or sparsely vegetated land that is common in the region.

Watershed Development and Management Program was initiated during 1980s to address these limitations of the rainfed AER (Planning Commission, 2001). Soil and Water Conservation Structures (S&WC) viz., check-dam, stone weirs, contour bund, live bunds, vegetative cover, key-line plantation, grass way etc. were planned to provide impediments to overland - runoff which induce soil erosion and depletion of nutrients from agricultural fields. Structures were laid to guide runoff to designated farm ponds and tanks for water harvesting on the surface, besides impounding water for facilitating deep percolation for groundwater recharge. Thus, Watershed Development Program (WDP) was considered the most comprehensive program for achieving agricultural and ecological sustainability in the rainfed regions in India. As India envisages sustaining an agricultural growth rate of 4.0 to 4.5 per cent in order to reduce food insecurity and poverty, while increasing rural purchasing power, it is essential to strive for achieving sustainable development through watershed development.

Watershed Development Program (WDP) in India

One of the primary reasons, in favor of watershed-based development in rainfed AER, is the enormous cost of major water projects like the under-construction Narmada river-valley project. Hence emphasis was shifted to augmenting water resources through small and decentralized projects and the WDP for rainfed regions in rural India, have remained the accepted strategy for rural transformation. Watershed Projects have been undertaken under six major national programs, viz. Drought-Prone Area Program (DPAP), Desert Development Program (DDP), National Watershed Development Project for Rain-fed Area (NWDPRA), Watershed Development in Shifting Cultivation Areas (WDSCA), Integrated Watershed Development Project (IWDP) and Employment Assurance Scheme (EAS) etc. by four Central Ministries of Govt. of India namely, Ministry of Rural Development (MORD), Agriculture (MOA), Environment & Forestry (MOEF) and Water Resources (WR).

Significantly, 70 per cent of funds for watershed development in India are being spent under these six major programs. There are also, a lot of commonality in the WDP undertaken by these four ministries, in view of which, a inter-ministerial sub-committee (1999) evolved a common approach and principles for undertaking of WDP in India. The Perspective Plan of India envisages a holistic and integrated development of rainfed areas in the country on watershed –basis to cover app. 63 million ha at an estimated cost of Rs. 76,000 crore or USD 1520 m (Planning Commission, 2005). A Technical Committee Report submitted to the Department of Land Resources (MORD) in January 2006 (Parthasarathy, 2006), estimates that at current level of outlay, it may take 75 years to complete watershed treatment in India. The Committee opined that if S&WC measures needed to be completed by 2020, the Government must allocate Rs. 10,000 crore (USD 20 m) annually for the purpose till then.

Evaluation of impact of Watershed Development Program (WDP) in India

Most of the studies undertaken to evaluate the impact of package of practices implemented under WDP have been based on qualitative data with some quantitative information for which econometric analysis had to be performed. All the studies faced two major problems due to which their scope of analysis was restricted. Firstly, baseline information of watershed villages is extremely difficult to obtain from Project Implementing Agencies (PIA) as there were no systematic methods or process put in place to collect and archive them; hence meaningful evaluation was always difficult. Next, periodic monitoring of WDP was neither undertaken by PIA nor the funding agency. As a consequence, most evaluation studies were forced to report on qualitative information only. These problems had been widely discussed and in more recent WDP, amendments have been made and a definitive process has been put in place to avoid similar problems. P.K. Joshi et al (2005) undertook meta-analysis of over 311 watershed projects and documented efficiency, equity and sustainability benefits. The authors point out that mean B: C ratio of a watershed program in the country was quite modest at 2.14. Internal rate of return was 22 % that was comparable with many other rural developmental programs.

To address these lacunae with reference to evaluation of sustainability of watershed projects in India, two research projects were undertaken at CRIDA under the Ad-hoc scheme and the ICAR National Fellow Scheme of the author to develop a methodology and a toolkit for evaluation of watershed development projects in the peninsular region of India since 2004. For this purpose, tools of Geo-informatics like GIS, Remote sensing techniques, DGPS and Spectro-radiometer were used to supplement information generated from actual field survey, soil analysis and socio-economic survey conducted in the selected watersheds and villages. Databases were created in MS-Access and thematic maps were drawn using ArcGIS. Multi-spectral satellite data were procured from NRSA for pre-project period i.e., 1998 and post-project periods, i.e., 2004 to 2006. The satellite imageries were interpreted to understand the processes of change using various indicators. A methodology was thus developed to generate baseline information for pre-project period for various parameters from field and satellite data which were in turn, used as sustainability indicators to assess sustainability of watersheds projects. In Figure 1 the modular scheme of the evaluation study has been depicted. The impact of non-implementation of WDP was compared in an untreated watershed in the vicinity for a clearer understanding. Photo 1 depicts the use of DGPS for Geo-referencing of SWC structures in the treated watershed while Photo 2 shows how spectral signatures were matched in the field to help in interpreting satellite data. Figure 2 indicates the location of various watersheds taken for evaluation. Maps were prepared using ArcGIS software.

Conclusion

In order to evaluate sustainability of WDP, it is essential to undertake a multidisciplinary approach using the tools indicated in this paper. Soil fertility status was evaluated in conjunction with socio-economic conditions prevalent in the selected watersheds.

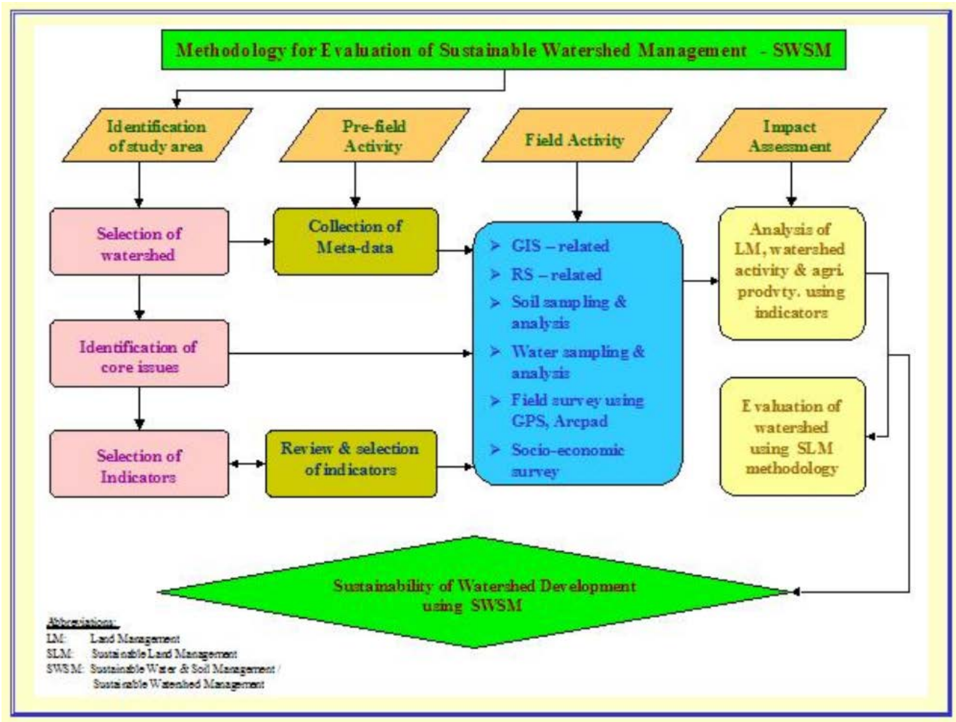

Fig.1: Multidisciplinary methodology used to evaluate sustainability of WDP

Photo 1: Geo-referencing a check-dam in Pamana

Photo 2: Using handheld spectro-radiometer to collect spectral signature

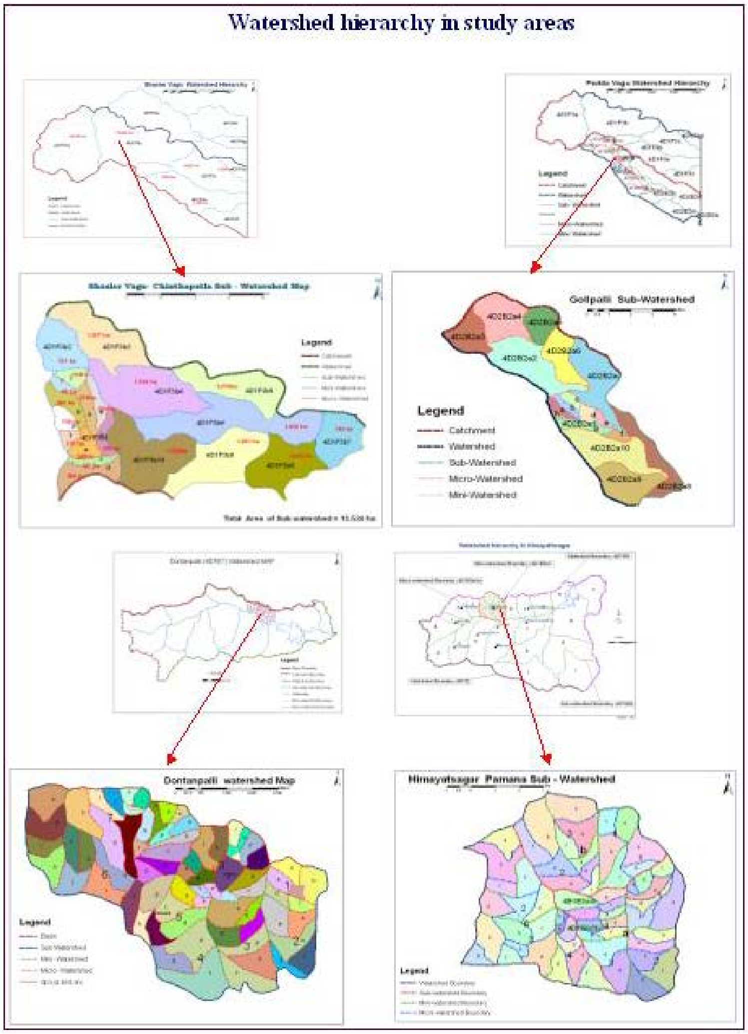

Fig 2: Delineating watershed boundaries using ArcGIS

Application of GIS & RS was found to be useful to geo-reference sustainability indicators and in construction of baseline information for pre-WDP period so as to facilitate a comparison of the situation. Study of ten micro-watersheds in the five villages in AESR 7.2 undertaken during 2004-2011, indicates that watershed projects are essential for rainfed agriculture and they must be implemented with zeal if migration has to be checked. It was seen that most villages are predominantly peopled by marginal and small farmers and any rural development programs including WDP, must be fine–tuned for them, if sustainability has to be achieved. A DSS for monitoring and evaluation of watershed project has been developed and a brief write-up is appended herewith.

Knowledge Product from CRIDA

DSS (Methods & Tools) for Monitoring & Evaluation of Watershed projects located in Rainfed AESR 7.3

Watershed development program is a major strategy for addressing twin problems of soil erosion and water scarcity restricting agricultural productivity in rainfed regions.

Investments in the program have not yielded more than 20 % returns necessitating need for understanding which aspects or factors are critical for sustainable development of rainfed agriculture and which indicators could serve as signpost for monitoring and evaluation (M&E) of sustainability of watershed project. To achieve this, a multidisciplinary comprehensive evaluation procedure was developed. A set of fifty-one multidisciplinary indicators were constructed including sixteen RS and GIS-related indicators, with score-card to evaluate five aspects of agricultural sustainability, namely, *agricultural productivity, livelihood security, environmental protection, economic viability* and *social acceptance* at three spatial levels – *Household-, Field-* and *Watershed-level.*

Indicators were used to evaluate eight pilot live-watersheds (four treated and 4 untreated) in AESR 7.3 in Andhra Pradesh for a period of six years (2005-2011) and six *Monitoring* and six *Evaluation* Indicators were identified using two statistical techniques – Principal Component Analysis (PCA) and Bivariate Correlation techniques (*Table 1 & 2).* A Raster Calculator Tool was added to improve spatial accuracy of evaluation (*Fig. 3*). Thematic maps pertaining to each indicator were generated and combined in Raster Calculator to arrive at a *Composite Sustainability Index* for each field / landholding in the watershed. Indices were categorized based on deciles for each watershed into three categories indicating probability of sustainable development, viz., deciles 1-4 denoting poor, 5-7 indicating moderate to fair and 8-10 indicating good chance for success. Indicators are non-correlated, measurable, robust, objective and replicable. They will serve both, the project implementing agencies and the watershed funding agencies.

Study indicated that increased emphasis on aspects pertaining to these indicators if implemented zealously, could contribute up to 68 to 80 % of agricultural sustainability. At present <20% of land in treated watersheds were found to be sustainable *(Fig.4).* Vegetation Index (NDVI) indicated an increase in post-monsoon period and Sustainable Yield Index (SYI) indicated higher yield in treated watersheds. Land Use Cover Change (LCCS) study indicated a decline in extent of rainfed agriculture in the region owing to overlapping development programs like Accelerated Irrigation Benefits Program; Repair, Renovation & Restoration (RRR) of Water Bodies linked to Agriculture, besides Watershed Development Program and recurrent extreme weather events in the region in the last decade.

Table 1: Indicators for Monitoring Sustainability of Watershed Program

Watershed - level	**Contribution to sustainable development (%)**
Availability of fodder	3.5
Total crop production	7.8
Gross agricultural income	7.8
S & WC structures	17.9
Soil moisture conservation	17.9
Farm OM recycling	13.4

Contribution to sustainable agricultural development	**68.3**

Table 2: Indicators for Evaluating Sustainability of Watershed Program

Watershed-level	**Contribution to sustainable development (%)**
Soil Organic Carbon	13.4
Credit facility	15.9
Gainful employment	13.4
Availability of fodder	12.2
Soil fertility	12.4
Crop Diversity Index	13.6
Contribution to sustainable agricultural development	**80.9**

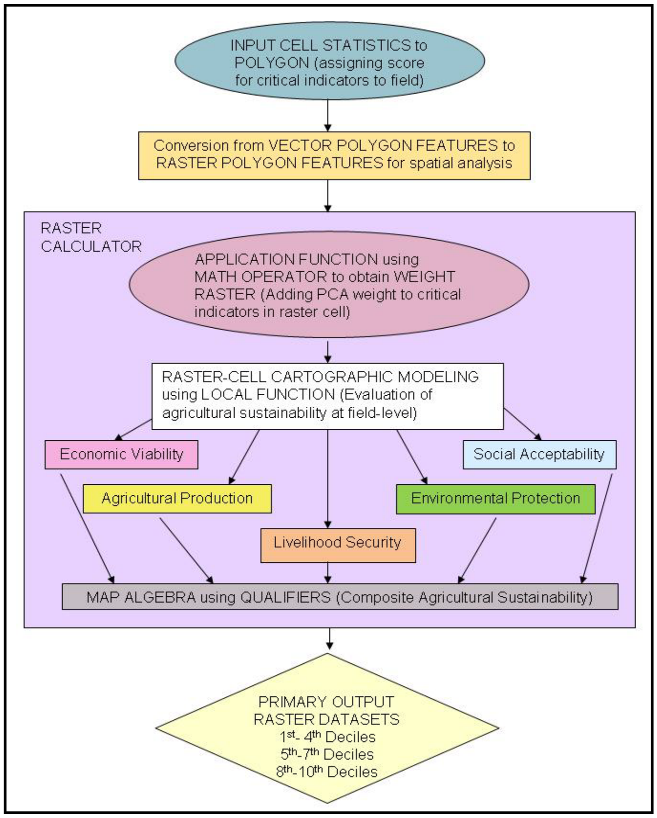

Fig. 3: Raster Calculator used for spatial evaluation of sustainability at field-level

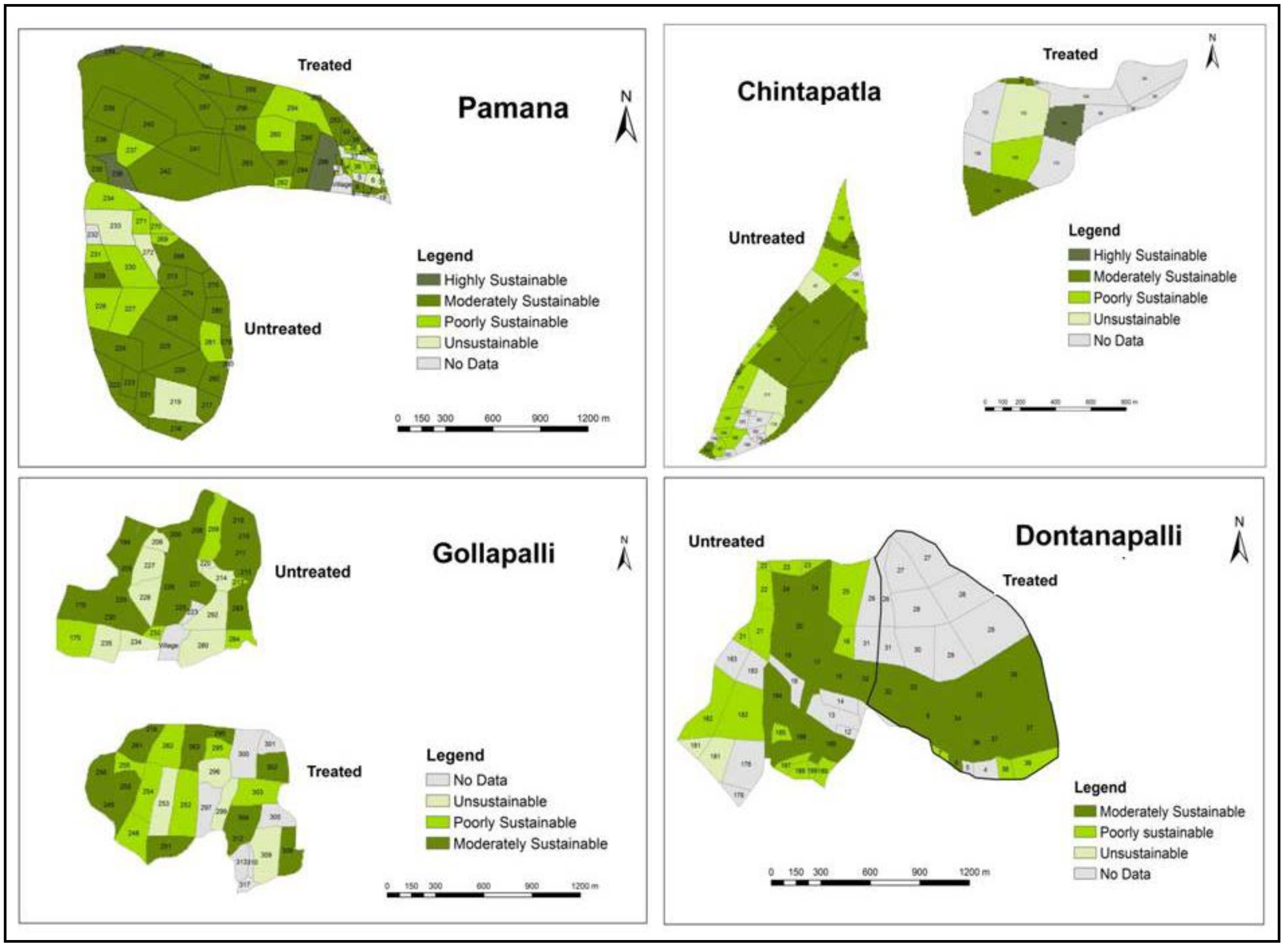

Fig. 4: Evaluation of watershed projects in Telengana region, Andhra Pradesh

ROLE OF IMPROVED FRUIT AND VEGETABLE PRODUCTION TECHNOLOGIES IN RAINFED AREAS

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ABSTRACT

Currently farmers in Dryland areas are not getting sufficient net returns from traditional Dryland crops like sorghum and smaller millets due to weather vagaries. They are shifting towards other production systems. These shifts are essentially driven by the market demand and social factors. Diagnostic surveys indicated that the farmers prefer fruit trees compared to fodder and fuel-wood trees. Further the economic returns are found to be in favour of agri-horticultural systems compared to traditional farming in low and marginal rainfall areas. Sheep and goat rearing has become another lucrative option for many farmers apart from milch animals, particularly buffaloes. To meet the growing demand for fruit and fodder, horti-pastural system, a combination of fruit trees and pastures, was therefore identified as one of the potential alternate land use options in shallow and medium deep soils.

The native pastures are not capable of supporting the growing livestock population and introduction of high yielding grass and legume is the need of the hour. Introduction of perennial pastures is one of the options to provide vegetative cover and to reduce the runoff and soil loss. There is a need to integrate fodder component in their system by introducing fodder species in the tree crops for overall sustainability of the production system. In general, fruit tree species selected for agri-horticultural system ought to be such that they provide Food, Fodder, Fiber and Fruits. Mango, ber, phalsa, wood apple, aonla, tamarind, guava etc., are such potential fruit species which can provide alternatives and a basis for sound farm economy, improve nutrition and health standards of the family and provide stability to income. In mango orchards, vegetables like tomato and chilles, fruits like papaya and phalsa, pulses like cowpea, moongbean and blackgram and above all nutrition cereals like sorghum and fodders like stylo legume and buffel grass can be grown successfully.

Introduction:

Environmental degradation is now recognized as an issue of concern in the developing world. With the increasing population pressure, the basic necessities of mankind such as food, fodder, fuel and fibre are becoming scarce. Geophysical and socio-economic constraints in augmenting irrigation resources have left Indian Agriculture to focus major thrust at rainfed farming to enhance production for meeting the ever increasing demands of the world's largest democracy. This puts tremendous pressure on the already fragile rainfed agro ecosystems wrought with multidimensional problems, all leading to severe and accelerated erosion. The need of the hour is to conserve and manage these ecosystems not only to achieve higher productivity for the present but also to sustain it on a long term basis.

Huge sums of money were spent for relief works during drought years with lack of direction or vision in solving the problem on a permanent basis. There were no follow up measures either. The development programmes when organized on individual problems they became less effective. Hence it was felt more appropriate that the area development approach was more effective than individual problem oriented approach. Soil, water and vegetation are the most important resources and proper management of these resources is essential for the success of agriculture in any area.

Watershed approach, apart from recognizing the importance of geo-hydrological relationships in planning sustainable conservation measures also assesses the land capability and its carrying capacity. Watershed management, through improving and stabilizing the productivity of rainfed agro ecosystem, is also expected to improve the socio-economic conditions of people living below the poverty line. Large amount is spent on watershed development in the country with Rajasthan being an important state in implementing the programme.

Horticultural crops cover about 6.8% of the total area contributing 18% of gross agricultural output. The choice of Horticulture crops as one of the alternate land use systems in drylands depends on the type of lands available for cultivation, fertility status of the soils, rainfall pattern and the economic conditions of the farmer. In India fruit crops are grown on 4.54 m.ha of land yielding 48m.tonnes of fruits making it as the World's largest producer of fruits. The vegetables are grown in an area of 51.2 m.ha yielding 80.8m tonnes. Due to the development of large number of varieties/hybrids coupled with matching production technologies, the area and productivity have been increasing fast. Generally on lands with gentle to moderate slopes and on deep soils with poor fertility, the farmer prefers to plant horticultural species. The extent of land required for such purpose is normally more than that for agricultural use. Given the required inputs and initial capital, an enterprising farmer can establish horticultural crops in conjunction with other crop combinations in drylands by adopting the appropriate production technologies, some of which are highlighted below:

Soils:

In Andhra pradesh, North Telangana plateau has hot, moist semi-arid eco-sub region soilscapes having moderately to gently sloping Patancheru series of Udic Rhodustalfs and Kasireddipalli series of montmorillonitic. Typic Pellusterts, are the predominant red and black soils in the region. Kasireddipallli soils are the representative soils in Medak district. While Patancheru series are extensively found in parts of Medak and Ranga Reddy districts and the adjoing areas. The texture of Patancheru series vary from sandy loam to loamy sandy with heavy and compact sub soil horizon due to increased clay content and mild acidic nature. The problems are presence of gravel and high bulk density, poor moisture availability and frequent drought conditions .The soils of Kasireddipalli series are very deep, very dark grey strongly alkaline and calcareous with high and uniform clay content in the pedon. These are imperfectly drained, highly susceptible to erosion with high shrink – swell potential.

Deccan plateau hot arid ecoregion comprises of mixed red and black soils. Red loams represented by Garnimitta series comprising Typic Rhodustalfs and the black soils are represented by Raichur series comprising Typic Pellusterts. They are highly susceptible to erosion and frequent drought. Sub soils is very hard when dry and acts as hard pan for root penetration and infiltration of water. Representative soils of Garnimitta sandy loams are slightly acidic to neutral with depth and clay content abruptly increases in the sub-surface layer. The Raichur soil series are very deep, dark Grey and moderately alkaline in soil reaction.

Physical and chemical properties of few representative soils.

Depth (cm)	Clay%	pH (1:25)	EC (dsm-1)	OC(%)	$CaCO_3$ (cmol(p+)Kg-1
Udic Rhodustalf (Patancheru Series)					
0-25	18.2	6.5	-	0.8	8.2
25-50	33.5	6.7	-	0.8	14.3
50-100	39.5	7.8	-	0.5	18.3
Typic Pellusterts (Kasireddypalli Series)					
0.25	53.7	8.8	0.1	2.0	0.7
25-50	58.4	9.4	0.1	9.5	0.5
50-100	67.4	9.4	0.4	20.0	0 .3

SELECTION OF CROPS:

The crops / varieties should be selected in such a way that they complete maximal growth during the period of moisture availability. Soil moisture stress is low from end of May onwards in the South and from July in the North. Fruits crops such as mango, lime, lemon, guava, pomegranate, aonla, jamun, wood apple and tamarind may be grown in areas where the rainfall is more than 600mm. Fruits like custard apple, ber, phalsa, karonda, lasora, pilu and jamun may be grown in areas where the rainfall is less than 500mm. The crops may be selected which possess Xerophytic characters like summer dormancy (as in ber), deep root system (as in ber and mango), high bound water in the tissues (as in fig and cactus), leaf surface having sunken stomata, thick cuticle, wax coating and pubescence (as in ber, fig, phalsa, tamarind), reduced leaf area (as in aonla) and ability to adopt to shallow soils, rocky, gravelly and undulating waste lands (pomegranate, aonla, cashew, *Buchanania lauzan*).

SUITABLE FRUIT AND VEGETABLE VARIETIES FOR DRYLAND

REGIONS

CROPS	CULTIVARS
FRUITS:	
Ber	Gola, Umran, Banarasi Karaka, Kaithli.
Pomegranate	Ganesh, Jyothi, P-26, Jalore seedless.
Mango	Banganapalli, Alampur Baneshan, Nelum, Mallika, Bombay Green, Amrapali, Kesar.
Sapota	Cricket Ball, Kalipatti.
Sweet orange	Mosambi, Kodur Sathgudi, Valencia, Blood Red ,Malta.
Lime	Tenali, Promalini, Vikram.
Custard apple	Bala Nagar, Arka Sahan.
Guava	Allahabad Safeda, Sardar, Arka Mridula.
Papaya	Coorg Honey Dew, Pusa Delicious, Pusa Majsty, Pusa Dwarf,Taiwan
Aonla	Kanchan, Krishna, Narendra –7.

Fig	Poona, Black Ischia.
Tamarind	PKM-1, Pratisthan, Yogeshwari.
Bael	Narendra Bael-5, Narendra Bael-9.
Passion fruit	Kaveri.

VEGETABLES:

Onion	Arka Niketan, Arka Kalyan, Pusa Red, Nasik Red, Pusa Ratnar, Pusa White Round, Pusa White Flat, Patna Red, Arka Pitambar (for export).
Tomato	Pusa Ruby, Pusa Early Dwarf, Swarna Mani,Vaishali,Naveen, Rupali, Rashmi
Brinjal	Arka Navneet, Pusa Purple Long, Pusa Purple Round, Pusa Kranthi, Arka Sheel, Arka Kusumakar, Arka Shirish, Swarna Shree, Swarna Manjari.
Chillies	G-5, G-3, Pusa Jwala, NP-46A, Arka Gaurav, Arka Lohit, Bharat, Sindhur.
Drumstick	PKM-1
Cowpea	Arka Garima, Pusa Komal, Pusa Barsati, Pusa Rituraj, Pusa Dofasali
Cluster bean	Pusa Navbahar, Pusa Sadabahar.
Amarnath	Chhoti Chaulai, Badi Chauli.
Okra	Arka Anamika, Arka Abhay, Parbhani Kranti, Pusa Makhmali.
Water melon	Arka Manik, Arka Jyothi, Sugar Baby.
Musk melon	Pusa Sharbati, Hara Madhu, Punjab Sunheri, Pusa Maduras.
Bitter gourd	Arka Harit, Priya, Kalyanpur Sona.
Ridge gourd	Swarna Manjari, Pusa Nasdar.
Round melon	Arka Tinda.
Cabbage	Pusa Mukta, Pride of India, Golden Acre, Pusa Synthetic, Pusa Drumhead, Shree Ganesh Gol.
Cauliflower	Pusa Deepali, Improved Japanese, Pusa Snowball.
Pumpkin	Arka Chandan, Arka Suryamukhi.

In frequently drought prone areas, crops like ker (*Capparis decidua*), pilu (*Salvadora oleoides*) lasora or gonda (*Cordia myxa*), gondi (*Cordia gharaf*) and ber (*Zizyphus spp*.) can be taken up. Flowering and fruiting are synchronous to monsoon period in *Zizyphus spp*. which is an added adoptive character in the dry arid regions.

In still drier areas crop species having maximal period of growth and fruiting during the period of maximum soil water and low atmospheric vapour pressure deficit, would be the most suitable ones. Such fruits can be cultivated under rainfed conditions using suitable water harvesting techniques eg *Carissa carandas*, *C.grandiflora*, custard apple, pomegranate, guava etc.

Aonla is suitable for cultivation in saline / alkaline soils with some soil amendments. Fruit trees like aonla, seedling mango, tamarind can be grown even along the National Highways in high rainfall regions.

Vegetable based cropping system:

Since the vegetable crops vacate field early, small and marginal farmers can cultivate vegetables year round. Vegetables are short or medium duration in nature and can give a cropping intensity of 400%. Intercropping of vegetables even in field crops provide sustainability to the small and marginal farmers.

Export oriented vegetable farming:

In addition to meeting the local demand, vegetables are now being considered as one of the potential commodities for export. APEDA has identified traditional vegetables like onion, bitter gourd and chilli; and non-traditional vegetables like asparagus, celery, sweet pepper, paprika, sweet corn, baby corn, green peas, french bean, cherry tomato and gherkins for good export earnings.

Onion accounts for 70% of total foreign exchange earnings among vegetables. Among others, okra accounts for 60%, green chillies for 20% and the remaining 20% include bitter gourd, french bean, capsicum. Among traditional vegetables- onion, okra, bitter gourd, green chillies etc. meet the requirement of South East Asia and Gulf countries and to some extent United Kingdom. Tomato products, especially puree and paste have great demand in export market.

With proper varieties, propagation methods, planting cum spacing methods, nutrient management, integrated insect pests disease management and water management including water harvesting usage of antitranspirants and mulches, the risks can be minimized in dryland horticultural crop production. Monocropping is often risk prone under dryland conditions. Profitable cropping systems involving horticultural crops can be taken up under dryland conditions.

Microcatchment or farm pond water harvesting system:

Heavy rains resulting in the heavy down pours is not uncommon resulting in runoff even in dry land regions. About 15-30% runoff water could be capitalized for water harvesting and runoff recycling. Efficient utilization of harvesting water requires an elaborate consideration of selection of site, runoff inducement, storage, seepage, evaporation losses, water lifting and conveyance devices and their efficiencies. A farm pond of 150m^3 capacity with side slopes of 1.5:1 is considered sufficient for each hectare of catchment area in the black soils with a provision of emptying it to accommodate subsequent events of runoff.

Horti pastoral cropping system :

Soils of the semiarid tropical regions are characterized by poor fertility, structurally degraded, undulating physiography and shallow depth. Soil erosion is a serious problem in rainfed areas because of lack of appropriate vegetative cover. Deforestation and overgrazing are the two principal factors responsible for degradation of vegetative cover. The population explosion has brought the marginal and sub-marginal rainfed lands under cultivation, posing a serious threat to already fragile rainfed ecosystem. Thus a necessity exists to make the best utility of available resources viz., soil, water and vegetation, based on land capability keeping in view the long term goal of sustainability on which depends the sustenance of human beings and livestock.

In order to keep the options open with regard to the farmers liking in the region, a viable alternative land use system may be worked out keeping horticultural as well as pastural components in the system. There is also an urgent need to give equal thrust to agri-horti pastural system for overall sustainability of the farming community so as to make use of the marginal and degraded lands in the rainfed agro-ecosystem.

Improved varieties of important forage crops

Crop	**Variety**	**Area of cultivation**	**Green forage yield(t/ha)**
Cultivated fodder legumes as inter crops in non- bearing young orchards.			
Cowpea	Russian Giant, EC4216 Shweta(No.988) C-88	North India North, West and Central India Mahaastra Punjab.	30-35 35-40 30-35 25-35.
Field bean	JLP-24	Whole Country (Annual/Binneal)	15-35
Cluster bean(Guar)	Guara-80 IGFRI-212 IGFRI-2395-2	Punjab and Haryana Entire guar growing tract.	20-30 17-35
Rice bean	K-1	Bihar,WestBengal, Orissa,Northeast regions and A.P.	20-35
Cultivated fodder cereals			
Sorghum	PC-6,9,23 MP Chari, UP Chari-2(Sel-278) Hara sona Pant Chari(UpFS-23) Meethi Sudan(SSG-59-3)	Whole country(Early to medium , Single cut) North india (Single cut) T.N., A.P.(Single cut) U.P. (Single cut) Whole country(Multi cut)	35-50 38-45 35-45 35-45 65-85.
Pearl millet	Giant Bajra(single cut) Giant bBajra (multicut) UUJ-1V-M, TASC-1 Rajko	Maharashtra and Central India Entire country Entire Pearl millet tract Gujarat and Rajasthan.	35-45 55-100 30-48 32-45.
Maize	African Tall Vijay Composite	Whole country Whole country	55-80 35-48
Cultivated fodder-Perennial grass			
Guinea grass	Hamil	Souuth,North east,East and CentralIndia.	70-90
Cultivated fodder –Annual grass			
Dinanath grass	PS-3,IGFRI-4-2-1. ,IGFRI-43-1.	Wholecountry	50-80
Setaria	Nandi,Kazungula,Narok	Whole country	60-90
Anjan grass	Bundel Anjan(IGFRI-3108), Marwar Anjan(CAZRI-75)	Arid and Semi Arid areas of India.	15-40 15-25
Blue Anjan	Co-1(Fs-391)	Tamilnadu (Semi arid areas)	28-47
Yellow Anjan	Marwar Dhaman(CAZRI-76)	Arid and Semi arid areas of India.	19-20.

Crops are selected according to the soil depth. Millets perform much better than Sorgum on light and shallow soils. Where as Sorghum is favoured on deep heavier soils. Fodder sorghum is preferred in areas with 600-800mm rainfall, where as Pearl millet grows better in areas with 300-600mm rainfall. Maize grows better in areas with high rainfall areas (>800mm).

In marginal and sub marginal lands, several perennial grasses and legumes can be grown. Depending upon rainfall , several range grasses and legumes can be grown which will augment the much needed forages in these areas. Some legumes such as *Desmodium spp., Macroptilium artopurpureum, Clitoria ternatea and Stylosanthes spp* are suitable as perennial forages. Amongst different *Stylosanthes spp*, *Stylosanthes hamata* is found to be most suitable in regions with 600-1000mm rainfall. *Stylosanthes guinensis* performs well in areas receiving high rainfall (850-1400mm). In low rainfall regions (400-750mm*),Stylosanthes scabra* is most suitable. Several of the fodder trees such as *Albizzia lebbek,* A.*procera, A.amara, A.acacia* are useful as fodder trees for silivipasture.

Grass Species suitable in tree crops under different agroecological regions

Region/Grasws	**Rainfall(mm)**	**Soil type**	**Dry forage yield (t/ha)**	**Crude proteien content(%)**
Semi arid				
Sehima nervosum	600-1000	Mixed red and black	3.5	5-8
Dicanthium annulatum	500-1000	Sandy loam ,Clay silty loam	2.5	4-7
Hetyeropogon contortus	600-1000	Mixed red and black,red soils	3.0	2-3
Chrysopongon fulvus	600-1000	Hilly areas and crevices of rocks	3.5	4-7
Iseilema laxum	700-1000	Low lying,clayey black soils.	3.0	4-6
Arid				
Lasiurus sindicus	100-150	Sandy	3.5	8-14
Cenchrus ciliaris	150-300	Sandy	4.0	8-9
Cenchrus setigerus	150-300	Sandy	3.0	8-9
Panicum antidotale	200-600	Sandy	3.0	9-14

Legume species suitable as intercrops in different orchards

Region / Legume	Soil preference	Dry forage yield (t/ha)
Semi-arid (600-1000mmrainfall)		
Desmodium intertum	Versatile	3.8
Desmodium uncinatum	Versatile	3.0
Glycine wightii	Well drained soil	3.0
Stylosanthes guinensis	Versatile	3.6
Stylosanthes hamata	Well drained soil	3.5
Stylosanthes humilis	Well drained soil	3.2
Lablab purpureus	Versatile	3.0
Macroptilium ateropurpureum	Versatile	1.8
Arid(<600mmrainfall)		
Stylosanthes scabra	Versatile	2.5
Atylosia Sp.	Versatile	2.0

MECHANIZATION FOR ENHANCED PRODUCTIVITY IN RAINFED AREAS

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Farm Power Scenario in India:

Experience has shown that there is a definite and positive relationship between farm power availability and farm production levels. Farm power availability to individual farms varies from 0.1 to 6 kw/ha depending upon the economic status and need of the farmer. Farm power availability of 1 to 1.5 kw/ha seems to be comfortable in completing all field operations in time and hence would help in attaining good crop yields. Therefore, there appears to be good scope in India to substantially increase the crop yields even with incremental increase in the levels of power availability, provided such power sources are utilized to optimum levels with good energy management. Improved farm implements and machinery with higher capacities and improved cultivation practices can play a vital role in achieving this target. Low power availability can considerably delay a farm operation there by decreasing the yields. This could be overcome either by increasing the power availability, or by utilizing the existing power sources more efficiently. Field operations like tillage, sowing, fertilizer application, interculture, weeding, spraying and dusting (of plant protection chemicals), harvesting and threshing are very important and timeliness of these operations enhances and assures good crop yields. Delay in field operation has adverse effect on crop husbandry and results in reduction of yields from 10-80%. Availability of matching farm implements having high capacity is another factor. Timely availability of other inputs like seed, fertilizer, chemicals along with proper crop management are also equally important in crop production.

From above review, it was found that the mechanization play a vital role increasing the food production at the targeted rate. Now the following subheads deal with the specific machinery and methods of mechanization for different operations.

Animal drawn Tillage and seed bed preparation implements:

1. M.B. Plough
2. 3or 5 tyne cultivator
3. Disc harrows: They are equipeed with 4-6 dics are widely used for secondary tillage. Output 0.12/ha
4. Leveller and land smootheners: Levelling blades, singh pata, ladders and patella harrows . Wide leveling plank helps in compacting soil aggregates in top layer which reduces the loss of soil moisture due to evaporation .(output 0.25-0.35ha/h)

Tractor drawn Implements:

1. M.B. plough
2. Disc pough
3. Shovel type cultivator
4. Duckfoot type cultivator
5. Disc harrows trailed or mounted type (tandom, off-set)
6. Ridger plough

Most of primary tillage implements such as m.b. plough, disc plough are two bottom type and are suitable for 25-35 hp size tractor. Three bottom implements are suitable for 35-45 hp size tractors. Field capacity varies from 0.2 to 0.3 ha/h for plough (for single bottom) and 0.4- 0.5 ha/h for disc harrows. Depth of operation is in the range of 100-150mm.

Levelling of field is mostly done by sing levelers or dumpers. In case the fields are leveled, the surface compaction is achieved by sing 2-3 M wide plank pulled by tractor.

The ridger bottoms mounted on a standard frame are mostly used for making ridges and furrows for planting of crops like potato and sugarcane. Single ridger bottom is used for making drains to remove excess rain water from the field. Field capacity of ridger varies from 0.4 to 0.5 ha/h.

Bed-furrow formers: Though animal drawn bed –furrow formers are available, their efficiency is very less. The tractor drawn be-furrow former is capable of forming alternate beds and channels. It saves 90 % of labour. These beds are suitable for planting crops like sorhum maize, cotton. This sbed and furrow system is ideal for efficient irrigation management.

Rotavators and residue incorporation implements: Rotavators are best suitable for pulverization of the soil after primary tillage and also for incorporating the residue which is left in the ground as well as green residue if any grown on the surface of the soils. Field capacity of the rotavator is around 0.45 ha/hr. It is driven by the pto of the tractor. Blades with different shapes can be used in the rotavator. A 35-hp tractor can be sufficient enough to use these implements.

Rotavator in operation

Planting and Planting Machinery:

The basic objective of sowing operation is to put the seed and fertilizer in rows at desired depth and seed to seed spacing, cover the seeds with soil and provide proper compaction over the seed. The recommended row to row spacing, seed rate, , seed to seed spacing and depth of seed placement vary from crop to crop and for different agro-climatic conditions to achieve optimum yields.

Different types of furrow openers ate used to suit the varying soil conditions.

1. Double end pointed shovel
2. Pointed bar type
3. shoe type
4. Runner or sword

Plough planter, 2-row seed drill, 4- row seed drill are the main types in bullock drawn equipment.
4-row, 6-row and 9-row seed drills are available in tractor drawn implements. The can cover the area of 1 ha in an hour if the skilled operator is available.

Some of the precision planters like pneumatic planters are also available in India for breeding type experiments.

CRIDA 6-row planter

Pruning is the principal technique available to grape growers to regulate their crops. It is a process that requires pruners to think not only of the effect it will have on this year's crop but also how their actions will affect future years' crops. Secature is the most commonly used for pruning grape.

Harvesters and combines:

Harvesting operation involves cutting/digging/picking/laying/gathering/curing/transport and stacking of the crops. In normal practice loss observed up to 5-10 % due to cutting and conveying losses. It can be reduced by using the precision harvesters and combines.

Types:

Reapers: Reapers are used for harvesting of crops mostly at ground level. It consist of crop-row-divider, cutter bar assembly, feeding and conveying devices. Reaper are classified on the basis of conveying of crops such as vertical conveying reaper, horizontal conveying reaper, bunch conveying reaper and reaper binders.

Strippers: Stripper is used for collection of matured seeds/pods from the plants or seed crops.
Diggers: For digging the groundnut and potato and other crops. Bullock drawn and tractordrawn diggers are available in the market.

Cobine harvester: Various designs of combine harvester having 2-6 m long cutter bar are commercially available. The function of combine harvester is to cut, thresh, winnow and clean grain. It consists of header unit, threshing unit, separation unit, cleaning unit and grain collection . The function of the header is to cut and gather the crop and deliver it to the threshing cylinder. The crops are threshed between cylinder and concave due to impact and rubbing action. The material is shaken and tossed back by the straw rack so that grain moves and falls through the openings in the rack on to the clening show while the straw discharged at the rear. The grain is conveyed with collected in a grain tank.

SUSTAINABLE RURAL LIVELIHOODS – NAIP EXPERIENCES

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The origin of technical communication **a prominent mode of documentation** has been variously attributed to Ancient Greece, The Renaissance, and the mid 20th Century. However, a clear trend towards the professional field can be seen from the First World War on, growing out of the need for technology-based documentation in the military, manufacturing, electronic and aerospace industries. In 1953, two organizations concerned with improving the practice of technical communication were founded on the East Coast of the United States: the Society of Technical Writers, and the Association of Technical Writers and Editors. These organizations merged in 1957 to form the Society of Technical Writers and Editors, a predecessor of the current Society for Technical Communication (STC).
Documentation refers to the process of providing evidence ("to document something") or to the communicable material used to provide such documentation (i.e. a document). Documentation may also (seldom) refer to tools aiming at identifying documents or to the field of study devoted to the study of documents and bibliographies

Subfields of documentation includes

- Scientific documentation
- Technical documentation (e.g. software documentation, product specifications or a patent document)
- Legal documentation (e.g. a travel document system)
- Administrative documentation
- Historical documentation
- Process documentation

Documentation understood as document is any communicable material (such as text, video, audio, etc., or combinations thereof) used to explain some attributes of an object, system or procedure.

A professional whose field and work is documentation used to be termed a documentalist. Normally, documentalists are trained or have a background in both a specific subject and in the field of documentation (today information science). A person more or less exclusively to write technical documentation is called a technical writer. Technical writers are similarly trained or have a background in technical writing, along with some knowledge of the subject(s) they are documenting. Often, though, they collaborate with subject matter experts (SMEs), such as development professionals.

PRINCIPLES OF DOCUMENTATION

While associated ISO standards are not easily available publicaly, a guide from other sources for this topic may service the purpose. David Berger has provided several principals in document writings, regarding the terms using, procedure numbering and even lengths of sentences etc.

Procedures and Techniques

The procedures of documentation varies from one sector, or one type, to another. In general, these may involve document drafting, formating, submitting, reviewing, approving, distributing, repositing and tracking etc. and are convened by associated SOPs in a regulatory industry.

PROCESS DOCUMENTATION

Process documentation is considered a professional task for which organizations either hire specialized employees, or outsource their needs to communication firms. For example, a professional writer may work with an organisation to produce a user manual. Other times, technical communication is regarded as a responsibility that technical professionals employ on a daily basis as they work to convey technical information to coworkers and clients. For example, a computer scientist may need to provide software documentation to fellow programmers or clients.

The process of developing information products in technical communication begins by ensuring that the nature of the audience and their need for information is clearly identified. From there the technical communicator researches and structures the content into a framework that can guide the detailed development. As the information product is created, the paramount goal is ensuring that the content can be clearly understood by the intended audience and provides the information that the audience needs in the most appropriate format. In the context of a development research project such documentation is very essential to the process of upscaling the outcomes of the project on a large scale.

Just as technical communication is important to engineers mainly for the purpose of being professional and accurate, process documentation is necessary for development professionals to learn quickly from the mistakes of others.
The process documentation can be divided into five steps:

1. Determine the purpose of documentation based on intended auidence
2. Collect information
3. Organize and outline information
4. Write the first draft
5. Revise and edit

Determine the purpose of documentation based on intended auidence

All documentation is done with a particular end in mind. The purpose is usually to facilitate the communication of ideas and concepts to the audience, but may sometimes be used to direct the audience in a particular course of action. The importance of the audience is in the notion that meaning is derived from the audience's interpretation of a piece of work. The purpose may be something as simple as having the audience understand the details of some technological system, or to take a particular action using that system. For example, if the workers in a bank were not properly posting deposits to accounts, someone would write the procedure so these workers might have the correct procedure. Similarly, a sales manager might wonder which of two sites would be a more appropriate choice for a new store, so he would ask someone to study the market and write a report with the recommendations. The sales manager would distribute the report to all parties involved in making that decision. In each of these instances, the person who is writing is transferring knowledge from the person who knows to the person who needs to know.

COLLECTING INFORMATION

The next step is to collect information needed for accomplishing the stated purpose. Information may be collected through primary research, where the documentatlist conducts research first-hand, and secondary research, where work published by another person is used as an information source. The documentalist must acknowledge all sources used to produce his or her work. To ensure that this is done, the documentalist should distinguish quotations, paraphrases, and summaries when taking notes.

ORGANIZING AND OUTLINING INFORMATION

Before writing the initial draft, all the ideas are organized in a way that will make the document flow nicely. A good way of doing this is to write all random thoughts down on a paper, and then circle all main sections, connect the main sections to supporting ideas with lines, and delete all irrelevant material.

Once each idea is organized, the writer can then organize the document as a whole. This can be accomplished in various ways:

- **Chronological:** This is used for documents that involve a linear process, such as a step-by-step guide describing how to accomplish something.

- **Parts of an object:** Used for documents which describe the parts of an object, such as a graphic showing the parts of a computer (keyboard, monitor, mouse, etc.)

- **Simple to Complex (or vice versa):** Starts with the easy-to-understand ideas, and gradually goes deeper into complex ideas.

- **Specific to General:** Starts with many ideas, and then organizes the ideas into sub-categories.

- **General to Specific:** Starts with a few categories of ideas, and then goes deeper.

Once the whole document is organized, it's a good idea to create a final outline, which will show all the ideas in an easy-to-understand document. Creating an outline makes the entire writing process much easier and will save the author time.

Writing the First Draft

After the outline is completed, the next step is to write the first draft. The goal is to write down ideas from the outline as quickly as possible. Setting aside blocks of one hour or more, in a place free of distractions, will help the writer maintain a flow. Also, the writer should wait until the draft is complete to do any revising; stopping to revise at this stage will break the writer's flow. The writer should start with the section that is easiest for them, and write the summary only after the body is drafted.

The ABC (Abstract, Body, and Conclusion) format can be used when writing a first draft. The Abstract describes the subject to be written about, so that the reader knows what he or she is going to be told in the document. The Body is the majority of the paper, in which the topics are covered in depth. Lastly, the Conclusion section restates the main topics of the paper.

The ABC format can also be applied to individual paragraphs, beginning with a topic sentence that clearly states the paragraph's topic. This is followed by the topic, and finally, the paragraph closes with a concluding sentence.

Revising and Editing

Once the initial draft is laid out, editing and revising can be done to fine-tune the draft into a final copy. Four tasks transform the early draft into its final form, suggested by Pfeiffer and Boogard:

Adjusting and Reorganizing Content

During this step, the draft is revisited to 1) focus or elaborate on certain topics which deserve more attention, 2) shorten other sections, and 3) shift around certain paragraphs, sentences, or entire topics.
If required professional help can be sought for editing for style, grammar and context.

MICRO-IRRIGATION TECHNOLOGIES FOR ENHANCING WATER PRODUCTIVITY FROM FARM PONDS

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Water availability affects the life style of human being and almost all the flora and fauna on the earth. It is directly used as a resource by mankind for changing the natural pattern of agricultural productivity through irrigation, domestic and industrial purposes. Water is a renewable natural resource which simultaneously reprocessed and delivered within a framework known as hydrological cycle.

Insufficiency of soil moisture, particularly when it coincides with the critical growth stage of crops, is one of the major constraints seriously affecting the productivities. The reproductive phase of short duration crops (100-110 days duration), usually has 30 days, typically between August -September and February-March in case of *kharif* and *rabi* season respectively. In this region, half of the duration of the reproductive phase experience soil moisture deficit of 20 per cent below saturation moisture content and hence crop yield is adversely affected. Thus, the provision of supplemental irrigation is necessary to maintain the soil moisture regime at optimal level for obtaining higher production. Construction of small ponds of capacity less than 1000 m^3 is a good economical alternative for storage of excess rainwater and its utilization as supplemental irrigation during dry spell of monsoon season and pre-sowing irrigation to the crops of *rabi* season.

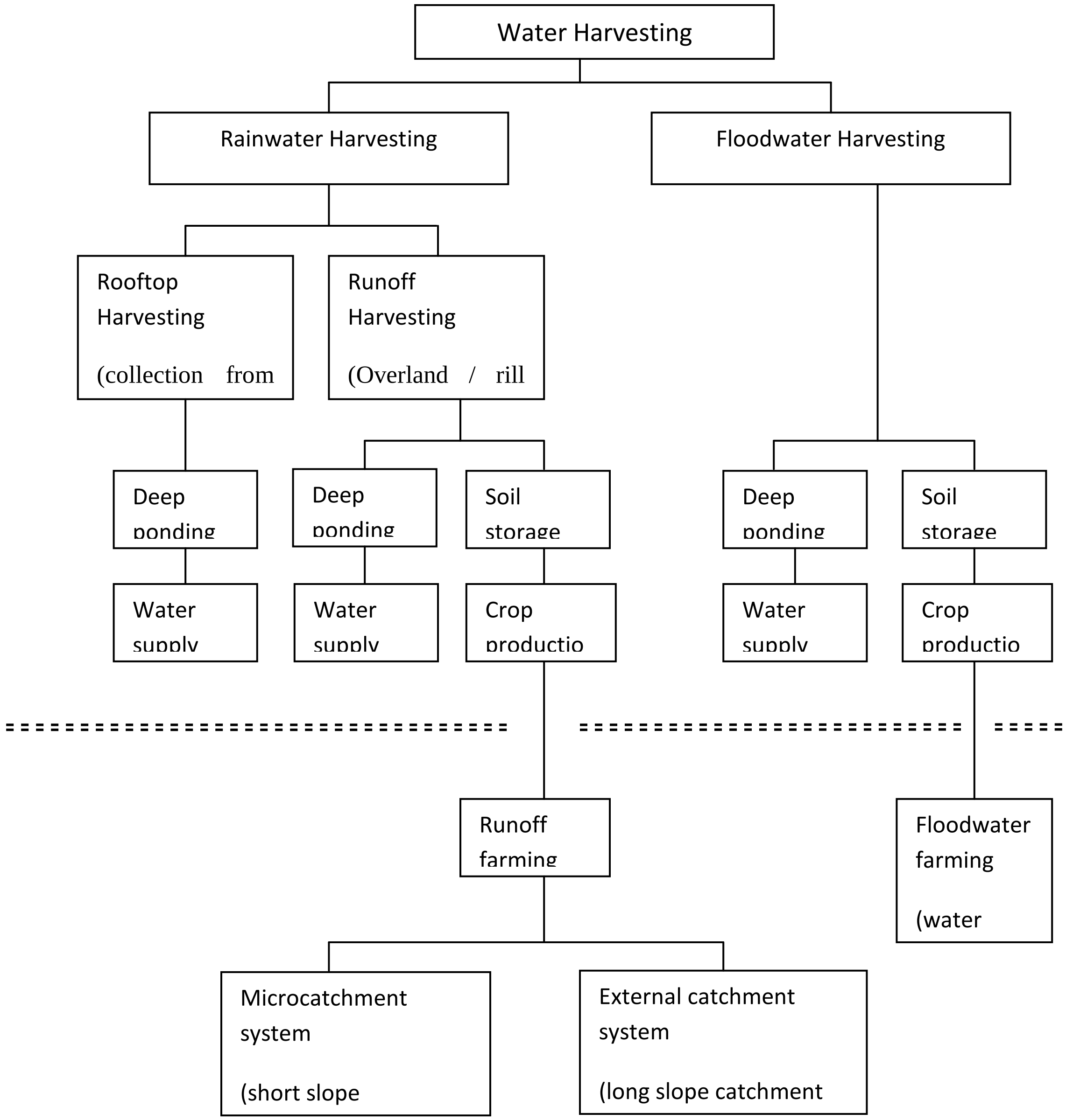
Definition and classification

Water harvesting in broad sense defined as the "collection of runoff for its productive use". In other words, it is the process of collecting, conveying and storing. Runoff may be harvested from roofs and ground surfaces as well as from intermittent of ephemeral watercourses. Productive uses of harvested water include provision for domestic and stock water, concentration of runoff for crops, fodder and tree and water supply for fish ponds.

The simplest method of water harvesting is probably the collection and storage of natural flow from a watershed. The basic components of a water harvesting system are;

- Precipitation
- Collection of water from surface of catchment
- Water storage
- Distribution of water

Classification of water harvesting techniques is vastly varied. Different researchers use different names and often disagree about definitions. A general and practical classification that established within the context of the "Sub-saharan water harvesting study" undertaken by the World Bank in 1986-89 is presented in figure 1.



LDPE Film Lined Farm Pond

To increase the irrigation potential in dryland agriculture, it is necessary to develop the water resources by means of small farm ponds (capacity up to 1000 m^3). The criterion for the design of ponds should be such that it not only reduces the seepage losses but also cost effective. The cement pond for instance is able to check the seepage losses but the cost becomes the limiting factor in economic exploitation of water resources. Moreover due to settlement of land, cemented pond is prone to cracks. On the other hand unlined ponds prone to heavy seepage losses (300-400 litre per day per m^2) and may not supply water for irrigation when it is needed. Thus for the effective water storage, the pond should minimize the seepage loss and be cost effective.

Low density polyethelene (LDPE) film has been used successfully to control the seepage loss effectively at lower cost than the cement ponds. The film used should have minimum thickness of 200µ (0.2 mm) and by virtue of this it becomes prone to physical damage. To avoid the physical damage and weathering from sunlight the protection of the film is necessary. This can be realized through application of covering material e.g. stones, tarfelt sheet, *khas khas* grass etc.

3.3.1 Design

The design of LDPE pond involves various components such as capacity, dimension of pond, site and crop water requirement. The design of outlet and inlet are also important. The capacity of the pond should be designed in such a way that it should cater the irrigation need during the acute water shortage period e.g. April to June. The various steps in the design of pond have been illustrated in the following paragraphs.

Design consideration

Example: The following considerations that are prevailing in the rainfed agriculture should be made for designing the standard size LDPE pond.

- Area of command: 1000 m^2 (0.1 ha)
- Type of Irrigation: Micro irrigation (Discharge: 1lph)
- Crop season : March (Transplanting) to June (Harvesting)
- Spacing: 50 X 50 cm

Assumption:

- The site represents the typical dryland conditions.
- Irrigation is provided at uniform rate.
- The region receives the winter rain and the pond become full by the 31^{st} December of the year.
- The stored water in the pond lost only due to evaporation.

Irrigation schedule:

Average operation time of the system: 1 hour

System operation: Alternate day

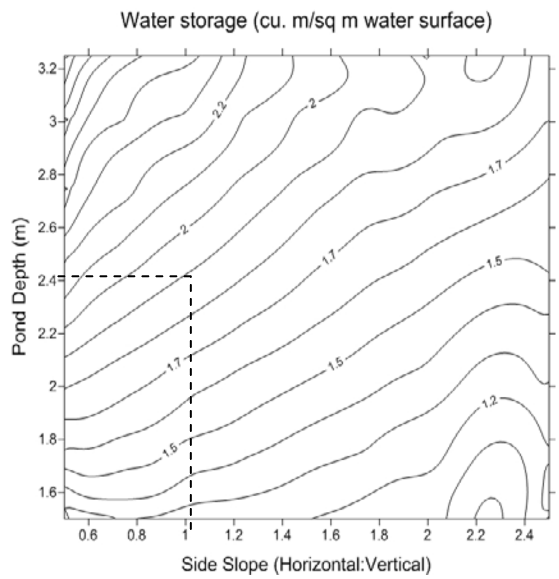
Computation of pond dimension:

- Total water lost as evaporation: 1000 mm (Based on the weekly evaporation data). Thus the depth of the pond should be greater than 100 cm plus 25 cm as free board i.e. 1.25 m.
- Water application as irrigation:
  - No. of irrigation: 50
  - Volume of water required per irrigation: 1 (discharge during 30 min) X 4000 (No of plants) = 4000 litre = 4 m^3
- Total volume of net irrigation water: 4 X 50 = 200 m^3 excluding the evaporation losses.

3.3.2 Development and illustration of a nomograph:

Calculation of length and width of a pond matching net irrigation water is usually based upon a trial and error procedure using lengthy formulae calculating volume of a trapezoid shaped pond. To short out this problem, one nomograph was developed in which we have depth and side slope as known parameters which leads to the solution for top and bottom dimensions of length and width.

The X and Y axis of the graph represent side slope and depth of pond, respectively. The curve represents the net available water per unit of top surface area of the pond (Fig below). Now the pond dimensions can be calculated from the nomograph given below.



Example

Suppose the calculated volume of net irrigation water is 200 m^3. Let the net depth of pond is to be kept as 2.4 m and side slope as 1:1. The line drown (dotted line) from respective values intersect at curve value of 1.88. Hence for given conditions of depth and side slope, the net available water per unit of top surface area will be 1.88 m^3. Thus the surface area of the pond at water level will be 200 divided by 1.88, which equals to 106.4, say 110 m^2. It means top surface at net water level length and width are 11 and 10 m respectively. The bottom dimensions are now calculated from the following equation.

$$B = T - 2nd \qquad \ldots 1$$

Where, B is the bottom dimensions, T is the top dimension actual water level, d is the depth of pond and n is the slope (n: 1). Thus bottom length and width are computed as = 6.2 m (10-2X1.0X2.4) and 5.2 m (7-2X1.0X2.4) respectively. Since the evaporation loss of 1.0 m (1000 mm) and free board of 0.25 m (25 cm) has to be accommodated thus overall top length will be 13.5 m (11+2X1.0X(1.0+0.25)) and 12.5 m (10+2X1.0X(1.0+0.25)) respectively.

3.3.3 Construction of LDPE film lined ponds

The construction procedure mainly involved four steps which are site selection, excavation of pit, treatment of pit, laying of LDPE film and covering the film.

Site selection

The pond construction site should be kept nearer to the command area. However, due consideration must be given to the location of water source availability. The following points are considered while selecting site for LDPE film lined ponds.

Location and availability of water source: Before planning the pond it is mandatory to decide availability and nature of water sources that will store in the pond. This water source can be from natural springs or runoff. In case of assured water source, the pond should be constructed nearest to the source in order to minimize the conveyance cost. However, in places where surface runoff is to be stored, the pond must receive the runoff water generated from the catchment.

- Soil depth: The depth of soil in the proposed land for pond must be given due considerations. The LDPE ponds are essentially dug-out ponds; hence the excavation is major component. Excavation is difficult in the stone rich soil that increases the cost and poses the threat to the plastic film to get punctured. In order to reduce the excavation cost, the soil must be 1 meter deep where the dug-out soil can be placed at the top of the pond as embankment. This increases the storage:excavation ratio to greater than 1.5 which further reduces storage cost.
- Present use of the land where pond is proposed: The use of land decides the capacity of the proposed pond. The water requirement for different crop sequence including the evaporation rate must be computed and thus the water balance dynamics of the pond and its command are established.

Pond Layout

First of all the selected area based on the considerations listed above, are marked. Marking is done considering the provision for burying the film at the corner of the pond, side slope and bottom dimension. Marking is done by the procedure illustrated in the figure 3.3. L and W are the length and width of the land where pond is proposed, n is the side slope, h is the height of embankment and d is the depth of excavation.

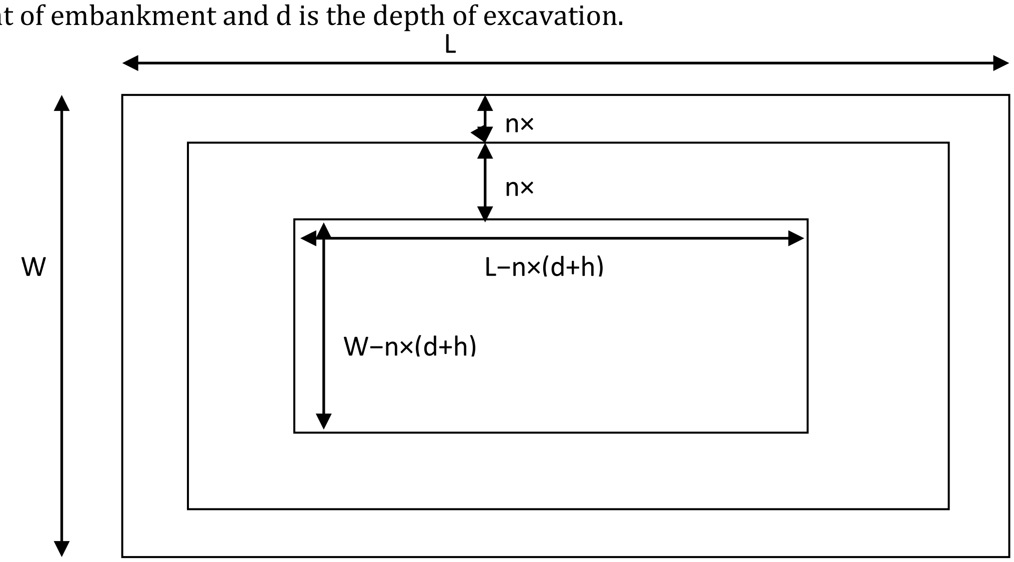


Figure 3.3: Layout procedure of the tank

Excavation of pit

The pits are usually excavated manually. The top and bottom dimension are marked on the land using pegs before the excavation process. The excavated soils are kept on side of the pond in embankment form (Fig 3.4).

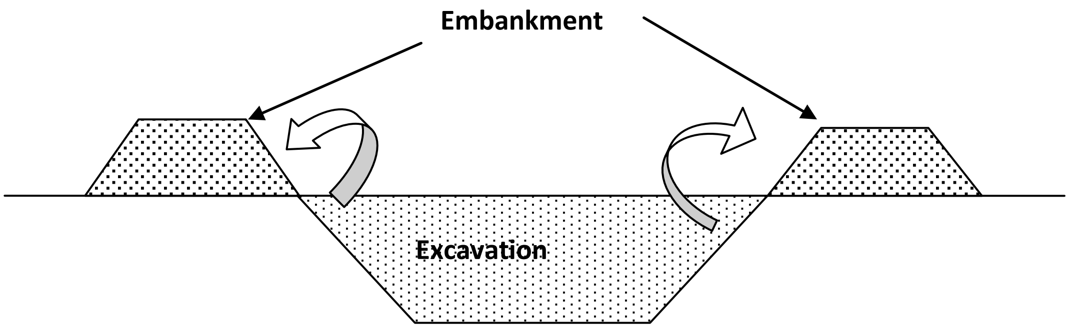


Fig 3.4 Excavation of pit and embankment of the dug out soil

Treatment of pit

After excavating the pit, the bottom and the side wall should be compacted in order to suppress the angular projections. Compaction of bottom and side are necessary so that the film could be saved from puncture caused by these projections. After compaction, the side wall and bottom are treated with 0.4% atrizine (weedicide solution) so that the plastic film could be saved from puncture caused by root infestation. After these, the surfaces of side wall and bottom are smoothened using dung and soil mixed with water.

Laying of LDPE film

The LDPE (Low Density Poly Ethylene) films are spread over the excavated pit. The minimum specifications of the LDPE film are given in table 2.1. Care should be taken to avoid the wrinkles. The film must be pleated at the corner (Plate 1 &2).

Table 3.1 Specification of LDPE film

S No	Specification	Value
1	Thickness	200 micron
2	Density	200 grams per sq. meter
3	Colour	Preferably black

Jointing of film

The LDPE films are joint using bitumen, used intensively in hot mix road construction. For jointing, both films are spread on the flat surface. The edge (15 cm) of both the films then scrubbed using emery paper or sand paper (120 grade). The bitumen heated to 80^{o}C, when it started flowing freely, are then pasted over the scrubbed edge of the film and are then overlapped (15 cm) by both the films and some weight are kept over for setting. After 30 minutes, the film joints firmly. Another jointing method is by the application of SR 989 adhesive pasted over the scrubed surfaces of the films.

Outlet

The film punctured at the bottom corner and 25 to 40 mm pipe (GI, PVC or HDPE) inserted inside the pond from pond side. To fix the pipe with the film, 10 cm thick CC is applied. Outside of the pond one gate valve is provided to regulate the flow from the pond. Alternatively, 12 to 16 mm PVC pipe may also be used as siphon tube. The length of this pipe may vary from 4 to 10 m. This siphon tube is brought to pond site at the time of irrigation and when the irrigation is over the tube can be stored at the proper place.

Covering the film

The LDPE film has the lower dart impact resistance (110 gram; ASTM D1709) and thus prone to puncture. This film also deteriorates with direct sunlight. To avoid the puncture and protection from sunlight it is necessary to safeguard the film. The method of stone pitching is extensively used in anchoring the film. However, other material such as tarfelt sheet (mica impregnated coal tar sheet) and *khas khas* matting can also be used for covering the film.

Stone pitching

The LDPE film has the lower dart impact resistance (110 gm; ASTM D1709) and thus it is prone to puncture. To avoid the puncture and provide protection from sunlight pitching is required. The stone pitching involve the arrangement of stones (10 to 20 cm boulder with no conical projections at the side of the pond. The stone pitching is recommended where the side slope of the pond is higher than 1:1. The larger boulders are arranged at the lower side and gradually smaller boulders are arranged towards the top. Cement pointing is provided to fix the boulder. 10 cm thick soil layer is spread on the bottom so that people can work in the pond while laying the stones, during cleaning of the pond and the other activities to avoid the puncture of LDPE film at the pond bottom. However, some local material can also be used in place of stones for pitching.

Efficient water utilization

The wastage occurring through storage, conveyance and distribution ultimately result in delivery of 30 to 35 % of stored water for plant uptake. The traditional flood or ridge and furrow method of irrigating field suffers from numerous problems such as considerable seepage, conveyance and evaporation loss; higher energy cost; lower water productivity; irrigation-induced soil erosion, and leaching of costly agricultural inputs causing sub-surface water pollution. Moreover, this method is supply driven rather than crop-demand driven causing mismatch between need of the crop and the quantity of water supplied. The decrease in the availability of water for agriculture, coupled with the requirement for the higher agricultural productivity, means that there is no option but to improve the water use efficiency. This has to include an efficient utilization of available water which otherwise would evaporate or percolate from the root zone of the soil.

The recent advances in irrigation technology have made inroads in the cultivation of vegetables and horticultural crops. The frontier technology of micro-irrigation system not only provides higher water productivity but also minimize the problems associated with the traditional irrigation system.

The major points in efficient utilization of water are

- Irrigation Scheduling
- Irrigation water source
- Irrigation management
- Irrigation system

Irrigation scheduling

Irrigation scheduling is the process of planning and providing crops with the amount of water needed, when they need it. It involves monitoring, record-keeping, and calculations to determine field water capacity, losses and gains and determine

- when to irrigate
- how much water your crop requires, using practical and accurate methods
- how to change the amount of water applied if soil types change across your farm
- how to account for rainfall when you estimate crop water needs.

Benefits of Scheduling

- increased yields and quality; better returns on investment of irrigation equipment
- more efficient use of water resources
- more efficient use of equipment, management time and labour
- avoids delaying irrigation until moisture stress has occurred and damage to yield and quality is irreversible, i.e., optimizes application timing
- reduces the possibility of excess moisture that will lead to leaching or runoff because the exact water-holding capacity of the particular soil is known

Factors in Scheduling

- specific infiltration rates and available water-holding capacities of the various soil types must be known
  - some calibration work may have to be done
  - you may have to measure the performance of the soil using known quantities of soil and water
- crop rooting depth - deeper-rooted crops will need less frequent but deeper irrigations than shallow-rooted crops
- the probability of rainfall - this affects frequency and amount of irrigation needed
- overwatering a field can cause excessive leaching or runoff, which can lead to a deterioration in soil structure

Avoid wasting water during application. Be aware of the water intake rate of the soil. This is the rate at which water infiltrates the soil and it determines how much water to apply per hour. The table 1 lists the maximum rate of water to apply per hour for various soil types. Coarse-textured soils have a higher water intake rate than fine-textured soils. Rain or irrigation guages should be placed in the field to help you determine how much irrigation water you've applied.

Most crops have certain growth stages, during which drought stress can severely reduce yield and/or quality. While adequate moisture is desirable at all growth stages, irrigation is especially important during the critical growth periods. Using simple monitoring methods and calculations, scheduling can make irrigation more timely, precise and less wasteful.

Ranges in Available Water Capacity and Intake Rate for Soil Textures

Soil Texture	Available Water Capacity (in. of water/in. of soil) (mm of water/ mm of soil)		Intake Rate			
			(in/hr)		(mm/hr)	
	Range	Average	Range	Average	Range	Average
Sands	0.05-0.08	0.065	0.5-1.0	0.70	12-25	18
Loamy Sand	0.07-0.10	0.085	0.3-0.8	0.55	7-20	14
Sandy Loam	0.09-0.12	0.11	0.3-0.8	0.55	7-20	14
Loam	0.13-0.17	0.15	0.3-0.8	0.55	7-20	14
Silt Loam	0.14-0.17	0.16	0.2-0.3	0.25	4-8	6
Silty Clay Loam	0.15-0.20	0.18	0.2-0.3	0.25	4-8	6
Clay Loam	0.15-0.18	0.17	0.2-0.3	0.25	4-8	6
Clay	0.15-0.17	0.16	0.1-0.25	0.20	2-6	4

Irrigation water source

When you draw water for irrigation, you must ensure there are no long-term implications for the local environment, and no short-term interference with other uses. More specifically, you need to know:

- an estimate of how much water might be needed
- how continuous the supply is (or the recharge rate), especially during the time of need when conditions are the driest and supplies usually the lowest
- that the quality of water matches the needs of the crop to be irrigated
- how the location of the water supply impacts the design and cost of the system, i.e., horizontal distance and vertical lift
- the repercussions if adequate water isn't available
  - a shortage of water with micro-irrigation systems can be disastrous
  - running out of water while protecting a crop from frost can also be disastrous - e.g. small fruit or berry growers should have a water inventory capable of use for several consecutive nights of frost protection
- whether the amount of water you're taking is environmentally sustainable

- o the effects on fish and fauna - a large suction inlet cuts down on water velocity entering the intake pipe, and allows fish to escape in special circumstances
- o effects on quality and quantity of water in adjacent bodies of water
- o effects on the water table.

Irrigation management

The best management practices in this section provide tips that increase crop productivity and quality and, where technology is available, save water. Presented here is an overview of water efficiency. See the printed version of this book for tips on the best systems and critical irrigation periods for key irrigated crops, from fruit trees to nursery stock.

Water Efficiency

Here are some general best management practices for most crop operation using irrigation:

Match crop to suit soil conditions

- if your soils are droughty and the crop considered is highly responsive to irrigation, choose another crop or another site

Build healthy soils - you want water to infiltrate and be available for crop use

- add organic matter (manure, green manure, compost, cover crops): your soil's structure will improve and the amount of water available to your crop will increase
- avoid compaction: don't work wet land, especially heavier soils
- reduce tillage: less tillage means less drying and less organic matter loss
- o you may wish to try reservoir tillage: it holds water a the soil surface for infiltration
- with reduced tillage and higher organic matter, earthworm populations will increase

Irrigate efficiently

- harvest water from watercourses during peak flows, or from ground water when water table is high
- sprinkle irrigate when winds are less than 3 mph (5 km/hr)
- choose drip irrigation next time you upgrade
- apply the right amount of water when the crop needs it - use irrigation scheduling
- avoid irrigation during the heat of the day

Reduce water loss from crops and soil (evapotranspiration)

- use dwarf grasses between orchards and nursery crops
- schedule short-season crops for spring or fall
- manage crop residues to reduce runoff, increase infiltration so that they can act like a mulch
- space plants to cover soil surface quickly
- use plastic or organic mulches
- control weeds early

Irrigation system

Probably the most fundamental best management practice for irrigation is choosing the right system. This requires more than grower experience. Your irrigation system should be designed by experts.

An irrigation system has some form of the following components:

water source power source filtration emission points, e.g. sprinklers
pumps conduit pipe water-efficient hardware.

All components must be suitably matched.

The main principle of irrigation is quite simple: to provide the root zone of your crop with usable amounts of water during periods of need. This is accomplished by delivering irrigation water to a field and then distributing it within the field.

- sprinkler irrigation - spraying the water over the entire soil surface of the field
- micro-irrigation (trickle, drip) - piping the water directly and only applying the water to the soil around each plant

sub-irrigation - piping water into the soil below the root zone.

Micro-Irrigation (also called drip or trickle irrigation)

Design & Hardware

- the basic micro-irrigation system components include a water source, pump, filtration system, flow meter, mainline, header lines, pressure reducers (if required), lateral lines and emitters
- pumps are smaller, less power is required, less energy is used, and the water conveyance lines are smaller
- lateral lines are made up of small-diameter flexible plastic pipe (10-15 mm diameter), and when laid out are left there from season to season
    - emitters are manufactured right inside or can be inserted into the pipe
    - some lateral lines are a disposable-tape type of line are are replaced yearly; longer-life tapes (up to 7 years) are available at higher cost
- large selection of emitters
    - can be of a spray, drip or trickle type, depending on the zone to be wetted
    - can be in-line or offset
    - emitter(s) can be positioned at each plant or spaced closely together 200-600 mm to water a continuous row (e.g. vegetable having row to row and plant to plant spacing)
- clean water is a must for emitters to function properly, and to reduce maintenance requirements - filtration systems are usually needed
- a high level of design is imperative for this system to operate properly, especially on rolling terrain - pressure-compensating emitters can largely overcome the challenge presented by uneven terrain and long runs: the emitter will deliver more volume by opening up when pressure is reduced and less volume by closing down as pressure is increased, resulting in a uniform flow rate.

HOW IT WORKS

- system supplies a small amount of water ([2-8 L/hr) near the base of each plant - the amount of water is controlled by the length of time the system runs
- system components can be downsized because water is delivered on a more continuous basis (usually on a daily basis when needed) and only the rooting areas are watered (not between the rows)
- used most commonly for fruit trees, berry crops, vegetables and ornamentals

ADVANTAGES

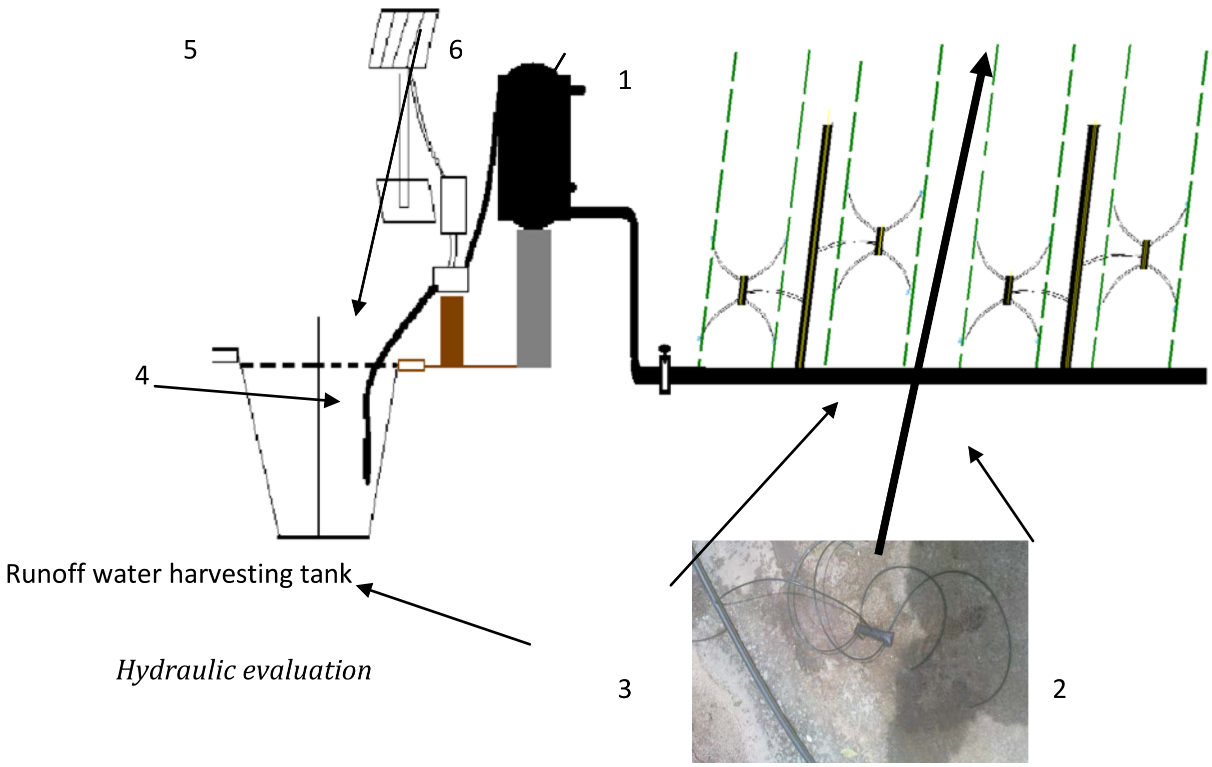
- based on the concept of preventing rather than relieving moisture stress – crop
- response is good
- very low labour
- easily automated
- water-efficient: can reduce water usage by one-third to one-half compared to overhead systems
- can be used for chemigation and fertigation
- can be applied on windy days or during spraying operations
- can be functioning without interruption of harvest operation
- foliage is not wetted - reduces disease problems for some crops
- does not remove crop protection materials from leaf canopy or maturing fruit
- operating costs are relatively low
- Disadvantages
- cannot be used for frost protection
- root systems don't usually develop fully, so water supplies must be dependable crop could suffer badly if irrigation is interrupted during a dry period
- occasional rodent damage
- may present a problem where tillage or mowing devices are used near crop row lines can get tangled in equipment
- Solar power operated small scale micro-tube irrigation system:
- The traditional drippers are replaced by the micro-tubes of suitable length in order to enable the proper pressure dissipation. The star configured micro-tube drip system helps in reducing the unit cost of irrigation setup and enables low pressure requirement. To match the flow requirement the solar power enabled water lifting system was developed and integrated with the water harvesting pond. The system consists of 150 watt solar panel that attached to central charge unit, 12 volt, 80 ah battery and 200 watt inverter. A 60 watt water pump was attached with the inverter and this pump successfully lifted the water upto 4 meter with discharge of 850 lph. The maximum suction of this pump was 1.5 meter. This system can be used in water lifting from small water harvesting ponds. The system was further evaluated for its function. However the system is still under development and testing trials.

Components of micro drip irrigation system.

1. Head: It consist of a pond of 1000 liter capacity, pump operated by solar power to lift water in to the pond and maintaining constant head.
2. Mains and sub-mains: These are normally of flexible material such as PVC or plastics. The diameter of the mains and sub-mains should be sufficient to carry the design discharge in the system.
3. Laterals or drip lines: These are small diameter flexible lines (usually 1 to 1.25 cm diameter black PVC tubes) taking off from the mains or sub-mains.
4. 60 watt pump. Discharge capacity 900 lt/hr
5. 140 watt solar panel.
6. solar power assembly including 200 watt battery, 300 watt inverter (to convert DC to AC) and Solar charge converter

Evaluation of drip irrigation system

In functional analysis of the irrigation system, standard evaluation parameters such as emitter flow rate variation, Christiansen uniformity coefficient and distribution uniformity were considered.



Hydraulic evaluation

The equation of emitter flow rate variation in which maximum and minimum flow rate are taken into the account, is described as following (Camp et. al. 1997)

$$q_{var} = \frac{q_{max} - q_{min}}{q_{max}} \times 100 \qquad \text{... (1)}$$

where, q_{var}, q_{max} and q_{min} are variation in emitter flow rate, maximum flow rate and minimum flow rate respectively.Figure: Star configuration of micro-tube emitters

The Christiansen uniformity coefficient (CUC), is described as the following equation (Kang et. al., 1999)

$$CUC = \left[1 - \frac{\frac{1}{n}\sum_{i=1}^{n}\left| q_i - \bar{q} \right|}{\bar{q}} \right] \times 100 \qquad \text{... (2)}$$

where, q_i and $\overline{q}$ are i[th] emitter flow and average flow respectively, n is number of emitter on the lateral.

The distribution uniformity (*Du*) suggested by Kang and Mishiama, 1996 was considered as the third parameter to functionally evaluate the irrigation system. *Du* is given as

$$Du = \frac{Average Low Quarter Discharge}{Average Discharge} \times 100 \qquad \text{... (3)}$$

The average discharge of the emitters was 2.97 lph. The emitter discharge was found consistent over the 26 m long lateral. The overall variation of 26.79 % was found in q_{var}, which was slightly higher than the acceptable limit of 20 % (ASAE 1985). The CUC of the various laterals at respective terraces was found as 94.30% which is within the permissible limit of ASAE criteria (ASAE 1985). The acceptable limit of the CUC for the drip irrigation system is greater than 85 %, thus the system qualifies the design criteria of CUC. The overall distribution uniformity was found as 90.63 which is again within the permissible limit of ASAE criteria.

Economics of drip irrigation.

Systematic economic evaluation of the drip system is required to decide on the feasibility of installation of the system. All attributable cost and returns should be included. The cost would include the fixed cost on the equipment and related items and the operating cost. The returns would be in the form of crop procedure, including its quality and quantity and the market price expected. Indirect benefits would include the applicability of poor quality of water, savings in labour, savings in water by limiting the water application specifically to the crop root zone and reducing weed growth. Savings in water, nutrients and labour resulting from the highly reduced weed growth are distinct advantages.

The main component of the cost of a drip irrigation system comprises of the cost of lateral, including emitters. The number of laterals is directly related to the row to row spacing of the crops being irrigated. The number of emitters would depend on the plant to plant spacing of the crop. The farther the row spacing the lower will be the no of laterals in a given area. Hence, the cost of the drip system has to be determined n the basis of crop grown, especially its row to row spacing. The cost is substantially low in orchard, and widely spaced vegetables.

In general, drip irrigation could be highly economical in water scarcity regions for irrigating high value fruit and plantation crops, vegetables and sugarcane. It is not suitable for close-growing crops where the number of laterals required will be high and the resulting cost prohibitive.

DESIGN OF APPROPRIATE PUMPS FOR LIFTING WATER FROM FARM PONDS

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Introduction

In climate change scenario the management of rainwater is felt prime important to protect rainfed crops from uncertain rainfall, frequent droughts and floods. In rainfed, average annual rainfall is ranging 700-1000 mm, which is quite enough to get healthy yield of crops but it could not so because of uneven rainfall distribution. Most of the time crop faces water stress due to which crop yield decreased substantially. Therefore, adoption of farm pond technology and recycling of harvested water in crop production system helps to survive the crop in critical situation. It is evident that giving 2-3 supplemental irrigation the crop yield was increased by 30-35% compared to non-supplemental irrigated crops.

Obviously, farm technology is a viable practice in rainfed but effective use of harvested water is still to be improved. Farmers often use large size pumpsets (5-7.5 HP) to lift water from open wells and irrigation through furrow and sprinkler. However, in case of farm pond large size pumpsets may not be appropriate as there is limited source of water available for small-scale irrigation. Farmers felt that large pump sets for supplemental irrigation or small irrigation on farm pond site is costlier. Since, most of the ponds are located in deep area they don't want to install pumpset on site due to theft problem. Frequent transportation involves drudgery and significant cost.

Innovations in Manual operated Pumpset

Many of the innovations evolved from the farmers and scientists in order to improve water lifting devices. Pedal operated centrifugal and reciprocating pump sets are some of the examples. Bicycle operated centrifugal pump developed by Shri Vikram Rathod of Adilabad is shown in fig-1. It consisted bicycle, rim, pulley, flywheel, impeller etc. Pumping capacity is about 2500 lt/hr. Total cost of the unit is Rs 3000/-.

Fig-1 Bicycle operated centrifugal pumpset

Fig-2 Pedal operated reciprocating pump

Tridal pumpset is shown in fig-2. It is pedal operated reciprocating pump having pumping capacity of 2000 lit/hr. The cost of pump set is Rs 2000/-. Although manual operated pumpsets are low cost, these are not adopted by the farmers on wider scale because of drudgery involved.

Portable Pumpsets

Portable pumpsets are the suitable options for water lifting from farm pond. Pumpset profile available in market showed that specific fuel consumption of the portable pumpsets (1.5 HP) is 0.7 lt/hr as against 2.0 lt/hr in case of 5-7.5 Hp diesel pumpsets. However, these small pumpsets are commonly used for furrow irrigation. It is commonly believed that portable pumpsets are suitable only for furrow irrigation and not for sprinkler. To generate the information on sprinkler performance using portable pumpst, Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad (AP) has conducted feasibility tests of small-size pump sets for lifting and distribution of harvested water from farm pond through sprinkler irrigation.

Selection of Portable Pump sets

In Indian Market, portable pump sets of 1.5-2.0 HP size operating on Petrol or Kerosene are available on large scale, however, only few firm are manufacturing Petrol-start-Diesel Pump sets. We prioritized Petrol-start-Diesel Pump sets of 1.5 HP as it is easily available and cost effective compared to petrol (fig-3). Kerosene is cheaper than diesel but its accessibility is only on Public Distribution System that too limited quantity; hence, Petrol-start-Diesel engines are prioritized. Detailed specifications of selected Portable Pump sets is given below,

1. Engine Model : HSMF, MK-12
2. Make : Greaves Cotton Ltd, Chennai
3. Rated RPM : 3000 rpm
4. Rated Power : 1.5 hp
5. Fuel : Petrol start & Diesel run
6. Pump : 2" X 2" Monoblock
7. Pressure Head : 12 meter
8. Discharge : 5 lps (liters per seconds)
9. Pumpset weight : 34 kg

Plate-3 Portable Diesel Pumpset of 1.5 Hp

Feasibility Tests of Portable Pump set

Using identified pumpsets, about 236 m^3 of water from farm pond was recycled for supplemental irrigations of 0.1 ha redgram (Fig-4) and also 0.15 ha for vegetable crops (Okra and Brinjal, Fig-5) through sprinklers. Performance of 1.5 hp Portable pumpset was found to be satisfactory during tests without any operational defects and repair. The detailed performance of portable pumpset for sprinkler irrigation is given in Table-1

Table1: Performance test of portable pump sets for sprinkler irrigation

Sr. No.	Particulars	Observations
1.	Engine speed, rpm	2000
2.	No. of sprinklers	06
3.	Sprinkler spacing, m	12
4.	Radius of spray obtained, m	10
5.	Net Area Irrigated, m^2	714
6.	Discharge at delivery, m^3/hr	09
7.	Irrigation yield, mm/hr	10 mm
8	Fuel consumption, l/hr	0.686
9,	Fuel cost for irrigation (10 mm), Rs/acre	160

With identified pumpset, it was observed that six sprinklers could be operated at a time covering an area about 700 m2. Total cost of fuel was 160 Rs/acre for 10 mm irrigation. This information suggested that the portable pumpset are suitable for small-scale irrigation using sprinkler irrigation as improved method. Moreover, its overall weight is 34 kg, which can easy for transportation.

Fig-4 Lifting of water through portable pump set and irrigation to crops near by pond

Fig-5 Lifting of water through portable pump set and irrigation to crops 130 m away from pond

CONSERVATION AGRICULTURE FOR SUSTAINING RESOURCES IN RAINFED AREAS

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India is endowed with a rich and vast diversity of natural resources, particularly soil, water, weather, multipurpose trees and bio-diversity. To realize the potential of production system on a sustained basis, efficient management of the natural resources is very crucial. With the advent of high-yielding crop varieties and intensive cultivation, the food grain production has increased from 51 million tones (mt) in 1950-51 to a record figure of 210 mt during 2007-2008. This impressive achievement has pulled the country in to self-sufficiency for food demand. With adoption of intensive agriculture to meet the varied growing demands for food, fuel, fiver, feed, fertilizer and products in the recent year, the natural resources are however, put under intense strain resulting in fast degradation and lowering of their production efficiency.

Land degradation is a major threat to our food and environmental security. There is 150 m ha degrades land constituting 45.5% of total geographical area. The area suffering due to water and wind erosion is 109.7 and 11.7 m ha respectively. The area under waterlogging, salinization/alkalization and other problems are 9.0,9.2 and 10.3 m ha respectively. The widespread erosion tin the hilly catchments area is resulting in excessive siltation of multipurpose reservoirs and other water-bodies to the country at rates higher than their designed capacity.

A major factor responsible for the degradation of the natural resources is soil erosion, The accelerated soil erosion has irreversible destroyed some 430 m ha of land area covering 30% of the present cultivated area in different countries of world. In general soil erosion is more severe in mountainous than undulating areas. Their rate of natural erosion for the world is of the order of 1.5 to 7.0 t/ha/year for the mountainous region and 0.1-7 t/ha/year for the undulation plains. If the global warming trends (caused by increases in atmospheric, Co2,expected to reach 600 ppm by 2070,continues, global erosion rate may increase considerably., Erosion by water is most serious degradation problem in the Indian context. It has been estimated that soil erosion was taking place at an average rate of 16.35t/ha /year totaling 5,334 mt/year,nearly 29% of the total eroded soil was parentally loss to the sea and nearly 10% was deposited in reservoirs, resulting in the reduction of their storage capacity by 1-2% annually. The remaining 61% of the eroded soil was transferred from one place to another. The annual water erosion rate values ranged from <5 t/ha/year to more than 80 t/ha/year.

Conservation agriculture (CA) is concept for resource saving agricultural crop production that strives to achieve acceptable profits together with high and sustainable production levels. While concurrently conserving the environment, CA is based o enhancing natural biological processes above and below ground. Intervention viz., mechanical soil tillage are reduced to an absolute minimum and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere to disrupt the biological processes.

What is conservation Agriculture

Conservation Agriculture (CA) refers to the system of raising crops without tilling the soil while retaining the crop residues on the soil surface. It has the potential to emerge as an effective strategy to the increasing concerns of serious and widespread natural resources degradation and environmental pollution, which accompanied the adoption and promotion of green revolution technologies, since the early seventies,

Over the past 2-3 decades globally, CA has emerged as a way of transition to the sustainability of intensive production systems. It permits management of water and soils for agricultural production without excessively disturbing the soil, while protecting it from the processes that contribute to degradation like erosion, compaction, aggregate breakdown etc,

The key features which characterize CA include:

a) Minimum soil disturbance by adopting no-tillage and minimum traffic for agricultural operations,

b) Leave and manage the crop residues on the soil surface, and

c) Adopt spatial and temporal crop sequencing/crop rotation to derive maximum benefits from inputs and minimize adverse environmental impacts.

Conservation agriculture permits management of soils for agricultural production without excessively disturbing the soil, while protecting it from the processes that contribute to degradation e.g. erosion, compaction, aggregate breakdown, loss in organic matter, leaching of nutrients etc. Conservation agriculture is a way to achieve goals of enhanced productivity and profitability while protecting natural resources and environment, an example of a win win situation. In the conventional systems, while soil tillage is a necessary requirement to produce a crop, tillage does not form a part of this strategy in CA. In the conventional system involving intensive tillage, there is a gradual decline in soil organic matter through accelerated oxidation and burning of crop residues causing pollution, green house gases emission and loss of valuable plant nutrients. When the crop residues are retained on soil surface in combination with no tillage, it initiates processes that lead to improved soil quality and overall resource enhancement.

Benefits of CA have been demonstrated through its large-scale adoption in many socioeconomic and agro-ecological situations in different countries the world over.

Benefits to Farmers

These include:

- Reduced cultivation cost through savings in labour, time and farm power.
- Improved and stable yields with reduced use of inputs (fertilizers, pesticides).
- In case of mechanised farmers, longer life and minimum repair of tractors and less
- water, power and much lower fuel consumption.
- Benefits of CA come about over a period of time and in some cases, might appear less
- profitable in the initial years.

Benefits to Natural Resources

These include:

- Reduced soil degradation through reduced impact of rainfall causing structural
- breakdown, reduced erosion and runoff.
- Gradual decomposition of surface residues leading to increased organic matter and
- biological activity resulting in improved capacity of soils to retain and regulate water
- and nutrient availability and supply.

- Improved biological activity and diversity in the soil including natural predators and competitors.
- Reduced pollution of surface and ground water from chemicals and pesticides, resulting from improved inputs use efficiency.
- Savings in non-renewable energy use and increased carbon sequestration.

Conservation Agriculture Global Scenario

According to current estimates globally, CA systems are being adopted in some 96 million ha, largely in the rainfed areas and that the area under CA is increasing rapidly. USA has been the pioneer country in adopting CA systems and currently more than 18 million ha land is under such system. The spread of CA in US has been the result of a combination of public pressure to fight erosion, a strong tillage and conservation related research and education backup and public incentives to adopt reduced tillage systems. Other countries where CA practices have now been widely adopted for many years include Australia, Argentina, Brazil and Canada. In many countries of Latin America CA systems are fast catching up. Some states of Brazil have adopted an official policy to promote CA. In Costa Rica a separate Department of Conservation Agriculture has been set up. A redeeming features about CA systems in many of these countries is that these have come more as farmers' or community led initiatives rather than a result of the usual research extension system efforts. Farmers practising CA in many countries in South America are highly organized into local, regional and national farmers' organizations, which are supported by institutions from both south and north America. Spread of CA systems is relatively less in Europe as compared to countries mentioned above. While extensive research over the past two decades in Europe has demonstrated the potential benefits of CA yet the evolution of practice its has been slower in EU countries vis-a-vis. other parts of the world possibly due to inadequate institutional support. France and Spain are the two countries where CA was being followed in about one million ha of area under annual crops. In Europe a European Conservation Agriculture Federation, ECAF, a regional lobby group has been founded. This body unites national associations in UK, France, Germany, Italy, Portugal and Spain. Conservation agriculture is being adopted to varying degrees in countries of south-east Asia viz. Japan, Malaysia, Indonesia, Korea, the Philippines, Taiwan, Sri Lanka and Thailand. Central Asia is another area prospective of CA. In South Asia CA systems would need to reflect the unique elements of intensively cultivated irrigated cropping systems with contrasting edaphic needs, rainfed systems with monsoonic climate features, etc. Concerted efforts of Rice-Wheat Consortium for the Indo-Gangetic Plains (IGP) a CG initiative and the national research system of the countries of the region (Bangladesh, India, Nepal and

Pakistan) over the past decade or so are now leading to increasing adoption of CA technologies chiefly for sowing wheat crop. According to recent assessments in more than one million ha area wheat was planted using a no-till seed drill in the region. Experiences from Pakistan (Punjab, Sindh and Baluchistan provinces) showed that with zero-tillage technology farmers were able to save on land preparation costs by about Rs. 2500 per ha and reduce diesel consumption by 50 to 60 litres per ha. Zero tillage allows timely sowing of wheat, enables uniform drilling of seed, improves fertilizers use efficiency, saves water and increases yield up to 20 percent. The number of zero tillage drills in Pakistan increased from just 13 in 1998-99 to more than 5000 in 2003-2004. Farmers have also adopted bed planting of wheat, cotton and rice. Wheat straw chopper has also been adapted to overcome planting problems in wheat crop residue. Bed and furrow planting of cotton is finding favour with the farmers due to savings in irrigation water and related benefits of improved use-efficiency of applied fertilizers, reduced soil crusting, etc. There is widespread use of laser land leveller which helps in curtailing irrigation, reduces labour requirement, enhances cultivated area and improves overall productivity. In 2003-04 around 225 laser land levellers were being used.

Conservation Agriculture in Rainfed Semi-arid and Arid Regions

Rainfed semi-arid and arid regions are characterized by variable and unpredictable rainfall, structurally unstable soils and low overall productivity. Results of most research station studies show that zero/ reduced tillage system without crop residues left on the soil surface have no particular advantage because much of the rainfall is lost as runoff due to rapid surface sealing nature of soils. It would therefore appear that no tillage alone in the absence of soil cover is unlikely to become a favored practice. However, overall productivity and residue availability being low and demand of limited residues for livestock feed being high also poses a major limitation for residue use as soil cover in the arid and semi-arid regions. In the semi-arid regions there is wide variability in rainfall and its distribution and nature of soils. It would appear that there is need to identify situations where availability of even moderate amount of residues can be combined with reduced tillage to enhance soil quality and efficient use of rainwater. There appears no doubt that managing zero-tillage system requires a higher level of management vis-a-vis conventional crop production systems. Also there exists sufficient knowledge to show that benefits of CA mainly consist of reversing the process of degradation and that its advantage in terms of crop productivity may accrue only gradually.

CA or no-till farming has spread mostly in the rainfed agriculture allover the world. However, in India its success is more in irrigated belt of the Indo-Gangetic plains. Considering the severe problems of land degradation due to runoff induced soil erosion, rainfed areas particularly in arid and semi-arid regions requires the practice of CA more than the irrigated areas to ensure a sustainable production.

Unlike the homogenous growing environment of the IGP, the production systems in arid and semi-arid regions are quite heterogeneous and diverse in terms of land and ware management and cropping systems. These include the core rainfed areas which cover up to 60-70% of the net sown area and the irrigated production systems in the remaining 30-40% area. The rainfed cropping systems are mostly single cropped in the red soil areas while in the black soil regions; a second crop is taken on the residual moisture. In **rabi** black soils farmers keep lands fallow during **kharif** and grow **rabi** crop on conserved moisture. The rainfall ranges from >500 mm in arid to 1000 mm in dry sub-humid zones. Alfisols, vertisols, inceptisols and entisols are the major soil orders. Soils are slopy and highly degraded due to continued erosion by water and wind. Sealing, crusting, subsurface hard pans and cracking are the key constraints which cause high erosion and impede infiltration of rainfall. The choice and type of tillage largely depend on the soil type and rainfall. Leaving crop residue on the surface is another important component of CA, but in rainfed areas due to its competing uses as fodder, little or no residues are available for surface application.

Experience from several experiments in the country showed that minimum or reduced tillage does not offer any advantage over conventional tillage in terms of grain yield without retention of surface residue. Leaving surface residue is key to control runoff, soil erosion and hard setting in rainfed areas which are the key problems. In view of the shortage of residues in rainfed areas, several alternatives strategies have emerged for generation of residues either through in situ cultivation and incorporation as a cover crop or harvesting from perennial plants grown on bunds and adding the green leaves as manure cum mulching. Agro forestry and alley cropping systems are other options where biomass generation can be integrated along with crop production. This indicates that the concept of CA has to be understood in a broader perspective in arid and semi-arid agriculture which include an array of practices like reduced tillage, land treatments for water conservation, on-farm and off-farm biomass generation and agro forestry. Here, conservation tillage with reduced retention on surface is more appropriate than zero tillage which is emphasized in irrigated agriculture.

Constraints in Adopting Conservation Agriculture Systems

Conservation agriculture poses a challenge both for the scientific community and the farmers to overcome the past mindset and explore the opportunities that CA offers for natural resources improvement. CA is now considered a route to sustainable agriculture. Spread of CA, therefore, will call for a greatly strengthened research and linked development efforts.

- Although significant successful efforts have been made in developing and promoting machinery for seeding wheat in no till system, successful adoption of CA systems will call for greatly accelerated effort in developing, standardizing and promoting quality machinery aimed at a range of crop and cropping sequences, permanent bed and furrow planting systems, harvesting operations to manage crop residues, etc.
- Conservation agriculture systems represent a major departure from the past ways of doing things. This implies that the whole range of practices including planting and harvesting, water and nutrient management, diseases and pest control etc. need to be evolved, evaluated and matched in the context of new systems.
- Managing CA systems will be highly demanding in terms of knowledge base. This will call for greatly enhanced capacity of scientists to address problems from a systems perspective, be able to work in close partnerships with farmers and other stakeholders and strengthened knowledge and information sharing mechanisms.

How Long Does It Take to See Benefits

Usually the full benefits of CA take time and, in f act, the initial transition years may present problems that influence farmers to disadopt the technology. Weeds are often a major initial problem that required integrated weed management over time to get them under control. Soil physical and biological health also takes time to develop. Three to seven years may be needed for all the benefits to take hold. But in the meantime, farmer save on costs of production and time and usually get similar or better yields than with conventional systems. Farmers should be encouraged to continue this sustainable pract ice and correct problems as they arise.

Conclusions

Crop production in the next decade will have to produce more food from less land by making more efficient use of natural resources—and with minimal impact on the environment. Only by doing so can food production keep pace with demand, while land's productivity is preserved for future generations. This is a tall order for agricultural scientists, extension personnel, and farmers. Use of productive but more sustainable management practices described in this paper can help solve this problem. Crop and soil management systems that improve soil health parameters (physical, biological, and chemical) and reduce farmer costs are essential. Development of appropriate equipment to allow these systems to be successfully adopted by farmers is a prerequisite for success. Overcoming traditional mindsets about tillage by promoting farmer experimentation with this technology in a participatory way will help accelerate adoption. Encouraging donors to support this long-term, applied research with sustainable funding is also an urgent need.

Integrated farming system models for sustaining rural livelihoods in rainfed areas

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During the last 4-5 decades of agricultural research and development in India, major emphasis has been given to component- and commodity-based research projects involving developing new crop varieties, animal breeds, pest management, nutrient management etc mostly conducted in isolation and at the institute level. Researchers often do not address the location-specific, socio-economic issues in their agricultural research and technology development framework. Consequently, this component-, commodity- and discipline-based research has not proved wholly adequate in addressing the multifarious problems of small farmers (Jha, 2003). The problems of Indian agriculture are suited to a holistic approach to research and development efforts. It has been recognized that a new vision for agricultural research in the country, one that allows the commodity- and component-based research efforts at an institute level to be shifted to farmercentric research and development efforts, is desirable (Mahapatra & Behera, 2004). In view of the decline in per capita availability of land from 0.5 ha in 1950 to 0.15 ha by the turn of the century and a projected further decline to less than 0.1 ha by 2020, it is important to develop strategies and agricultural technologies that enable adequate employment and income to be generated, especially for small and marginal farmers who constitute more than 80% of the farming community (Jha, 2003). No farm enterprise is likely to be able to sustain the small and marginal farmers without resorting to integrated farming systems (IFS), i.e., a system in which different enterprises (e.g. fishery, dairy, crop etc.) are included in farm activities in an integrated manner with a major focus on bio-resource recycling within the system, for generation of adequate income and gainful employment year round (Mahapatra, 1994).

A farming system adopted by a given farming household results from its members allocating the four factors of production (land, labor, capital and management), to which they have access, to three processes (crop, livestock and off-farm enterprises) in a manner which, within the knowledge they possess, will maximize the attainment of the goals for which they are striving (Norman, 1978). Indian farmers generally practice mixed farming in which crop and animal production constitute about 70-90% of the agricultural enterprises. Because of the complex interactions with the environment, research with a farming systems perspective is a unique approach to increase the body of knowledge about existing farming systems and to solve specific problems in the farming systems of small and marginal farmers (Norman, 1978; Behera et al., 2008). The approach aims at increasing income and employment from smallholdings by suitable integration of various farm enterprises and efficient utilization of by-products of each enterprise within the farm. Such farming systems give an opportunity to the farmer to get a basket of multiple choices comprising alternate but matching, location specific and socio-economic specific enterprises.

The farming system models can be adopted in rainfed agriculture on a watershed basis or with a farmer centric approach.

1. Watershed based farming systems

Farming systems approach on a watershed basis is a method designed to understand the farmers' priorities, strategies and allocation of enterprises and decision-making. It should start with analysis of farmers' knowledge, problems and priorities in a given hydrological unit. This approach should relate to the land use that results in an efficient, optimum and sustainable use of natural resources including biotic, socio-economic and related infra-structural resources. Farming systems model in a watershed should address arable, non-arable, common pool resources and private property resources integrating the components of soil and water conservation measures, crops, parkland systems, trees on bunds, wind breaks, silvi-pasture systems, agri-horticulture systems, block plantations, high value low volume crops and live fences in a holistic manner. In this approach, the focus is more on managing natural resources viz. soil, water and biodiversity in a topo-sequence, prioritizing the farming systems decisions in an area basis.

In regions with rainfall of 500 to 700 mm, the farming systems should be based on livestock with promotion of low water requiring grasses, trees and bushes to meet fodder, fuel and timber requirements of the farmers. In 700 to 1100 mm rainfall regions, crop, horticulture and livestock based farming systems can be adopted depending on the soil type and the marketability factors. Runoff harvesting is a major component in this region in the watershed based farming system. In areas where the rainfall is more than 1100 mm, integrated farming systems integrating paddy with fisheries is ideal. There are several modules of rainfed rice cultivation along with fisheries in medium to low lands of rainfed rice growing regions of the eastern states of India.

A model farming system for small holders with 1.15 ha area in an Alfisol watershed has been developed by CRIDA covering arable crops, green manuring, bushes on bunds, economic fruit yielding plants on the lower side and grasses on the upper topo-sequence of the micro-watershed. Economic analysis of the model after a 3-year period (2005-08) indicated that the module covering arable crops on 0.4725 ha, agro-forestry on 0.3496 ha, vegetables on 0.1150 ha, grasses on 0.1256 ha and bushes on 0.0890 ha gave the highest gross income of Rs.16080/-, and net income of Rs.9793/- and a BC ratio of 2.38. The individual enterprises of arable cropping, agro-forestry, vegetables, grasses and bushes contributed 38.2, 10.3, 27.2, 7.1 and 17.2 %, respectively to the total net income (CRIDA, 2008).

Under the technology assessment and refinement programme of the NATP, an IFS module comprising 35.4% area under cereals, 25.7% under pulses, 21% under oilseeds, 17.3% under commercial crops and 1.2% area under fodders along with backyard poultry (6 birds per household) was found to be ideal for small and marginal farmers in Dharwad region of Karnataka (TAR-IVLP, 2005). The poultry component played a major role in stabilizing the farmers' income during drought years. Similarly, in Arjia region of southern Rajasthan, an IFS module of maize, pulses, oilseeds and forage grasses combining with in-situ rainwater management and bio-fencing gave 22.37% higher profitability than sole maize (AICRPDA-Arjia, 2006).

2. Farmer/family centric farming systems

In this system, the focus is on the individual households particularly of small and marginal farmers and their livelihood security. In this approach, the strengths and weaknesses of the traditional farming systems being followed by the farmers need to be assessed based on which selective productive enhancement and enterprise diversification interventions should be introduced. This calls for a detailed analysis of each household for their resources, investment capacity, labour availability and so on through participatory farming systems analysis tools. This can be done through focused group discussions, household level surveys and assessing local market needs.

Based on the income derived from each enterprise by the family (>50%), the family centric farming systems can be grouped into crop, agroforestry and livestock based systems (Subba Reddy and Ramakrishna, 2005).

2.1 Crop based Farming Systems

In this system, crops are the main source of livelihood. Animals are raised on agricultural wastes, and animal power is used for agricultural operations and the dung is used as manure and fuel. In low rainfall areas, agri-sheep farming involving cotton production in one ha of marginal lands and rearing of 10 lambs gave the net returns of Rs. 27500/ha as compared to growing cotton alone (Rs. 8700/ha) at Warangal in Andhra Pradesh (TAR-IVLP, 2003). The integrated farming system model in dryland vertisols at Kovilpatti (Tamil Nadu) showed that Crop + Goat + Poultry + Sheep + Dairy recorded the highest gross income (Rs. 35301) followed by Crop + Goat + Poultry + Dairy (Rs. 30807), while the conventional system having crop cultivation alone gave only Rs. 5860/acre as gross income. The animal waste from cow (20-22 kg/day/animal), sheep and goat (400-450 g/animal/day) and poultry litter (40 kg/batch of 20 broilers) were collected and applied to the IFS field, which resulted in improved soil fertility and crop yields. Employment increased from 75 man-days in conventional cropping system to 272 man-days in IFS model (AICRPDA-Kovilpatti, 2006). At Chattisgarh, a model having 2 bullocks + 1 cow + 2 buffaloes + 15 goats + 20 poultry and 20 ducks along with the crops in 1.3 ha gave the net income of Rs.58456/year against arable farming alone (Rs.18300/ year) and employment generation of 571 man-days (Rama Rao *et al*, 2005). Integration of sheep rearing in groundnut based farming system offered a gainful employment in rainfed areas. In scarce rainfall zone of Andhra Pradesh at Anantapur, the highest net returns were recorded with groundnut cultivation (2 ha) + poultry (Rs. 43360) followed by groundnut cultivation + dairy (3 buffaloes) (Rs. 40606) while sole crop of groundnut (2.6 ha) recorded the net returns of Rs. 14872/ha (Reddy, 2005).

In high rainfall areas crop based farming systems will include fisheries. In rainfed rice-based production system at Orissa, conserving excess water in the refuges at the down stream of rice field and rearing of fish recorded the highest net returns (Rs. 21,197/ha) with BC ratio (2.78) as compared to the growing of rice alone (Rs. 15294/ha) (James *et al.*, 2005). In Jharkhand, improved rice (IR-64) + fish (mixed carps) – wheat (PBW-443) enhanced the net returns (Rs.58557/ha) as compared to the farmers practice of rice-fallow system (Rs. 2770/ha). Also in Jharkhand, Fish-cum-pig rearing (2:3) along with paddy increased the net returns (Rs. 53100/ha) with a B: C ratio of 4.12 as compared to farmers practice of rearing fish alone in the ponds (Rs. 12125/ha) (TAR-IVLP, 2004).

The hilly terrain of NE hill region is suitable for sustainable multi-enterprise system. The Tripura center of this region has developed a farming system model combining agriculture with horticulture, forestry and livestock rearing on one ha land. The enterprises taken are: cereal crops, pulses, oilseeds, horticultural crops such as mango and pineapple, vegetables, and livestock components of duckery, piggery and fishery in the water harvesting structures. The results indicated that the multi-enterprise system is nearly five times more profitable than traditional monocrop rainfed rice cultivation, which gives maximum production of 10 q/ha of rice.

2.2 Agro-forestry based Farming Systems

Perennial components like trees and grasses imparts stability to farming due to less effect of yearly variation in rainfall on these components besides protecting crops from water and wind erosion and improvement of soil fertility. Several studies carried out at CAZRI, Jodhpur showed higher benefit cost ratio from tree based farming systems as compared to pure arable cropping. Agri-pasture and silvi-pasture systems were found to be more stable and profitable than arable farming. The agri-silviculture system is recommended for land capability class IV with annual rainfall of 750 mm. Short duration dryland crops such as perarlmillet, blackgram and greengram combined with widely spaced tree rows of *Faiderbia albida* and *Hardwickia binata* have been found compatible in semi-arid tropical areas (Korwar, 1992). At CRIDA, the horti-pastoral system involving *Cenchrus/Stylos* in rainfed guava and custard apple, *Cenchrus* yielded dry forage of 7 t/ha during the first year while *stylos* recorded 5.6 tons of dry fodder during the second year of plantation. In ber based agri-horti system, pearlmillet + pigeonpea (Solapur), pigeonpea + blackgram (Rewa), castor (Dantiwada) and clusterbean (Hyderabad) showed promising results in rainfed environment.

In the black and red soil region, the land scape is often undulating. The canals run on the ridge. The seepage water travels through the porous *murrum* layer to areas at lower elevation, picking enough salts on the way to salinize lands on the slopes or in the valley. A belt of agro-forestry plantations involving trees capable of transpiring large amounts of water can effectively intercept such saline seeps and protect highly productive valley lands. *Acacia nilotica* and *Dalbergia sissoo* account for about 86 and 84% interception of the seepage over the control, respectively (Patil, 1994).

However, the popularity of tree-based systems is largely governed by the market infrastructure and price trends. *Eucalyptus tereticornis* based agro-forestry became quite popular in early eighties and large scale plantations came up as boundary plantations and block plantations. By the time these plantations became ready for harvest in early nineties, the prices crashed to all time low. The farmers harvested Eucalyptus and sold at through away prices. This markedly affected farmers' interest in agro-forestry. The same scenario happened with *Kinnow* and grapes in Punjab. The recent price trends of the most dominant poplar based agro-forestry in Punjab, Haryana and western UP is a reflection of what happened with Eucalyptus in ear1y nineties. To promote adoption of such diversified agro-forestry systems, policy initiatives like assured procurement, post-harvest and value addition are needed.

2.3 Livestock based Farming Systems

The livestock based farming systems in rainfed agriculture are complex and generally based on traditional socio-economic conditions. An understanding of production factors (livestock, capital, feed, land and labour) and processors (description, diagnosis, technology design, testing and extension) that effect animal production is pre-requisite for livestock integration. The productivity of livestock in farming systems in rainfed agriculture can be improved by increased fodder production as an intercrop with cereals, relay and alley cropping, forage production on bunds, improving the feed value of stover by chopping, soaking with water, urea treatment, strategic supplementation of concentrate, urea molasses etc. Establishment of fodder banks in areas where surplus fodder is available, artificial insemination with semen approved bulls, removing low grade animals through castration and adoption of preventive measure like vaccination and de-worming through health camps improve the productivity of milch animals (Mishra, 2002). At CRIDA, field studies indicated that urea treated straw increased the milk yield by 0.47-1.2 l/day in IVLP villages of Ranga Reddy district (Andhra Pradesh). The paddy straw consumption was also increased with 1-1.2 kg/animal due to this intervention. Urea molasses mineral block (UMMB) enhanced quality and quantity of milk by 25-30% in cows and buffaloes. It also helped in maintaining the overall health and productivity of animal particularly when fodder scarcity was acute in drought period. Mineral supplementation gave higher milk yield (58%) and net returns (Rs. 6816) compared to the farmers' practice of grazing alone (Rs. 2156).

2.4 Multi-enterprise farming systems for deep water rice growing areas

There are large areas of waterlogged fertile alluviums in eastern India (3.28 M ha) where water stagnates above ground for over six months in a year. The adverse physical conditions allow only one anaerobic paddy crop with a very low yield potential of less than 1.0 t/ha. A number of farming models integrating fish and prawn culture, cultivation of paddy, vegetables, fruits, poultry, duckery, piggery, rabbitry and cattle were evaluated at different locations. The systems based on multiple recycling of carbon, energy and nutrients from biomass to livestock/poultry/piggery/fishery etc also minimized environmental loading with pollutants (Samra et al., 2003). The average net return of Rs. 69,275/ha/year from integrated farming system was higher than the traditional rice cultivation. Such enterprising ventures need to be promoted in Orissa, Bihar, Assam, West Bengal and Eastern Uttar Pradesh for enhancing livelihood and land quality.

A multi-enterprise option is generally followed in coastal wet1and areas. Integrating rice and fish culture in these ecologically disadvantaged environments helps improve the farm productivity through recycling of nutrients. Among the rice-based mu1ti-enterprise options tried, rice-rice-azolla and rice-azolla-calotropis+fish farming gave higher grain yield of 10.57 t/ha and 10.13 t/ha, respectively. The results indicate that on an average 173 kg/ha fish was harvested from rice-rice-azolla-calotropis+fish farming (Shanmugasundaram and Balusamy, 1993).

ADDING FURTHER VALUE TO FARMING SYSTEMS APPROACH

Post harvesting, processing and establishing market linkages add further value to the farming systems approach. Collective procurement and marketing if directly handled by the producers will significantly enhance the profitability. Establishment of agro-service centers in the villages can save the cost of inputs and can also get precise farm advisory services for higher profitability. Formation of commodity groups and self-help groups for farm women can help to promote off-season income generation activities which lead to livelihood improvement in villages.

Conclusion

Although the advantages of farming system approach are well established, there are still several constraints in upscaling the approach. The most important is the location specificity of the models and declining family labour availability for farming. While efforts are being made to replicate/popularize established farming system models, another approach would be to improve the existing farming systems of farmers through some simpler and cheaper interventions such as introduction of a new variety, an extra crop in the sequence or as intercrop, efficient resource recycling and its utilization etc. Because small and marginal farmers with capital scarcity, risk avoidance objectives, and a cautious learning process rarely make drastic changes in their farming system. Rather, they proceed in a step-wise manner to adopt one and sometimes two new inputs or practices at a time. The impact of market needs to be studied on a continued basis. Instruments like preferential credit should be designed for those farmers who adopt farming systems approach in view of their contribution to sustainability of agriculture as an enterprise.

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Integrated Pest Management in Rainfed Crops

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Major pests of Castor and their management

Castor is the major non-edible oil seed crop grown in an area of 8.4 lakh ha under varied agro-climatic zones and practices. Economically the crop is most important in certain rainfed areas, where the soils are not fertile and this is the most neglected crop by the farmers. From export angle castor crop has bright future. However, the average yields are very low, the reasons, in part, are attributed to the insect pests and diseases, which are responsible for over 25 per cent losses and total crop loss some times.

Major insect pests of Castor *Ricinus communis* Linn.

Common Name	**Scientific Name**
Castor semilooper	*Achaea janata* Linn.
Castor shoot and capsule borer	*Dichocrosis punctiferalis* Guen.
Castor hairy caterpillar	*Euproctis lunata* Wlk.
Red hairy caterpillar	*Amsacta moorei* Butler
Green jassid	*Empoasca kerri* Pruthi
Tobacco caterpillar	*Spodoptera litura* Fabr.

Management of key pests:

Castor Semilooper, *Achaea janta* Linn.

- Early sown crop (immediately with the onset of monsoon) gets more infestation.
- Peak infestation coincides with the initiation of primaries. Scouting for larvae should be done for shot holes
- Egg parasitoids, *Trichogramma chilonis* Ishii and *Telenomus* sp. are exert excellent a natural control to the extent of 30-92.2 per cent
- *Microplitis maculipennis* Szep. is the key mortality factor for the larvae of this pest causing upto 70% larval parasitisation
- Granulosis virus causes infection and disease in larval stages

- 18 species of birds predate upon the pupae of the pest. Adoption of bird perches is effective (both indigenous and bamboo bird perches)
- *Bacillus thuringiensis* (Bt) effectively controls larval stages when applied at 375 g a.i./ha
- Hot water extracts of *Vitex negundo* (10gm/100 ml) has phagodeterrent properties.
- As a last resort, Quinalphos at 0.5 kg a.i./ha can provide effective control of grown-up larvae

Castor shoot and capsule borer

- Aruna and JI-144 suffered only 6.1 and 4.6 per cent infestation compared to RC 1377 (29.3 per cent
- Mechanical collection and destruction of attacked shoots and capsules
- Destruction of off season stray castor plants.
- Larval parasitoids: *Diadegma ricini* Rao and Kurian, *D.trochanterata* Morley, *Theronia* sp., *Apanteles* sp. and *Bracon hebator* Say
- Dichlorvos 0.025% , fenitrothion 0.05% and Monocrotophos 0.05% can reduce capsule damage

Red Hairy Caterpillar, *Amsacta albistriga*

- Management of the pest has to be done on a community basis and a combination of strategies should be adopted.
- Erection of light traps soon after monsoon for 20-45 days to kill adults.
- Collecting and killing of adult moths are found very effective.
- Trap crop with cucumber.
- Vegetative traps with *Ipomoea, Jatropha, Calotropis* twigs
- Digging trenches around field and insecticidedusting.
- Insecticides options if situation warrants. Spraying with Quinalphos against early instar larvae

Tobacco caterpillar, *Spodoptera litura*

- Control measures have to be taken up if pheromone trap catches exceed 100 moths over one week or one to two egg masses are seen in a meter row (10 plants).

- Annonol(oil based annona formulation) at0.92 and 0.46% exhibited higher(53.00 & 50.64%) antefeedancy. Methanolic extracts of seed (0.14%) and leaf 0.125%recorded 51.24&47.91 percent were the next best. All fresh annona formulations were highly effective
- For late instar larvae of *Spodoptera* following bait is effective: Chlorpyrifos -50 ml or Monocrotophos-125 ml or thiodicarb 250g + water-10 lit + jaggery-1 kg + rice bran-10 kg. Must be mixed thoroughly, prepare small balls and spread in the field.
- Planting trap crop sunflower for egg laying and destroying eggs or 1st stage larvae
- As a last resort chemical insecticides may be used like Chlorpyrifos and Monocrotophos or thiodicarb

Major pests of Pigeonpea and their management

Pigeonpea is one of the most important grain legume crops of tropical and subtropical environments. Cultivated on almost 4 million hectares worldwide, it provides farmers with grain, fodder and fuel wood. More than 200 species of insects live and feed on pigeonpea, though relatively few cause heavy annual yield losses (Prasad and Singh, 1992). The few serious pests, however can be devastating. Most of the pests have a sporadic or restricted distribution of are seldom present at high densities. Pests that feed on reproductive structures, flowers and pods cause the greatest harm. Foliar damage rarely spurs seed yield reductions.

Major insect pests of Pigeonpea *Cajanus cajan* Linn.

Common Name	Scientific Name
Gram caterpillar	*Helicoverpa armigera*
Pod fly	*Melangromyza obtusae*
Spotted pod borer	*Maruca testulalis*
Pod weevil	*Apion clavipes*
Pod bug	*Clavigrella gibbosa*
Leaf roller	*Grapholitha critica*
Jassid	*Empoasca kerri*
Thrips	*Megaleurothrips usitatus*
Blue butterfly	*Lampides boeticus* (L.)
Plume moth	*Exelastis atomosa*

Gram caterpillar, *Helicoverpa armigera*

- Avoid the staggered sowings, different duration cultivars of pigeonpea.
- Adopt simultaneous sowing of pigeonpea to reduce the food availability throughout the year.
- Adoption of tolerant variety "Abhaya" or "ICPL-87
- Intercropping reduces the pest infestation. Medium duration pigeonpea + Sorghum, LDP + castor and SDP + Sorghum are effective.

- Crop rotation with sorghum/pearl millet/castor
- Mechanical collection of late instar larvae by shaking of the plants (Early pod formation stage but not at flowering)
- Adoption of "T" shaped bamboo bird perches 20 per hectare
- Use of NPV @ 250 LE along with adjuvants + 0.035 per cent endosulfan provides good control of *H.armigera* larvae in field.
- NSKE application @ of 5% or neem oil spray @ 3 ml/litre .

Redgram podfly, *Melangromyza obtuse*

- Destruction of off season survival hosts like weed legumes, *Flemingia conjesta* and *Rhyncosia minima*
- *Euderus lividus*, *Ormyrus orientalis* and *Eurytoma* sp. has been reported to parasitise the podfly
- Strip application of insecticides has been found to be effective and economical for both pod fly and gram pod borer

Major pests of Groundnut and their management

Groundnut is a major oilseed crop in India, occupying 8.6 million ha of which 85% is rainfed and 15% irrigated. The crop is cultivated in 45% of India's total oilseed area and accounts for 55% of the oilseeds produced in the country. Most groundnut insect pests are sporadic in occurrence an distribution. In general, insects cause 10-20% crop loss. However there are instances of total crop loss caused by a single pest species. Although many insect species live and feed on the groundnut crop only a few cause significant damage that results in large reductions in pod and haulm yields.

Major Insect Pests of Groundnut

Common Name	Scientific Name
Leaf miner	*Aproaerema modicella*
Red hairy caterpillar	*Amsacta albistriga*
Root grubs	*Holotrichia* sp
Tobacco caterpillar	*Spodoptera litura*
Aphid	*Aphis craccivora*

Management of Leaf miner

- Spreading varieties infested less
- Varieties MS 11, GN 1024, 191, 271, 362, 450 ICGV 86301 were resistant
- Crop rotation with leguminous crops.

- Collection and destruction of pest infested leaves along with larvae
- Groundnut intercropped with cowpea and black gram (3:1)
- Mulching with rice straw and close planting (20 x 10 cms) than normal (30 x 10 cms)
- Egg parasitoid – *Trichogramma* sp. and Laval parasitoids viz., *Brachymeria* sp. *B.pultellophaga* Girault and *Eupelmus* sp. were found parasitising the leaf miner in the field.

- Chemical control: Chlorpyrifos 0.05%, Dimethoate (0.03%)

Red Hairy Caterpillar, *Amsacta albistriga*

- Has to be done on a community basis and a combination of strategies should be adopted
- Erection of light traps soon after monsoon for 20-45 days to kill adults.
- Trap crop with cucumber
- Vegetative traps with *Ipomoea, Jatropha, Calotropis* twigs
- Digging trenches around field and Lindane dusting.
- Chemical control: Endosulfan (0.07%) or Quinalphos(0.05%) against early instar larvae

White grub

- Seed treatment with chlorpyriphos 6 ml / kg seed
- Early sown crop by mid June is infested less by white grub.
- Deep ploughing of fields to expose the pupae to predatory birds.
- Manual collection and destruction of beetles from avenue trees for three days after first shower of rains in June-July involving farmer's on campaign basis is the most effective method
- Birds *Corvus splendens* and *Acridotheres tristis* predate on the exposed grubs at the time of ploughing.
- Fungus *Metarrhizium anisopliae* is pathogenic to adults while bacterium, *Bacillus popillae* affects grubs
- Spraying host trees with Monocrotophos (0.05%) or Quinalphos (0.025%) provided effective control of beetles

Tobacco Caterpillar, *Spodoptera litura*

- For late instar larvae following bait is effective:
    - Chlorpyrifos -50 ml or
    - Monocrotophos-125 ml +
    - Water-10 lit +
    - Jaggery-1 kg +
    - Rice bran-10 kg

    Must be mixed thoroughly, prepare small balls and spread in the field.

- Planting trap crops like castor and sunflower for egg laying and destroying eggs or 1st stage larvae
- As a last resort chemical insecticides may be used like Chlorpyrifos and Monocrotophos or thiodicarb

Aphid

- Predators: *Coccinella repanda*, *Pseudendaphis circumflexa*, *Brumus suturalis* and *Verania* sp. were found predating upon aphids

Major pests of Sorghum and their management

Common Name	**Scientific Name**
Shootfly	***Atherigona soccata*****(**Rondani**)**
Stem borer	*Chilo partellus*
Foliar midge	CONTARINIA SORGHICOLA
Earheadbug	CALOCORIS ANGUSTATUS
Shoot bug	Peregrinus maidis
Armyworm	Mythimna separata
Corn leaf aphid	RHOPALOSIPHUM MAIDIS
Mites	*Oligonychus indicus*
Panicle feeding caterpillars	***HELICOVERPA ARMIGERA (HUBNER)*** *Euproctis subnotata (Walker)*

Management of insect pests of sorghum

Shootfly*: Atherigona soccata*(Rondani)

- Adjusting the planting time Kharif : •Plantings within 7-10 days of the onset of first monsoon; Rabi : Plantings between last and first weeks of Sep. and Oct

- Uprooting the infested seedlings and destroying them so as to reduce the multiplication of the pest
- Increasing the seed rate by 2.5 kg per ha and removing the deadheart plants so as to tolerate the damage due to shootfly and maintain the optimum population
- Seed soaking with Endosulfan 35EC @ 0.07 per cent concentration for 4h decrease shootfly incidence and increase germination percent and yield

- Granular application of Carbofuran 3G at sowing in seed furrows @ 20kg/ha (or)
- Spraying Quinalphos @ 1 L/ 500 L water

Stem borer *: Chilo partellus*

- Uprooting and burning of stubbles and chopping of stems prevents the carryover of the pest
- Application of 2-3 granules of Carbofuran 3G into the whorls at 25th and 35th day after emergence
- The treatments should only be given after ascertaining levels as evidenced by dead heart symptom

Foliar Midge : *Contarinia sorghicola*

- Early and uniform planting of sorghum over large area
- Chaffy panicles and the residues after threshing should be burnt to prevent the carryover of diapausing larvae

- Spraying systemic insecticide @ 1 L/ 500 L at ETL of 1 midge / earhead
- Resistant / Tolerant Varieties: DJ 6514, DSV 3

Earhead bug :*Calocoris angustatus*

- Early planting reduces the chance of flowering period coinciding with the peak headbug activity
- ETL - 4 bugs / earhead
- Dusting Malathion 5 D @ 20 kg/ha once at prebloom and again at 50% flowering stage

Shoot bug : *Peregrinus maidis*

- Spraying of Metasystax or monocrotophos @ 2ml/lt or quinalphos @ 1L /500 L water at 40 days after germination

Armyworm : *Mythimna separate*

- Plough the field soon after harvest of the crop so as to expose the pupae of armyworm

IPM in Sorghum

- ***TAKE UP EARLY SOWING SO AS TO AVOID SHOOTFLY DAMAGE***
- ***UPROOT THE INFESTED SEEDLINGS DUE TO BOTH SHOOTFLY AND STEMBORER AND DESTROY THEM SO AS TO REDUCE THE MULTIPLICATION OF THE PESTS***
- ***INCREASE SEED RATE BY 2.5 KG PER HA AND REMOVE THE DEADHEART PLANTS SO AS TO TOLERATE THE DAMAGE DUE TO SHOOTFLY AND MAINTAIN THE OPTIMUM POPULATION***
- Collect the stubbles and burn them so as to destroy the hibernating larvae of stemborer in the stubbles
- Plough the field soon after harvest of the crop so as to expose the pupae of armyworm and earhead caterpillars
- Early and uniform sowing of same cultivar over large areas reduces the damage by shootfly, midge and head bugs
- If sorghum is rotated with cotton, groundnut, sunflower , damage due to shootfly, earhead bug can be minimized
- Shootfly, stemborer, armyworm and midge damage is reduced when sorghum is intercropped with leguminous crops
- Intercropping sorghum with cowpea reduce the borer incidence by 50% and increase the grain yield by 10 - 12 % over sole crop of sorghum
- The use of pest-resistant cultivars should form the backbone of pest management in sorghum.
- M35-1, CSH 15R are less susceptible to shootfly and are suitable for cultivation in the post-rainy season where shootfly is a major problem
- DSV 3 and DJ 6514 are tolerant to midge
- Chemical control of pest population should only be adopted as a last resort but still it remains a main tool in Pest management
- Insecticide application should be based on ETL's taking into account the existing natural enemies

IPM IN CASTOR

- Use resistant variety in endemic areas for wilt
- Seed treatment with *Trichoderma viridae* @ 10 g /kg seed or carbendazim 1 g / kg seed
- Two to three releases of *Trichogramma chilonis* egg parasitoid @ 50000 / ha coinciding with semilooper and capsule borer incidence
- Adopt community approach for management of RHC with light traps/bon fires and vegetative barrier (cucumber, Ipomea twigs)
- Prohylactic sprays with local preparations of NSKE 5% starting 25 days after sowing
- For managing semilooper, sprays of locally produced baculovirus (200 LE/ac) or Bt (150 g/ac) could be used either alone or in combination. This practice is ecofriendly and conserves the good natural regulation of field populations of semilooper; In case of heavy attack apply Quinalphos @ 2 ml /l (Prabhar *et al*., 2003)
- Erect bird perches @ 20 /ha between 45 and 80 days after sowing
- Collecting and destroying leaves infested by gregarious mass of larvae can successfully manage Spodoptera infestation. Chemical sprays are can be avoided by this method

- In case continuous wet weather conditions coincide with capsule development stage in September/October, apply carbendazim @ 0.1% to save the crop from Botrytis grey rot disease

IPM IN GROUNDNUT

- The major pests/diseases affecting groundnut production in AP are: leafminer, Spodoptera, white grub, red hairy caterpillar, *Helicoverpa*, aphids, jassid, bud necrosis disease, leaf spots and peanut stem necrosis. Strategies to minimize pest damage are:
- Summer ploughing
- Use of resistant varieties
- Adopting required seed rate (40 kg/acre) for closer spacing. Sowing should be done at optimum soil moisture level to maintain adequate plant stand (33 plants /m2)
- Seed treatment with chloropyriphos @ 6 ml/l, carbendazim @ 1 g or mancozeb @ 3g / kg seed
- Intercropping groundnut with pearl millet or sorghum or castor or redgram @ 7:1 (Jayanthi *et al*., 2000).
- Sowing four rows of border crop with pearl millet or sorghum
- Timely weeding to remove alternate hosts (Parthenium, Azeratum, Acanthospermum, Achiranthus and Commelina) for peanut stem necrosis
- Community approach with light traps for management of red hairy caterpillar
- Monitoring of Spodoptera and Helicoverpa through pheromone traps (1 per hectare)
- For the management of Thrips (vector for viral diseases) apply Imidacloprid 0.5 ml/l
- In case of heavy attack by Spodoptera within 50 days after sowing, adopt poison baiting (rice bran 5 Kg + 500 g jaggery + 400-500 ml quinalphos)
- If necessary spray of Mancozeb (0.3%) and carbendazim (0.1%) for control of leaf spots at 60-70 days after sowing

IPM IN REDGRAM

- Summer ploughing
- Follow crop rotation
- Avoid staggered sowing
- Cultivate tolerant / recouping varieties such as ICPL 332, ICPL 84060, LRG 30 and MRG 66
- Grow intercrops (kharif: sorghum, soybean, gingelly, green gram, black gram, bajra) (Rao and Reddy, 2003).
- Grow short duration varieties in Telangana
- Monitor pod borer with pheromone traps
- Apply NSKE 5% at 10-25% flowering to reduce oviposition by pod borer, apply NPV @ 500 LE/Ha locally produced HaNPV at 25%-50% flowering targeting early instar larvae; If necessary apply insecticide at pod development stage to control the pod borer complex.
- Ensure thorough coverage of plants while spraying >700 liters per hectare

- Dislodge and collect larvae by shaking the plants at pod development stage (2-3 times at intervals)

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Economics of Rain Water Harvesting Structures – A Case Study of Farm Ponds

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Introduction

Even after realizing the full irrigation potential, about 50 per cent of cropped area will continue to be rainfed in India. Rainfed agriculture is characterized by poor resource base: poor and degraded soils, low and uncertain rainfall (CRIDA, 1997). The rainfed regions also shelter a majority of rural poor. The positive effects of green revolution by and large bypassed these rainfed regions. It was recognized that the inherent risk in rainfed farming acted as a constraint to adoption of yield-enhancing technologies. Rain water harvesting structures are used to capture the rainwater to be used later for irrigating the crops or for other uses. Thus, these structures are helpful in securing the crop yield by enabling farmers to give one or two supplemental irrigations to the crop during the critical periods of growth. Dug out farm ponds are the most popular rain water harvesting structures.

There are now emerging opportunities in the form of various government supported development programmes that have the potential to accelerate the adoption of these technologies. The Mahatma Gandhi Rural Employment Programme is one such programme wherein considerable share of resources was spent on creating soil conservation and rain water conservation programs in Andhra Pradesh and other states (Kareemulla et al., 2010). The present study was conducted in Anantapur with an objective of assessing the economics of dugout farm ponds and to examine the perceptions of farmers with respect to utility and constraints to adoption of farm ponds.

Study Area

Anantapur has a geographical area of 19.13 lakh out of which nearly 13% is under forests and about 70% is cultivated. The district has a cropping intensity of 106%. Only 10.5% of the area is under non-agricultural uses while permanent pastures constitute 2.2%. The per capita cultivated land is about 0.29 ha. The district has a livestock population of more than 15 lakhs with a grazing pressure of 10.6 ACUs per hectare of available grazing area. The district has a large number of small ruminants (4,81,849). Anantapur is the only arid district of the state with only 536 mm annual rainfall. This district lies in the rain shadow area of the state and suffers from frequent droughts. It has only 10% of area under irrigation with groundnut occupying maximum area under rainfed condition accounting for over 75% of the cropped area. Other important crops are sunflower (6.4%), gram (4.9%), pigeonpea (3.6%), rice (3.4%) and sorghum (2.2%). The productivity of the major crops is less than half a tonne per hectare reflecting the harsh production environment in the district. The district had over 21,000 ha under horticulture in 2000-01, which has increased to nearly 48,000 ha in 2005-06 with its share growing from 4.3% to 6.8% of the total area under horticulture in the state. Area under vegetables has marginally declined, while that in spices has drastically declined from over 16,000 ha to around 5,700 ha during this period. The per capita income of the district was Rs. 16939 during 2003-04 at constant prices. The district had a moderate annual growth rate in agricultural advances between 1995 and

2005. Among the 8 NAIP districts, Anantapur has the least number of Agriculture Produce Marketing Committees (1.5 APMC per one lakh ha of Net Sown Area).

Nearly 22000 farm ponds were dug in Anantapur district with support from the Mahatma Gandhi National Rural Employment Guarantee Programme during the last three years. As these ponds were found to vary widely in terms of size and cost, only those ponds that costed Rs. 18000 and above were considered to be included in the sample. Accordingly, four mandals, viz., Gandlapenta, Amadaguru, Kadiri and Narpala, were selected which had relatively higher number of farm ponds. Analysis was conducted using the data collected from one hundred farm ponds in these selected mandals. Economic viability was assessed by considering the changes in cropping patter, crop yields and economics of crop production that can be attributed to farm ponds.

General Features of Farm Ponds

It was observed that the average size of the plot where the ponds are located is about 1.1 ha. Most of the ponds are approximately 2 m in depth and 10-14 m in length and breadth. These ponds were rarely lined and hence mostly used as recharge ponds only. Farmers are often locating the ponds in the same plot where an irrigation source (bore well) is already existing. Farmers are also concerned about 'loss of land' to farm pond as is evident from the poor quality of land that is allocated to farm ponds. Many farmers did not invest in lifting water to crop for different reasons. Changes in crop yields, cropping pattern and cropping intensity were observed with adoption of farm ponds.

Table 1: Number of run off events observed in the farm ponds

Times	Number
0	21
1	39
2	39
3	1

Economics of Farm Ponds

Crop yields after farm ponds

Increased moisture/ water availability through farm ponds resulted in crop yields increasing by 20-25 per cent in most of the crops (Fig 1).

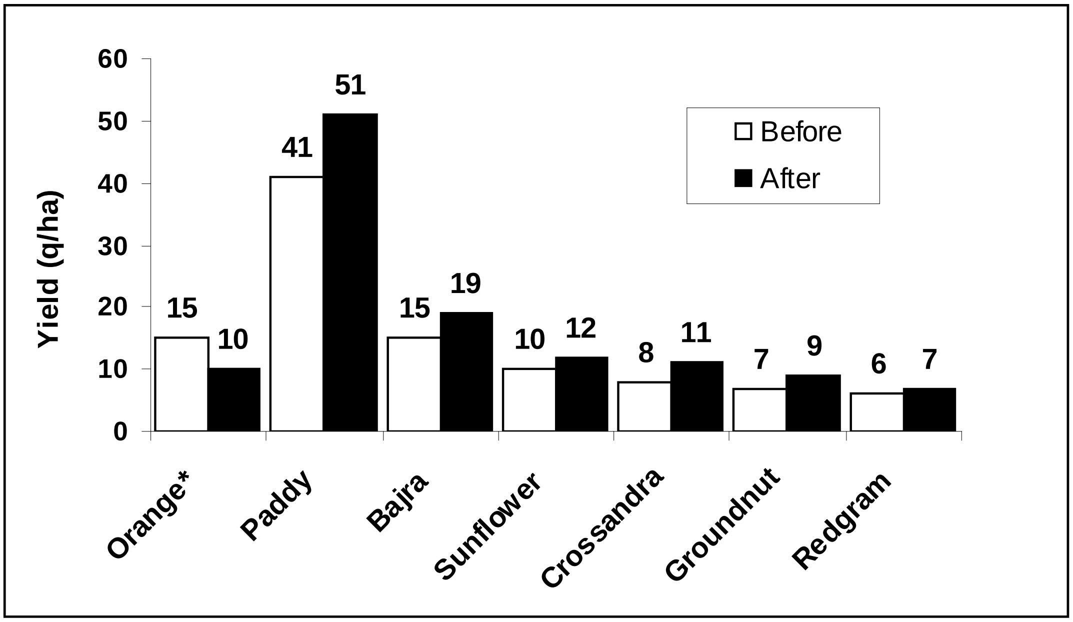

Fig 1. Change in cropping pattern before and after adoption of farm ponds

Economic analysis of farm pond was conducted with the observed changes in crop yields and cropping pattern. The yield of groundnut, the most important crop in the district, was observed to increase from 12.2 to 15.6q/ha because of additional irrigations that were possible because of the ponds. Considering a life of 10 years for the pond, a Net Present Value (NPV) of the pond was found to be about Rs. 0.61 lakhs and the benefit-cost ratio (BCR) was 2.7 (Table 2). If the life of the pond can be extended to 15 years, the NPV and BCR would increase to Rs. 0.93 lakhs and 3.5, respectively. Further, the profitability of ponds was found to be sensitive to the changes in annual rainfall as it would affect the filling of farm ponds. The profitability was observed to be affected badly if the initial years happen to be dry rendering the ponds ineffective.

Table 2: Profitability measures of farm pond

Profitability measure	**Life of farm pond**	
	10 years	**15 years**
Net present value (Rs lakhs)	0.61	0.93
Benefit-cost ratio	2.7	3.5
Internal rate of return (%)	43	44
Payback period (years)	8	8

Another typical case of farm pond is characterized by use of harvested water for recharging the irrigation well already existing. Because of the recharge, it became possible to enhance cropping intensity as well as to increase the crop yields significantly. The average yield increased from 18 to 23 q/ha and the area sown to rice from 1.5 to 3 ac as rice was grown during rabi as well unlike the situation before digging the farm pond. The gross benefit thus obtained was worked out to be 43 q of rice per year.

However, it is to be noted that the profitablility of farm pond is determined by the a variety of factors like the yield gains in the crop being grown, change in cropping intensity and the rainfall. A sensitivity analysis considering these situations to examine the changes in profitability. The results are presented in Table 3 and 4 for the farm pond described above, i.e., where water is used to irrigate rice through recharging the bore well.

Table 3: Viability of farm pond is sensitive to inter-annual distribution of rainfall and utilization of farm pond (NPV Rs lakhs)

Farm pond leads to	**Situation**			
	1	2	3	4
Area and yield effects	1.75	1.14	0.91	0.98
Yield effect only	0.3	0.11	0.04	0.08

1. All years are normal rainfall years with expected fillings and use of the pond water
2. Every 3rd year is a sub-normal year and the farmers operates in a 'without pond situation'
3. Same as above but the first year is a 'sub-normal' rainfall year
4. The first three years are 'sub-normal' years.

It can be observed from the table that the profitability of farm pond significantly increased when both area and yield effects are observed. Further, the profitability is highly sensitive to the filling and utilization of water during the initial years as the fall in the net present value of the ponds when the initial years happen to be sub-normal rainfall years leading to poor filling of the pond.

Determinants of economic viability of farm ponds

It was observed that out of the 100 ponds selected, 39 ponds got filled once or twice in the year (Table 2). Only one pond got filled thrice and 21 ponds never received enough water. It was observed that the impact was more conspicuous in extending the area under cultivation as can be seen from the increase in the cultivated area. In the absence of ponds, more area was left fallow. However, the impact on cropping pattern was not so conspicuous implying the same crops were grown in the area brought under cultivation because of the pond. It was observed that the proportion of area under vegetables and sunflower. The proportion of area sown to groundnut decreased to 58 from 62 per cent after adoption of farm ponds.

Table 4: Determinants of profitability of farm ponds in Anantapur district

Variable	**b**	**SE**	**β**	***t***
Constant	-3572.7	4798.6		-0.78
Plot size	1661.48	322.98	0.398	5.144
Pond size	39.49	23.21	0.144	1.702
If lifted	3874.34	1544.06	0.210	2.508
Δ cropping pattern	10456.89	2147.91	0.520	4.868
Slope	-4.01	82.79	-0.004	-0.048
Δ CI	-1432.24	2516.31	-0.061	-0.569
If bore well	-1783.83	1323.81	-0.130	-1.347
No. of fillings	-1162.58	837.163	-0.112	-1.389
R^2	0.55	n=100		
F	13.32	P=<0.001		

Based on the changes in cropping pattern and the yield gains attributed to the introduction of farm ponds, additional returns generated in the plots where ponds were located were computed. The results show that 14 out of 100 ponds generated an additional return of less than Rs.3000 and 10 ponds generated more than Rs.15000 (Fig 2). Majority of ponds generated an additional return varying between Rs. 3000 and 6000. Assuming these returns would occur every year for a period of 15 years, the economic viability in terms of NPV and BC ratio was calculated for all the 100 ponds. It was observed that 33 out of 100 ponds gave an NPV of less than Rs.30000 (Fig 3). It is interesting to note that four ponds recorded an NPV in excess of Rs. two lakhs and investment in 15 ponds was found to be unviable with a negative NPV. Similar findings were observed in case of BC ratio as well. The BC ration was found to vary between 2-4 in a majority of ponds studied.

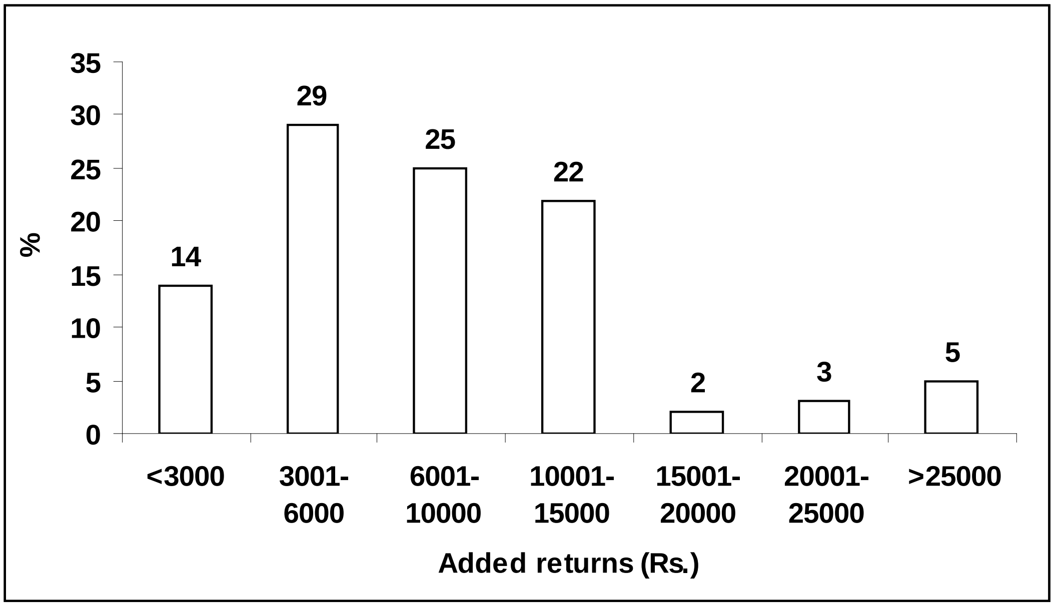

Fig 2. Distribution of farm ponds based on additional returns generated

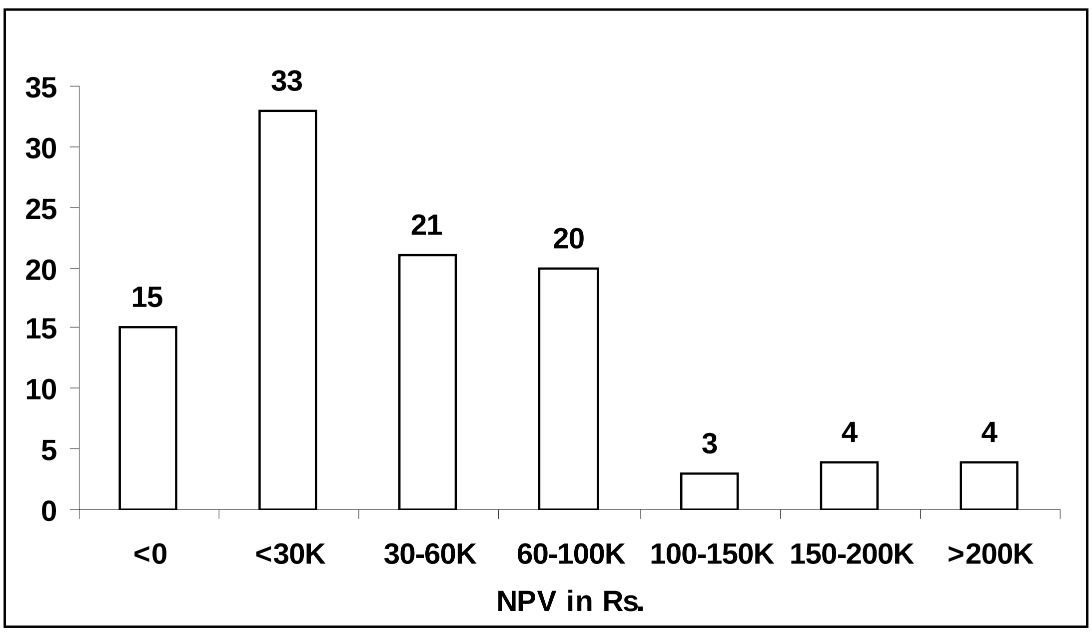

Fig 3. Distribution of farm ponds based on Net Present Value

In order to examine the determinants of profitability of ponds, the additional returns generated was regressed on independent variables, viz., size of the plot where the pond is located (ac), size of the pond (M^3), change in cropping intensity (%), whether water is lifted to irrigate the crop, whether there is a bore well in the plot and number of fillings in the season. The results indicated that four variables, size of plot, size of pond, change in cropping pattern and use of water for irrigation were found to have significant positive effect on the profitability. Variables such as slope of the plot, presence of a bore well and number of fillings were not found to have significant effect.

In order to further understand the determinants of profitability, the characteristics of five most profitable and five least profitable ponds were examined (Table 5). It was observed that the average size of the plot and pond were much higher in case of the most profitable ponds. Similarly, the yield effects were more prominent as well as the changes in cropping pattern. The profitability was found to be associated with changes in cropping pattern in favour of horticultural crops such as sweet orange and tomato.

Table 5. Characteristics of most and least profitable farm ponds

Variable	**Top 5**	**Bottom 5**
Cropping intensity	179	100
Bore wells in the plot	5	2
Pumping	3	1
Pond size (cu.m)	240	208
Plot size (acres)	5	2.3
Yield improvement (%)		
Paddy	32	15.4
Groundnut		6.7
Sunflower	18	3.1
Bajra	18.1	-
Sweet orange	20	-

The perceptions of the farmers with respect to utility of ponds were also elicited. It was observed that nearly 70 per cent of farmers saw a strong role in protecting the crops during the drought and about 20 per cent of them adopted the pond to recharge the bore wells existing. Further, about half of the farmers opined that ponds were 'very useful' during a drought year and about 10 per cent of them believed that the ponds did not make any difference during a drought year or a normal year.

AGRONOMIC PRACTICES FOR IMPROVED CROP PRODUCTIVITY

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The drylands in India constitute about 60 per cent arable land and they contribute about 49 per cent food production to our national food basket. Important problems that encounter in crop production of the dryland are unfavourable weather, limited choice of crops and varieties and low and unstable crop productivity.

In India, black soils occupy 73 m ha in total geographical area of 328 million ha and Alfisols occupied 71 m ha. Among the production factors, improved genotypes of crops contribute about 30 per cent increase in yields of rainfed crops. Hence selection of crops and cropping systems in rainfed black soils has to be viewed critically for getting higher and stable yields.

Development in dryland areas may be envisaged through the watershed concept as it is the holistic improvement of land in terms of soil and water as well as crops.

I. Selection of crop based on rainfall, soil type, season and location

I). CRITERIA FOR SELECTION OF CROPS AND VARIETIES

1. Land use capability concept:
It is an age old concept but rarely used in dryland agriculture production in India. In subsistence farming, food crops are grown according to household needs of the farmers. Hence, in dryland crop production, it is the moisture storage capacity of the soil and water availability periods that play key role in selection of crops and varieties in soils.

2. Water availability period:
The cultivars that grow in vertisols are sometimes longer in duration than water availability period. As a result, the crops invariably undergo moisture stress and resulting in low yields. The water availability periods for different agro climatic zones were worked out as guiding principle in selection of the crops and cropping systems in Vertisols.

3. Crop substitution:
Many crops often grown by the farmers are more for convenience. The crop is to be matched according to the resources and also should give highest possible yields. According to the productivity, traditional crops have to be replaced with efficient crops with greater stability.
In Vertisols, selection of crops has to be based upon slope and depth of the soil. During kharif season the total quantum and distribution of the rainfall play critical role in deciding crops and cropping systems in Vertisols. While in rabi season the conserved moisture at the time of planting becomes critical in deciding the crops and cropping systems for a given region.

II. EFFICIENT CROPPING SYSTEMS IN VERTISOL REGIONS

The scientists working in drylands in different agro-climatic zones developed appropriate cropping systems for getting stabilized yields in Vertisols (Table 1). Tillage, fertilizer and weed management practiced have to be followed in time to get higher yields in drylands. In regions, where the effective growing season is less than 17 weeks and quantum of rainfall is 300 to 600 mm usually mono-cropping is being adopted. The regions having the rainfall 600 to 750 mm, having more than 17 weeks of effective growing season, are suitable to adopt intercropping system. The regions having more than 700 mm and also effective growing season of more than 20 weeks are suitable for adopting double cropping systems.

TABLE – 1: PROMISING TREATMENTS FOR MITIGATING EARLY AND LATE SEASON DROUGHTS

LOCATION	**Crop**	TREATMENTS	
		Early season drought	**Delayed seeding**
Bangalore	Finger millet	Kaolin spray (5%)	Increased seed + fertilizer dose
		Cacl2 spray (2%)	Transplanting
		Defoliation	
Agra	Pearl millet	Straw mulch (5t/ha)	Increased seed and fertilizer dose
		Soil mulch	Transplanting with increased population
		Kaolin spray Urea spray	
Rewa	Paddy	---	Transplanting
Bijapur	Pearl millet	Removal of weaklings + straw mulching + anti – transparent spray + urea spray	---
Rajkot	Groundnut	Straw mulch @5t/ha Earthing up	---
Ananthapur	Groundnut	Application of sand @40t/ha during stress period	---
	Sunflower	Mulching with groundnut shells @5t/ha together with one supplemental irrigation	---

LOCATION	**Crop**	TREATMENTS	
		Early season drought	**Delayed seeding**
Solapur	Pearl millet	Formation of ridges and furrows before seeding for both early &terminal season drought	---
Phulbani	Upland rice	Deep seeding (5-7 cm) with the application of FYM and fertilizer in lines.	---
Ranchi	Upland rice	Application of 5 cm depth of water on minimal irrigation (or) straw mulch	Higher seed rate
Indore	Soybean – chickpea	---	Application of safflower stover @2t/ha
Bhawanipatna	Upland rice	Mulching with local weeds/farm waste from germination onwards	----
Dantiwada	Pearl millet	Cacl2 spray (5%)	----

TABLE 2: EFFICIENT CROPPING SYSTEMS FOR DIFFERENT DRYLAND AREAS IN INDIA

Soil zone and region	Water availability period (days)	Double cropping system	Intercropping system
Vertisol and related soil zone			
Malwa plateau (MP)	210-230	Maize-safflower/chickpea Soybean-wheat	Maize + soybean (2:2) Soybean + pigeonpea (4 or 6:2)
	190-210	Sorghum – safflower/chickpea Soybean-safflower	Sorghum + pigeonpea (2:1) Sorghum + soybean (2:2)
Baghalkhand (MP)	210-230	Rice-chickpea/lentil	Wheat + chickpea (2:2) Chickpea+linseed (2:1) Sorghum+pigeonpea (2:1)
	190-210	Sorghum-chickpea Blackgram/greengram-wheat Groundnut-chickpea	

Bundelkhand (UP)	190-220	Sorghum-chickpea Black gram-mustard/safflower Fodder cowpea-mustard	Pearl millet + fodder legume (1:1) Sorghum + pigeonpea (2:1)
Vidarbha (M.S)	190-210	Groundnut-safflower Sorghum-safflower	Sorghum + pigeonpea (2:1) Cotton+pigeonpea (2:1/2) Cotton+greengram/ Cowpea (1:1) Pigeonpea+greengram (1:3)
	170-190	Green gram – safflower	Pearl millet + Pigeonpea (2:1) Sorghum + greengram/blackgram (2:1)
Southern Maharashtra	160-180	Greengram-sorghum/safflower	Pearl millet + pigeonpea (2:1) Pigeonpea (2:1 or 2) Groundnut + sunflower (2 or 3:1) Chickpea – safflower (3:1)
	120-130		Pearl millet + moth bean (2:1)
Southern Rajasthan	160-180	Greengram – safflower	Maize + pigeonpea (1 or 2:1) Sorghum + greengram (2:1) Groundnut + pigeonpea (2:2) Chickpea + mustard (4 or 7:1)
Northern (central Karnataka)	130-150	Cowpea – sorghum Greengram – safflower	Pearl millet + pigeonpea (1:1) Groundnut + pigeonpea (3 or 4:1) Sunflower + pigeonpea (2:1) Chickpea + safflower (2 or 3:1) Sorghum + pigeonpea (2:1)
		100-120	Sorghum + coriander (2:1)
Saurashtra (Gujarat)		130-140	Groundnut + castor/pigeonpea (3:1) Pearl millet + pigeonpea/castor (2 or 4:1)
Southern Tamil Nadu		120-130	Sorghum + blackgram/cowpea (2:1) Cotton + blackgram (2:2)

iii. The possible options that can be considered under different rainfall areas are:

For the areas with rainfall < 500 mm (15 million ha arable land)

Linking arable farming with animal husbandry
Adopting arable farming limited to millet and pulses and adoption of agro-forestry, silvi-pastoral and horti-pastoral systems
Growing drought - tolerant perennial tree species that provide fuel, fodder and food.
Adopting arid-horticulture to augment farm income.
Emphasizing efficient management of rangelands and common village grazing lands, adopting improved strains of grasses, reseeding techniques, and developing fodder banks.

For the areas with rainfall 500-750 mm (15 million ha arable land)

Increasing emphasis on oilseed and legume based intercropping systems in not so favourable tracts.
Adopting high value (fruits, medicinal, aromatic bushes, dyes and pesticides) high tech (drip irrigation, processing, extraction and value added products) agriculture.
Encouraging watershed approach in a farming systems perspective
Efficiently utilizing marginal and shallow lands through alternate land use systems with agriculture – forests – pasture system with a range of options
Increasing afforestation in highly degraded undulating lands.

For regions receiving rainfall between 750-1150 mm (42 million ha area)

Developing aquaculture in high – rainfall, double cropped regions with rationalization of area under rice.
Adopting intercropping systems and improved crop varieties of maize soybean, soybean, groundnut and double cropping in deeper soil zones.
Rainfed horticulture
Tree farming

II. Drought Management strategies

Nature of drought	Management options
Early season droughts	
Delay in on set of monsoon	• Selection of drought tolerant varieties/crops and cropping systems (Mixed or intercropping systems) • Contingency crop planning • Alternate crops/varieties to match effective growing season
Mid season droughts	• Addl.interculture during dry spells • Closing of cracks in Vertisols • Additional Nitrogen (10 kg N/ha) after relief of dry spells • Additional Nitrogen (10 kg N/ha) after relief of dry spells • Adjustment of plant population and geometry • Mulch cum manure techniques
Late season droughts	• Rain water harvesting and recycling

Case Studies

1. Sorghum+pigeonpea (3:1) at Hyderabad, Fingermillet+ pigeonpea(3:2), pigeonpea+ dolichos(3:1), and intercropping of coriander and frenchbean in banana at Bangalore, sunflower+pigeonpea(2:1) at Solapur, little millet+pigeonpea(5:1) and relay cropping of horsegram and little millet at Dharwad were found efficient in getting higher profits (30-60%) under different micro farming situations.

Intercropping of sorghum (SPV-462) and pigeonpea (PRG-100) (5:1 and 3:1) recorded an additional sorghum grain equivalent yield of 665 and 700 kg/ha and net returns of Rs.4,096/ha and Rs.4,960/ha, respectively over traditional varieties in rainfed *Alfisols* at Hyderabad. Farmers preferred improved varieties to meet the fodder demand. In *Vertisols*, intercropping maize (Ganga-2, Sri Tulasi, Kargil, DHM-105) and pigeonpea (PRG-100, Durga, Maruthi) (5:1) gave higher net returns over the years.

2. Application of 10:30:0 kg NPK/ha recorded an additional grain equivalent yield of sorghum (470 kg/ha) and net returns (Rs.1164/ha) with improved varieties as compared to local varieties in sorghum and pigeonpea system (3:1) in *Alfisols* (1897 kg/ha) at Hyderabad. In sorghum and pigeonpea system (3:1), use of 20:30:0 kg NPK/ha during low/skewed rainfall years and 30:30:0 kg NPK/ha during good rainfall years was found optimum. Technology of 10:30:0 kg NPK/ha was adopted in 200 and 150 ha area in IVLP (Institute Village Linkage Programme) and surrounding villages, respectively. About 10% of the farmers are adopting 30:30:0 kg NPK/ha on 60 ha area for higher productivity of the system in IVLP villages. In castor, use of 10:30:0 kg NPK/ha was found economically optimum even under uneven rainfall years like 2000, 2001 and 2002. Moderate dosage of nutrients (10:30:0 kg NPK/ha) as basal along with 20 kg N as top dressing was found beneficial to bring stability in yield and income during good rainall years. About 30% farmers in IVLP villages are now applying 20 kg N as top dressing along with basal application of 10:30:0 kg NPK in castor. In *Vertisols*, use of 20 kg N/ha as top dressing at flowering enhanced the profitability by 63% in rainfed maize+ pigeonpea system. But the use of 40 kg K_2O/ha along with 10 kg N at knee height stage gave additional profitability (Rs.14,272/ha), compared to farmers practice (Rs.30,212/ha). Use of potassium improved the yield of pigeonpea and maize in the intercropping system.

3. ***In-situ* moisture conservation:** At Hyderabad, formation of conservation furrows at 1.2 m interval gave additional sorghum grain equivalent yield (318 kg/ha) and net returns (Rs. 890/ha) in sorghum+ pigeonpea cropping system compared to no conservation furrows (1,830 kg/ha) with local varieties. Conservation furrows with improved varieties contributed to additional productivity (486 kg/ha) and profitability (Rs.1,526/ha) over no conservation furrows (2,476 kg/ha and Rs.6,328/ha). In castor, soil conservation practices like conservation furrows and additional application of N @ 20 kg/ha after dry spells was evaluated against farmers practice. Among the components, additional N application after the dry spell and formation of conservation furrows increased productivity by 29 and 61%, respectively compared to farmers practice (361 kg/ha). About 90% of the marginal and small farmers adopted the conservation furrows and additional N application since these were simple and easy to adopt.

Farming Systems

A farming system is a collection of distinct functional units such as crop, livestock, processing, investment and marketing activities which interact because of the joint use of inputs they receive from the environment, which have the common objective of satisfying the farmers aims. The definition of the broders of the system depends on the circumstances, often it includes not only the farm (economic enterprise), but also the household (farm – household system)”

MIXED FARMING

Mixed farming is an important component of a farming system and has been used interchangeably by many workers in past. In fact, it is very hard to draw a line of demarcation because both of them involve enterprises other than crops. However, available definitions have been reproduced.

Mixed farming can be defined as a system of farming on a particular farm (regardless of size) which includes crop production, raising of livestock, poultry, fish and bee keeping etc., to sustain and satisfy as many necessary necessities of the owner as is possible.

CROPPING SYSTEM

A cropping system is the kind and sequence of crops grown on a given area of soil over a period of time. It may be a regular rotation of different crops in which the crops follow a definite order of appearance on the land or it may consist of only one crop grown year after year on the same area, other cropping systems may include different crops but lack definite or planned order in which crops follow one another or growing of two or several crops mixed together

RATOON CROPPING

The roots of harvested crop produce a subsequent crop in ratooning

CROP ROTATION

Crop rotation is more or less regular recurrent succession of crops on the same land.

III. Contingency crop planning and management

Under aberrant weather conditions, contingent crops like horsegram, rationing of sorghum can be grown with shallow tillage and wider spacings. However, seed availability is the prime concern for this strategy.

IV. Soil fertility enhancing technologies

To make soil resilient for encountering the drought, soil fertility enhancement through organics need to be carried out. Agricultural crop residues of low calorific value or of no alternative use are preferred for making manures and for application to the soil. Eg. Groundnut shell as cattle shed bedding in the interior villages.

Rain water harvesting and supplemental irrigation for enhancing yield and quality of FCV tobacco (*Nicotiana tobacum*) in semi arid tropical India

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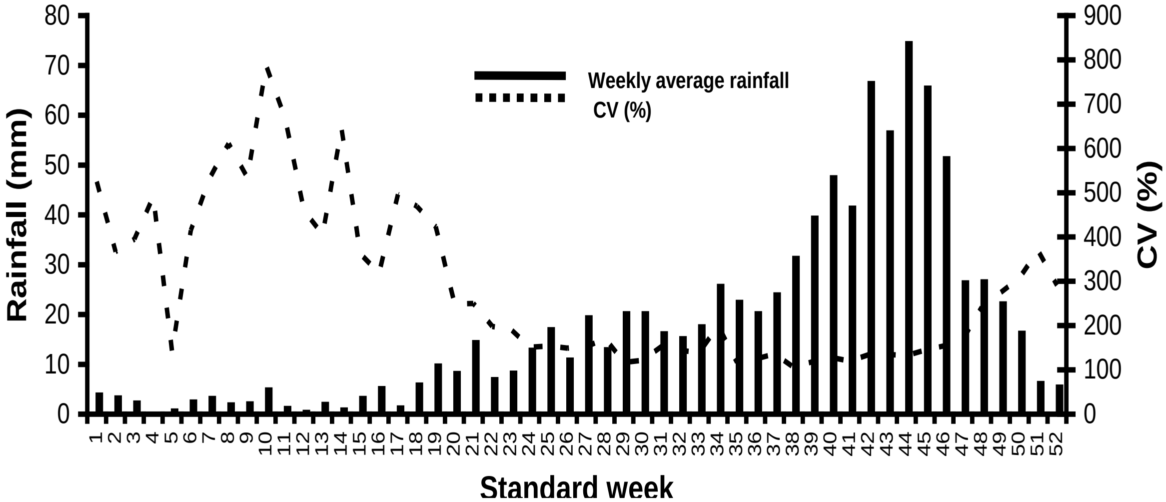
Water is one of the major limiting factors in agricultural development in the semi-arid tropics (SAT). Adequate and timely water supply assumes crucial importance in stabilizing crop yields and increases their productivity in the semi-arid zones, where rainfed farming is widely practiced. Tobacco crop, export oriented and highly remunerative, widely grown in southern light soil (alfisols) conditions of semi arid tropical India suffers from recurring droughts coupled with cyclonic rains. Thus the crop experiences limited water availability for full growth and waterlogging in the same season leading to crop quality deterioration. Further, poor ground water quality (high salinity and chloride) with low possibility for ground water recharge (due to compaction problem of soils) does not offer any succor to this persistent problem. However, the prevailing rainfall pattern with assured high intense storms offer scope for water harvesting through surface storage structures and their reuse is the major choice for overcoming the problem. In the absence of proper rainwater harvesting measures the rainfall mostly goes as a waste. During intense storms which occurs at least once in each year (>60 mm/day) the resource losses were also observed to be high. Properly designed surface drainage measures along with water harvesting ponds help in storing runoff, which could be used for supplemental irrigation at critical growth stages, which can ensure sustainability of yield with good quality.

1. Introduction

Prakasham district of Andhra Pradesh is the largest producer of Flue Cured Virginia tobacco in India with a production of 96.8 million kilograms of exportable FCV tobacco from 80,000 ha (Tobacco Board, 2007), from both under Southern Light Soils, representing alfisols and Southern Black Soils, representing vertisols of semi arid tropics respectively as a major *semi-monsoon* crop. FCV tobacco grown on alfisols is known for its good quality fetching a premium price. As the crop is grown under semi monsoon crop, tobacco crop suffers from severe moisture stress due to prolonged dry spells during active growth phase during the month of December leading to reduction in yield and quality. The crop also suffers from waterlogging problem due to high intense storms which are a regular feature in the district. Analysis of weekly rainfall pattern with historical rainfall data for 82 years (1920 to 2001) has shown wide variability with limited scope for dependable predictions. (Fig. 1**).** Occurrence of off seasonal cyclonic rains especially during crop maturity period and harvesting stage causes severe losses by way of waterlogging and high disease incidence. However, this could be seen as opportunity for enhancing the productivity, through safe disposal and recycling of rainwater to avoid crop damage.

Water harvesting (WH) and Supplemental irrigation (SI) is defined as the process of storing excess rainfall in a smaller area and application of this limited amount of water to the crop when rainfall fails to provide sufficient water for plant growth to increase and stabilize yields (Theib Oweis et.al., 1999). The amount and timing of SI are not meant to provide water stress-free

Fig.1 Rainfall Distribution (Historical Data of 82 years,1920-2001) Kandukur mandal, Prakasam Dt., A.P.



conditions over the entire growing season, but to provide enough water during the critical stages of crop growth to ensure optimal yield in terms of yield per unit of water (Oweis 1997).

In view of possibility for rain water harvesting and supplemental irrigation, the study was conducted to provide holistic solutions for increasing productivity through harvesting and utilizing of surplus rains, preventing of further land degradation and diversification of land uses for multiple outputs. Chronology of tobacco filed operations include raising a nursery during August, planting during September- October and harvesting in Jan spread over part of monsoon and non monsoon seasons. This necessitates a safe disposal system of surplus rainwater during wet spells, particularly on flat lands with negligible slope. Considering the nature of the crop for its succeptability to water logging and occurrence of high intense storms and dryspells during the crop growth period and poor quality ground water, the work , the study was designed to address the issue of safe disposal of excess runoff from cropped areas, harvesting runoff in ponds and reutilization during dryspells. Major objective of the study is rain water harvesting and supplemental irrigation through networking of farm ponds, which includes, safe disposal of rainwater to avoid crop damage during heavy rains and creation of rainwater harvesting structures and efficient utilisation of rainwater.

2. Materials and methods

Water harvesting

Total Area was surveyed for delineating micro watersheds covrering the entire farm area (100 ha) using total station (Sokkia) survey equipment and different thematic maps on drainage, cadastral and land use and land cover were prepared. Waterways were designed based on plot area of different fields, rainfall intensity and peak flow for safe disposal and harvesting of rainwater (Michael, 1978, Singh. 1983). The average size of the trapezoildal waterways (for an estimated peak flow, 0.56 m^3sec^{-1}) were, bottom width of 0.75 m, depth 0.55 m and top width of 2.25 m. Total lengths of 3926 m of waterways were dugout for safe disposal of runoff and were networked into different storage structures. Eight farm ponds (range of sizes) were dugout and three defunct wells were renovated creating facility for harvesting of rain water (Annual report 2005). A total capacity of 8360 m^3 size of storage structures were created in the entire farm . Cost of water harvesting is about Rs 38 to 40 per m^3 of harvested water.

Rainfall Analysis:

The district receives rainfall from South West monsoon as well as from North East monsoon, whose normal rainfall is 389mm and 393mm respectively and 30 mm during winter and 69 mm in summer. The normal annual rainfall is 873mm. The coefficient of variation is high (284.3%). The major part of total rainfall is received through N-E monsoon (56%) while 36% through S-W monsoon.Normal rainfall for Kandukur station is indicated in Fig.1 with probability of rainfall at 75 percent and 90 percent is about 910 and 708 respectively. Occurrence of rainfall during the months of Nov-Dec, which coincide with final critical stage of grand growth period, is low coupled with high coeeficient of variation. Since the assured availability of rainfall at 90 percent probability is only about 708 mm, it is necessary to provide one irrigation at critical growth stage, which happens to be around 40 mm. An assessment was carried on identify the trends in storm intensity per day and number of rainy days and their contribution to total rainfall and total number of rainy days.

Optimum depth of irrigation for supplemental irrigation:

A field experiment was conducted to evaluate depth of supplemental irrigation during 2003-07 at the CTRI micro watershed, Kandukur of Prakasham district located at latitude 79^o 55’44” and longitude 15^o 13’ 33’’ E with a mean sea level at 16.50 m MSL(**Fig.2**). Soils are sandy loams, neutral in reaction, low to medium in fertility status, moderately well drained, moderately low permeability with moderate water holding capacity and low to medium cation exchange capacity with more than 75 % base saturation. The minerals in clay component are Quartzite, Smectite and Kaolite. Quartz is predominant in silt fraction of the soil. The sand, silt and clay present in soil is 35, 33, 6 and 27 percent respectively. The bulk density of soil is around 1.55 g/cc. The EC values of water often exceed 10 dS/m making it unfit for drinking as well as irrigation. The chloride concentration of the ground water is very high, often exceeding 500 ppm thus making it unfit for irrigating majority of crops especially tobacco. The Maximum permissible limit for chlorides is 100ppm in soil and 50ppm in irrigation waters for FCV tobacco. High chlorides in leaf above 1.5% spoil the quality of leaf. (Krishnamurthy et *al*., 2002). The normal maximum and minimum temperatures recorded in the district are 38.2^0 C and 19.7^{0}C respectively. A total of 717.0 mm was received from June to December in 2004-05 with prolonged dry spells during August, November and December.

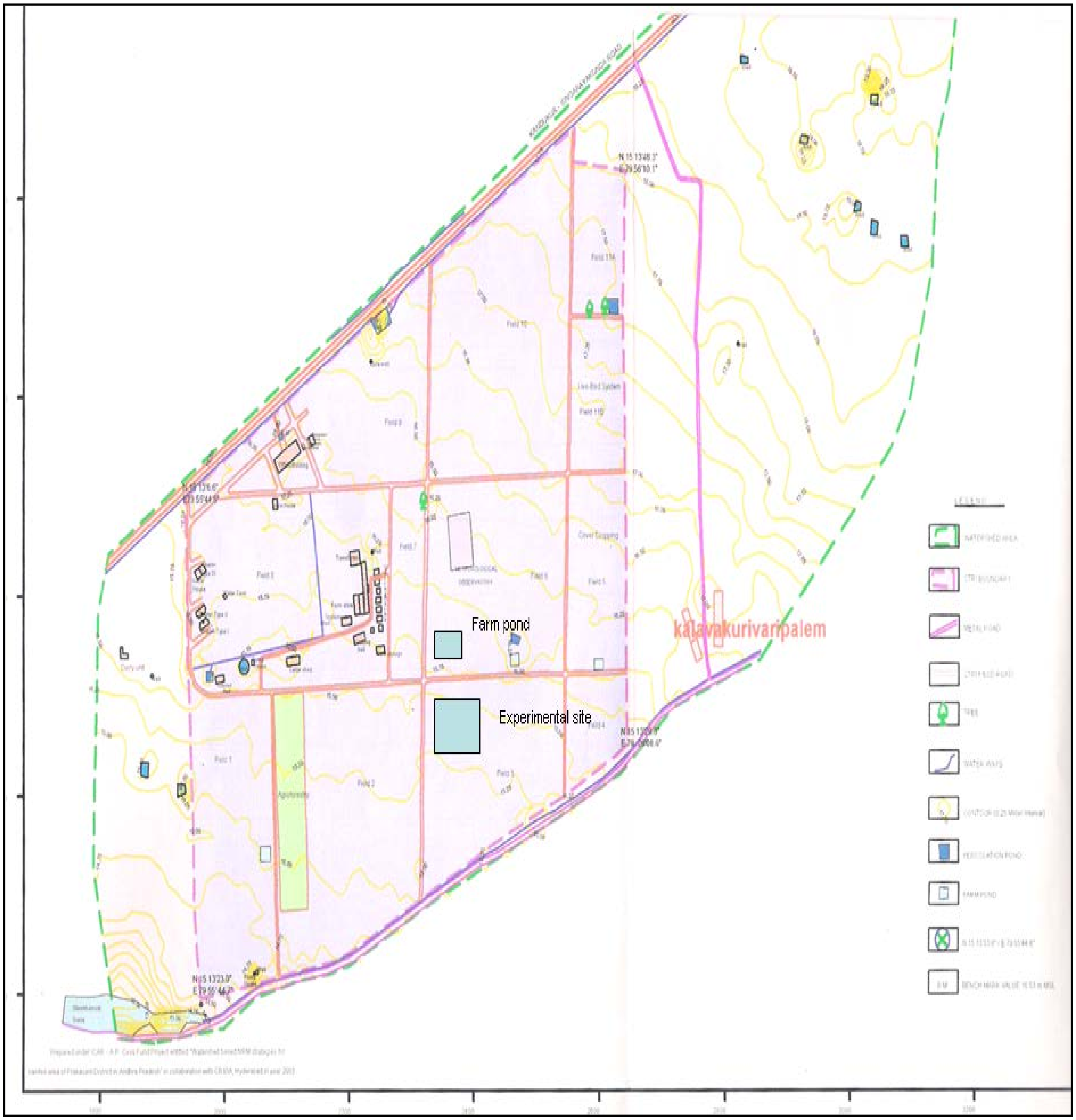


Fig. 2 the layout of the experimental site.

A field experiment was laid out for supplemental irrigation trials in Split plot design with, six treatments and three replications and furrow method of irrigation was adopted, using popular variety of tobacco, ***Hema*** during 2004-07, to study the influence of the level of irrigation on yield and quality of FCV tobacco. For Tobacco crop one life saving irrigation applied after 30 days after transplanting and second irrigation on 45 days after transplanting, 30^{th} and 45^{th} days were considered as critical stages (grand growth period) of tobacco crops and prior to attain stress conditions. Area of each plot taken for trial purpose is 114 m^2 with three replications.

Treatment T_1= 20 mm irrigation in 1 application
Treatment T_2 = 30 mm irrigation in 1 application
Treatment T_3 = 30 mm irrigation in 2 applications i.e. (15 mm + 15 mm)
Treatment T_4 = 40 mm irrigation in 1 application
Treatment T_5 = 40 mm irrigation in 2 applications i.e. (20 mm + 20 mm)
Treatment T_6 = Control, without any irrigation

Irrigation trials were conducted for the three seasons from 2004-05, 2005-06 and 2006-07. Water was applied to the treatments, from farm pond using a diesel engine pump set and connecting aluminium sprinklers pipes (75 mm) for conveying from source to the experimental plot. The irrigation system was designed to ensure full water coverage with uniform distribution. The quantity of irrigation is monitored through controlling time, to get a required quantity of irrigation (operating time).One irrigation was given at 30 days after planting of tobacco (i.e. during November/December in 2004, 2005 and 2006 @20 mm, 30mm and 40 mm in treatments T-1,T-2 and T-4 respectively. Treatments T-3 and T-5 received irrigation of 30mm and 40 mm in two splits first at 30 days and second at 45 days after transplanting. The results of the recordings after analysis of tobacco for leaf quality, grade and economics were shown in Table No. **2, 3** and **4**. Crop parameters viz. Green leaf, cured leaf, grade index and nicotine contents were studied.
in terms of Standard error mean(plus or minus), Critical Difference at 5% and Co-efficient of variation (%) for the significance of the treatments for their yields and quality of very high value commercial tobacco crop. The tobacco leaves were harvested on maturity at 7-8 intervals by priming (grading) and cured in the flue-curing barn. About 2-3 matured leaves were harvested at each time and on an average, 7 primings were done to complete the harvest. After curing and bulking, leaf was graded on the basis of colour and blemish. The data of cured leaf and bright leaf were recorded and grade index was calculated as per the formula suggested by Gopalachari (1984). Economics were calculated on the basis of prevailing market cost of inputs and market price.

Evaluation of water use efficiency

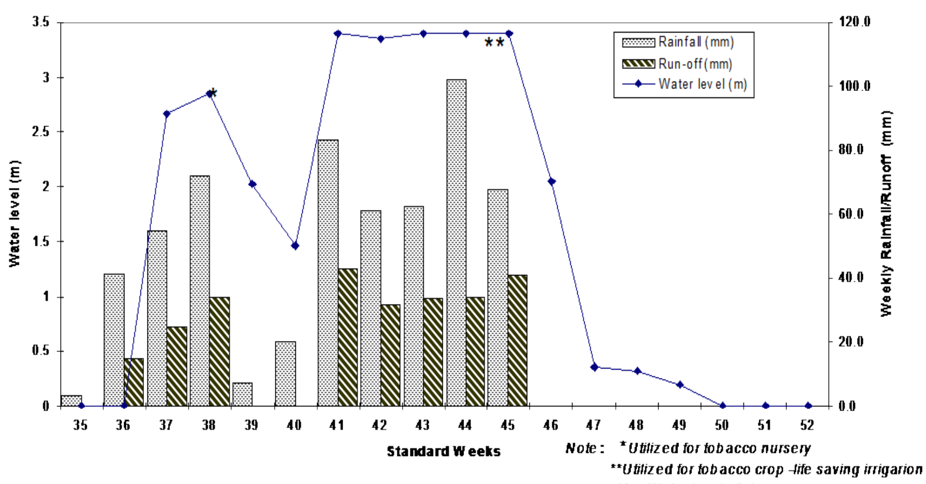
Water use efficiency (WUE), synonymously used as water productivity, was determined as the ratio of leaf yield per unit area, in terms of dry matter (biomass), to water applied (effective rainfall+irrigation)/crop evapotranspiration (mm). WUE is usually expressed either in kg/ha/mm or in kg/m^3 (kg of leaf or biomass per unit of consumed or evapo-transpired water). In the rainfed plots, rain and moisture previously stored in the soil were the sources of all water lost through evapotranspiration. In the supplemental irrigation plots, the sources of water included both rain and irrigation water, in addition to residual soil moisture.

3. Results and discussion

Water harvesting: The efforts of water harvesting through farm ponds and waterways improved the water availability in the farm. Though the north east monsoon contributes only about 70 percent of rainfall during 2004-05, 2005-06 and 2006-07 seasons, the crops could be given irrigation with harvested water. During 2003-04, total amount of rainfall received during south-west monsoon was 293.5 mm. Continuous dry spells during August effected the growth of crops. Rainfall received during north-east monsoon was 423.5 mm. During the year 2005-06, 783 mm rainfall received out of which 152 mm in south west monsoon period of June- October and 631 mm form north east monsoon with complete dry spell in the month of December. A total of 864 mm rainfall received during the year 2006-07, 152 mm through south west monsoon from June to September and 632 mm received during north east monsoon season and 80 mm for the rest of the period (March to May). Analysis of the rainfall data for 25 years from 1971 to 2006, analysis was conducted for storm intensity and corresponding number of rainy days. Daily rainfall was categorized into storm groups of 2.5-15mm, 15-30mm, 30-45mm,45-60mm, 60-100mm and more than 100mm per day. Though the probable rainfall analysis does not indicate the feasibility for water harvesting on conventional guidelines, present storm intensity based analysis shows lot of runoff yielding potential. Safe disposalof excess water from fields is also essential as storms more than 100 mm per day scontribute to 20% of total rainfall. The assessment also indicated that storms of greater than 60 mm per day are common in every year and about 25 percent of rainfall is received through storms. Thus it can be concluded that rain water harvesting can play a significant role in overcoming the dry spells during the crop season and also provide supplemental irrigation with high percent of probability in every year for stabilising the crop yields.

Harvested water were utilised for irrigating tobacco nurseries, during 38-39 standard weeks (i.e. during 2004-05) for irrigating seedlings, as tender seedlings are sensitive to high salt containing groundwater. The N-E monsoon failed during 2004-05 crop seasons and no rains were received after 45th standard week. The stored rain water in farm ponds were utilised from 47th to 49th standard weeks as shown Fig. 3 and crop at farm received one life saving irrigation at (grand growth period is it standard terminology) critical stage in tobacco. Statistical relationships were established for the yields and their quality

Fig. 3 Harvested rainwater utilized for life saving irrigation to tobacco nursery and crop during the year 2004-05. (Water level in what pond no. 2)



Optimum depth of irrigation: The yields were improved in all the irrigation treatments when compared to control. Maximum yield was recorded with 40 mm (20+20) (36.3%) followed by 30 mm (15+15) in two splits (32.7%), followed by 40 mm in one application (31.4%), and 30 mm in one application (28.7%) when compared to no irrigation (control) for three years (Table. 1,2 and 3). A high response to irrigation was obtained due to severe drought (Anonymous, 2004) during the year 2004-05. The impact of supplemental irrigation was evident on quality of cured leaf and nicotine content decreased accompanied by improvement in reducing sugars. During 2004-05, a total precipitation of 717.1 mm was received from June to December in 35 rainy days with prolonged dry spells during August, November and December which is low compared to the normal rainfall i.e. 1146 mm in 49 rainy days. The amount of rainfall received during south-west monsoon was 293.4 in 20 rainy days. Continuous dry spell during August effected the growth of crop. Rainfall received during north-east monsoon was 423.7 mm in 17 rainy days. However most of the rainfall (302 mm) was received during October and only 121.6 mm received during November 1st week with practically no rain up to harvesting of FCV tobacco crop. This restricted the growth and yields of FCV tobacco. Supplemental irrigation from farm ponds with harvested rainwater improved the yields of FCV tobacco by 26 to 36.3%.

Table 1. Yield of FCV tobacco, economics and chemical quality parameters as influenced by irrigation levels in the year 2004-05

Treatment	Tobacco yield (t/ha)				Economics (Rs. t/ha x 10^3)			B:C ratio	Chemical quality parameters			
	Green leaf	Cured leaf	Bright leaf	Grade index	Cost of cultivation	Gross returns	Net returns		Nicotine (%)	Reducing sugars (%)	Reducing sugars: nicotine	Chlorides (%)
T1	6.858	1.110	0.474	0.849	31.50	46.62	15.12	1.48	2.65	10.47	3.95	0.27
T2	7.238	1.213	0.517	0.937	31.70	50.95	19.25	1.61	2.23	9.78	4.38	0.2
T3	7.254	1.250	0.517	0.954	32.10	52.50	20.40	1.64	2.68	9.79	3.65	0.33
T4	7.337	1.238	0.529	0.962	31.85	52.00	20.15	1.63	2.27	10.75	4.74	0.35
T5	7.664	1.283	0.548	0.990	32.25	53.89	21.64	1.67	2.36	9.04	3.83	0.31
T6	5.477	0.942	0.374	0.709	30.00	39.56	9.56	1.32	3.19	8.83	2.77	0.29
General Mean	6.971	1.173	0.493	0.900	31.57	49.25	17.69	1.56	2.56	9.78	3.82	0.3
SEM ±	0.024	0.007	0.003	0.005								
CD(P=0.05)	0.758	0.207	0.106	0.164								
CV (%)	5.98	9.7	11.82	10.04								

Table 2. Yield of FCV tobacco, economics and chemical quality parameters as influenced by irrigation levels in the year 2005-06

Treatment	Tobacco yield (t/ha)				Economics (Rs. t/ha x 10^3)			B:C ratio	Chemical quality parameters			
	Green leaf	Cured leaf	Bright leaf	Grade index	Cost of cultivation	Gross returns	Net returns		Nicotine (%)	Reducing sugars (%)	Reducing sugars: nicotine	Chlorides (%)
T1	6.7590	1.1640	0.6800	0.9730	36.50	51.80	15.30	1.42	2.19	12.47	5.68	0.30
T2	7.1440	1.2390	0.6880	1.0280	37.70	55.14	17.44	1.46	2.35	9.98	4.25	0.30
T3	7.4120	1.2720	0.7230	1.0760	37.10	56.60	19.50	1.53	2.22	11.52	5.20	0.29
T4	7.2290	1.2490	0.7010	1.0420	36.85	55.58	18.73	1.51	2.33	9.39	4.03	0.32
T5	7.5670	1.3180	0.7340	1.1020	37.25	58.65	21.40	1.57	2.58	12.10	4.69	0.32
T6	5.7910	1.0030	0.5720	0.8340	35.00	44.63	9.63	1.28	2.31	11.17	4.84	0.25
General Mean	6.9840	1.2080	0.6830	1.0090	31.57	53.76	22.19	1.70	2.33	11.10	4.76	0.30
SEM ±	0.0292	0.0044	0.0036	0.1139								
CD(P=0.05)	0.9186	0.1376	NS	0.1215								
CV (%)	7.24	8.26	9.2	8.62								

Table 3. Yield of FCV tobacco, economics and chemical quality parameters as influenced by irrigation levels in the year 2006-07

Treatment	Tobacco yield (t/ha)				Economics (Rs. t/ha x 10^3)			B:C ratio	Chemical quality parameters			
	Green leaf	Cured leaf	Bright leaf	Grade index	Cost of cultivation	Gross returns	Net returns		Nicotine (%)	Reducing sugars (%)	Reducing sugars: nicotine	Chlorides (%)
T1	7.072	1.045	0.467	0.834	40.50	62.70	22.20	1.55	2.19	12.47	5.68	0.30
T2	7.426	1.096	0.493	0.874	41.70	65.76	24.06	1.58	2.35	9.98	4.25	0.30
T3	7.71	1.119	0.518	0.888	41.10	67.14	26.04	1.63	2.22	11.52	5.20	0.29
T4	7.438	1.102	0.57	0.879	40.85	66.12	25.27	1.62	2.33	9.39	4.03	0.32
T5	7.981	1.142	0.533	0.909	41.25	68.52	27.27	1.66	2.58	12.10	4.69	0.32
T6	6.78	0.983	0.45	0.78	39.00	58.98	19.98	1.51	2.31	11.17	4.84	0.25
General Mean	7.401	1.081	0.495	0.861	31.57	64.86	33.29	2.05	2.33	11.10	4.76	0.30
SEM ±	0.4064	0.0497	0.0466	0.0521								
CD(P=0.05)	Ns	0.1565	Ns	Ns								
CV (%)	9.81	8.3	16.86	11.91								

Similar trends were recorded during 2005-06 season. Though there were also prolonged dry spells in this season, but total amount of precipitation is little higher than the preceding year 2004-05, which leads to a slight increase in green leaf under rainfed conditions. The general mean of other parameters like Cured leaf, bright leaf and grade index also increased may be due to the increase in seasonal rainfall. Considering least amount of supplemental irrigation as 40 mm. This is sufficient to give supplemental irrigation in 16.0 ha with the farm ponds created of 8630 m^3.

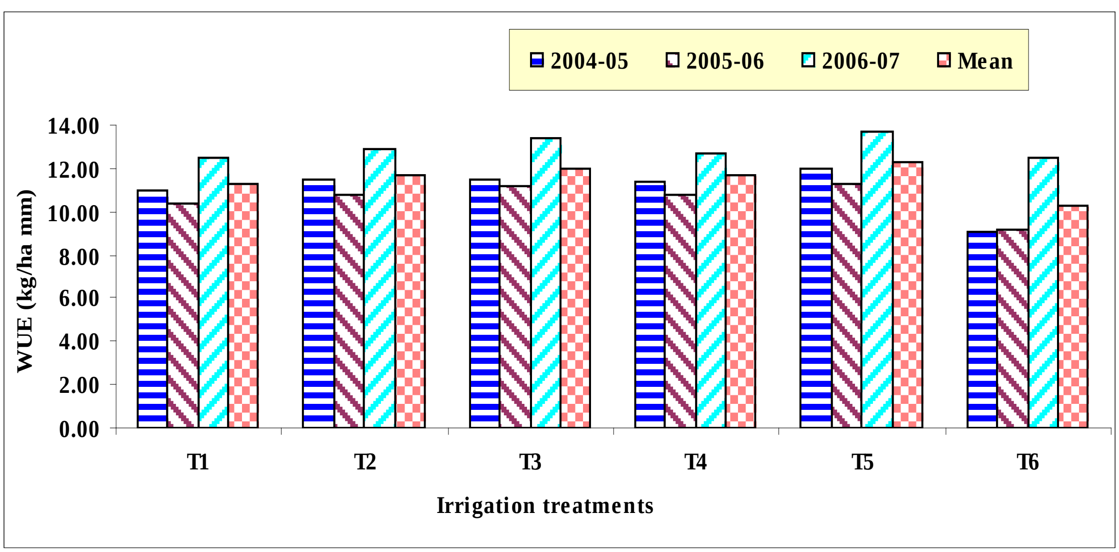
Leaf quality:

The chemical quality parameters of leaf like nicotine, reducing sugars, reducing sugars: nicotine and chlorides were with the acceptable range (**Table. 2,3 and 4**). Leaf chloride content was unaffected by irrigation levels. Usually leaf chlorides more than 2.0% are not preferred, because the leaf absorbs more moisture, becomes pale and slick, which adversely affects the burning quality of leaf. Nicotine (reducing sugars) for the season 2005-06 were slightly enhanced when compare to preceding season 2004-05, may be due to little higher seasonal precipitation but the differences were not discernible.

Water productivity:

Tobacco water productivity is estimated with the procedure described above for the supplemental irrigation experiment and is depicted in Fig 4. For the control treatment T6 ie. Without nay irrigation the lowest WUE was 7.64 kg/m^3 observed in the season 2005-06. While the highest WUE was 8.14 kg/m^3 in the season 2004-05. The mean WUE for the rainfed treatment T6 (control) was 7.89 kg/m^3. The corresponding lowest and highest WUE values for the irrigated treatments were 10.12 kg/m^3 for 40 mm irrigation in two splits of (20+20 mm) T5 in 2005-06 and 10.75 kg/m^3 in 2004-05. While the highest WUE was 10.44 kg/m^3. The water use efficiency is relatively less in the season 2005-06 compare to the preceding may be due to the slightly higher precipitation. In rainfed a condition, the optimum quantity of supplemental irrigation which enhances water productivity is essential to increases the farmer income, more area brought under cultivation.

Fig. 4 Effect of irrigation levels on water productivity.



Economics of water harvesting and supplemental irrigation:

The economics of one life saving irrigation was found to be quite favourable and the additional net return was Rs.7890/- per ha, due to improved grade index (203 kg/ha) @ Rs.43.3/kg of average price after deducting the cost of irrigation of Rs.900. There is a possibility of recovering the cost of pond Rs. 22,000/- (digging, shaping and transport of soil) in three to four years. Many water harvesting and supplemental irrigation systems have failed, despite good techniques and design, because the social, economic and management factors were inadequately integrated in to the development of the system (Bazza and Tayaa 1994). The success of Water harvesting and supplemental irrigation technology depends on the acceptance of the farmers (resource users). The chances are for successes are much greater if they are involved from the early planning stages onwards. The evaluation of a rain water harvesting system has shown that integrated farming approach of utilizing the system enhances the economics of the system, like horticulture crops on embankment of farm ponds, fish culture in stored water and duckery rearing etc.,(R.C Srivastava et.al., 2004)

4. Conclusion

A holistic methdolgy was developed for water resource management for tobacco cropping system in southern light soils of AP to overcome the problemsof waterlogging and long dryspells. The key interventions include waterways for safe disposal of excess rainfall to farm ponds/defunct wells and supplemental irrigation with this harvested water. Rainwater harvesting and supplemental irrigation technology holds a promise and can be extended to the farmers in a participatory mode for southern light soil areas, prone to drought and cyclones especially in areas where ground water is not fit for irrigation of FCV tobacco with funding from watershed program otr by Tobacco Board. Maximum yields and quality of FCV tobacco was recorded with 40 mm supplemental irrigation in two splits (36.3%) followed by 30 mm in two times (32.7%) followed by 40 mm in one application (31.4%), when compared to no irrigation (control). This output will serve as an input to the on going drought prone area programme (DPAP) and national watershed development programme for rainfed area (NWDPRA) and other programmes.

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