COMMUNITY BASED CLIMATE RISK MANAGEMENT THROUGH WATERSHED DEVELOPMENT

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This e-book is a compilation of resource text obtained from various subject experts for MANAGE – ICAR-IISWC, Udagamandalam collaborative training program on "Community based climate risk management through watershed development" Conducted during 2-4 May, 2022. This e-book is designed for researchers, academicians, extension workers, research scholars and students engaged in Natural Resource Management, Watershed Management, Horticulture, Dry Land Agriculture, etc. Neither the publisher nor the contributors, authors and editors assume any liability for any damage or injury to persons or property from any use of methods, instructions, or ideas contained in the e-book.

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PREFACE

This e-book is an outcome of collaborative online training program on "Community based climate risk management through watershed development" held from 02-04, May 2022. This is intended to sensitize and strengthen the scientists various research organizations, faculty of Agricultural universities, SAMETIs and NGOs, senior and middle level extension functionaries from the department of agriculture, IWMP, Irrigation and other line departments working in the field of irrigation and watershed management etc. It is an effort made to link the community based watershed management programmes in view of changing climate scenario with risk management strategies and effective mitigation measures. Furthermore, this e-book will update their knowledge regarding recent advances in technologies and innovations in the domain of watershed management.

The chapters in the e-book discuss about the community based watershed management, different climate risks and their mitigation strategies, climate smart practices through natural resource conservation & management in a watershed approach. It covers Climate change aspects, climate risks and mitigation strategies Watershed planning, implementation and evaluation, Community based watershed management, Tools & techniques in climate risk management, Climate smart agriculture practices , Natural resource conservation & ecosystem services, Water harvesting and utilization, Socio-economic aspects of watershed and institutions, Integrated farming system, diversification, alternate land uses & livelihood security, Carbon sequestration, trade-offs in economic, societal benefits & Institutions involved along with some case studies/success stories of watershed projects/programmes.

The experts and resource persons in the field of soil & water conservation and watershed management have contributed immensely and tirelessly to develop various chapters of this e-book in very short span of time. The editors extend their sincere thanks to all the experts who have contributed valuable time and put sincere efforts to produce this e-book. The editors also thank MANAGE, Hyderabad for the financial support to the training program. The editors express gratitude towards the director, ICAR-IISWC for the constant encouragement for this training and e-book creation for the participants. The editors hope that this e-book will help participants as well as other officers and extension people working in the domain across the country to gain valuable information and updates.

October, 2022 Editors

Foreword

Natural resource management is important for sustaining human life, livelihood and environment. Soil erosion due to water is the most dominant forms of land degradation causing loss of soil nutrients, reduction in crop production, increasing recurrence of extreme weather events and loss of biodiversity besides C-emission problems. Depleting water resources with erratic rainfall pattern is causing serious challenges to country's food security and environmental quality.
Awareness creation and capacity building of SHGs and local institutions to protect and sustain the use of natural resources is paramount important for sustainable agricultural development. Watershed development is a holistic approach through which the interventions such as advanced soil and water conservation technologies, climate smart practices and integrated watershed management approach with suitable climate change mitigation strategies can be taken up for the benefit of local communities which will be the true efforts made to achieve the targets of various Sustainable Development Goals (SDGs).

In this context, ICAR-Indian Institute of Soil and Water Conservation (IISWC), a premier institute in conducting research and extension in soil and water conservation technologies organized a 3 days online collaborative training programme sponsored by MANAGE, Hyderabad from 02-04, May 2022 on "Community Based Climate Risk Management through Watershed Development" at IISWC Research centre Ooty, Tamil Nadu. This training for scientists from ICAR and KVKs and other research organizations, faculty of Agricultural universities, SAMETIs and NGOs working in the field of agriculture and watershed management etc., Senior and middle level extension functionaries from the department of agriculture, IWMP, Irrigation and other line departments mainly aimed to strengthen them by providing the insight on community based watershed management, different climate risks and their mitigation strategies, climate smart practices through natural resource conservation & management in a watershed approach.

I congratulate MANAGE and ICAR- IISWC, Research Centre, Udhagamandalam for their fruitful collaboration towards benefit to farming community, and other stake holders in the sector. I also congratulatethe entire team behind organizing the training programme for their untiring work. I am pleased to note that the deliberations are published as an e-book compilation for the benefit of the participants and other stakeholders across the country. I wish the training a grand success.

Dr. M. Madhu
Director, ICAR-IISWC

Contents

Chapter 1

Soil and Water Conservation Strategies for Sustainable Agriculture in Changing Climate Scenario

M. Madhu

Director, ICAR-Indian Institute of Soil and Water Conservation (IISWC), Dehradun

Introduction

The status of global soil resources published by FAO, 2015 highlights that 'the majority of the world's soil resources are in only fair, poor, or very poor condition'. The report stresses that, soil erosion is still a major threat to ecosystem stability and agricultural productivity, worldwide. Anthropogenic factors such as unsuitable land use practices in modern agriculture, deforestation and overgrazing are some of the causes that trigger the soil erosion thus lead to cascading effects such as nutrient loss, loss of carbon stock and declining biodiversity. More intense hydrological cycles and extreme rainfall events induced by the changing climate are potentially accelerating the erosion rates. Climate change most likely to increase the soil erosion and sediment yield rate by changing the rainfall–runoff erosivity. The extreme rainfall events and continuously changing precipitation patterns are accelerating the rainfall-runoff erosivity and thereby impacts the soil erosion process (Bayramov *et al.*, 2019; Talchabhadel *et al.*, 2020).

Soil carbon stock is an important soil fertility component needed to sustain the agricultural production and also regulates the global carbon cycle by controlling the atmospheric CO_2. Soil erosion is a major hazard which is directly affected by the rainfall change caused by the climate change. Accelerated soil erosion as a result of change in the rainfall pattern also depletes the soil organic carbon. Kannan *et al.* (2019) reported that clay loss and organic carbon loss were 4.9 t/ha and 185 kg/ha at 28% slope in Nilgiri hills and these losses resulted in severe productivity loss in cabbage crop. Mondal *et al.* (2016) made an attempt to quantify the impact of climate change on future soil erosion and soil organic carbon under different slope and land use categories in Narmada river basin in India. Least square support vector machine method using Hadley Center coupled model version 3 was used to estimate the future rainfall and reported that, sediment load has changed by 5.33, 17.97 and 58.37% in the 2020s, 2050s and 2080s, respectively from the current erosion rate. Similarly, future rainfall data was generated by Khare *et al.* (2016) with the downscaling of global circulation model data to study the climate change impact on soil erosion in the Mandakini river basin, India. The results have clearly showed that, future soil erosion will be increased due to the increasing rainfall intensity due to the extreme weather events.

Besides, climate change not only impacts the soil erosion rate but also changes the sediment yield pattern in the major river basin of the world which has strong negative consequences on river flow as well as the reservoir storage capacity (Chen *et al.,* 2013; Bussi *et al.,* 2014). Amanambu *et al.* (2019) studied the spatio-temporal variation in rainfall-runoff erosivity resulting from changes in rainfall characteristics induced by climate change in tropical areas of West Africa. The study quantified the nature of spatio-temporal variability of erosivity from rainfall amount using the global circulation models. The study reported the increasing trend in the rainfall-runoff erosivity from the baseline climate, with an average change in rainfall-runoff erosivity of about 14.1%, 19%, and 24.2% for the 2030s, 2050s, and 2070s, respectively. There was an associated increase in soil loss of 12.2%, 19.3% and 20.6% from the baseline for the 2030s, 2050s, and 2070s, respectively.

Many studies have clearly indicated that, significant loss in crop productivity due to the soil erosion. Moreover, loss of the fertile top soil can have considerable impact on nutrient availability; soil water availability and plant growth properties. In a predominantly agricultural system, the objective of improving the productivity, profitability and prosperity of the farmers and achieving agricultural development on an ecologically sustainable basis can be attained only when conservation of the natural resources are assured. Soil erosion control is a pre requisite to achieve the agricultural sustainability in a climate change scenario. Soil erosion can be mitigated using sustainable land management techniques based on the engineering, agronomic, biological and scientific land management practices.

Soil and Water Conservation Strategies

The losses caused by extreme climatic events like high intensity rainfall, drought degradation of soil quality can be minimized if appropriate soil and water conservation measures are adopted. In rainfed farming, information on rainfall pattern and moisture deficits over time is very helpful in crop planning, rainwater management and other hydrological studies related to agriculture.

A. Agronomical Measures for Arable land

Biological or vegetative measures are preferred in soil and water conservation programmes as they are eco-friendly, sustainable and cost effective (Sharda *et al.,* 2006) These area measures are normally adopted on land having mild slope, less runoff and sediment flow. These can be adopted singly or in combination with mechanical measures depending upon the intensity of soil erosion.

1.0 Tillage

Land and water are closely interconnected and consequently they influence land productivity, therefore, land management techniques that encourage more rainfall to enter the soil are key strategies for improving productivity of rain-fed systems. Climate change scenarios predict an increase in the intensity and frequency of droughts in many cropping regions of the world (Olesen *et al.,* 2011). Deep tillage might be a tool to make crops more resilient to climate change and mitigate yield losses caused by droughts. The soil moisture content in the root zone during the crop growing period in these regions appreciably affects crop growth, development and the overall land productivity especially in semi arid regions. Tillage roughens the soil surface and breaks any soil crust. This leads to increased water storage by increased infiltration (Ali and Talukder, 2008). However, response to tillage varies with rainfall, soil type and kind of crops. The crops like maize, pigeon pea, cotton, castor, soybean and sunflower respond very favorably to deep tillage.

Table 1 Soil moisture, infiltration, sorghum yield and WUE influenced by tillage

Tillage practices	Soil moisture(mm /60 cm depth) at the time of sowing	Infiltration (cm/hr)	Sorghum grain yield (kg/ha)	WUE (kg/ha/mm)
Conventional tillage	278	9.0	433	2.21
Reduced tillage	210	8.2	388	2.0
Less tillage	195	7.4	343	1.87

Source: Patil *et al.* (2016)

Sharda *et al.* (2006) reported that deep tillage has a definite edge over shallow tillage in improving the yields of different dry land crops in the red soils also in southern India irrespective of type of season.

2.0 Land Configuration

Management of rainwater, especially *in situ* conservation, is an important component of resource conservation practices for augmenting crop productivity in slopy dry land conditions..Few of the land on figurations *viz.*, contour farming, land smoothening, dead furrows, compartmental bund broad bed furrow and raised and sunken bed system that are very effective in-situ rainwater-conservation measures, particularly in low-rainfall areas are discussed below.

2.1 Contour cultivation or cultivation across slope

Contour farming is an effective and low-cost method of controlling erosion, conserving moisture and improving crop yields. The purpose of contour farming is to reduce runoff and soil erosion on mild slopes. This practice can also increase crop yield through the soil moisture retention in arid and semiarid regions. Generally, the common method of cultivation on sloping land is along the slope and it cause poor rainfall infiltration and accelerates soil erosion. Carrying out all the field operations including sowing of crops across the slope and along contour (contour cultivation) provides a series of miniature barriers to running rainwater and reduces runoff, soil loss and increases soil water and nutrient storage in soil profile. Contour cultivation is recommended for all types of soils, rainfall up to 1,000 mm and slope varying from 0.5 to 4%. It helps in reduction of runoff by impounding rain water in small depressions and reduces the development of rills. In practice it is often difficult to establish all crop rows on the true contour because of non-uniform slopes in most of the fields under Indian situations. The effectiveness of this practice varies with rainfall, soil type and topography. Maximum effectiveness of this practice is on medium slopes and on permeable soil. The relative effectiveness decreases as the land grade becomes very flat or very steep. On long slopes, where bunding is done to decrease the slope length, the bunds can act as guidelines for contour cultivation. On the mild slopes where bunding is not necessary, contour guidelines may be marked in the field. On undulating fields having number of depressions and ridges, contour cultivation is likely to be difficult. Land smoothing is needed to fill up such depressions. Contour cultivation on steep slopes or under conditions of high-rainfall intensity may cause formation of gullies because row breaks may release the stored runoff water to next downstream row. The benefit of contour farming in increasing crop yield and environmental benefit is given in the table 2.

Table 2 Benefits of contour farming

Authors	Activity/soil	Benefit
Mourad and Joseph (2018)	Contour farming with vegetative strips in Alfisols	Reduction in sediment yield by 63%
Farahani *et al.* (2016)	Cntour farming clay soils	10% reduction in runoff and 49% reduction in soil loss
Seten *et al.* (2009)	Contour farming in clay soil	72% reduction in runoff
Ramajaneyalu *et al.* (2020)	Contour farming with inter crop in rainfed alfisol	Higher soil moisture and maize equivalent yield
Krisnappa *et al.* (1994)	Contour farming inn Alfisols	25% & 28% higher yield in finger millet and groundnut receptively
Ramamohan Rao *et al.* (2000)	Contour farming in Vertisol	68% to 85% higher yield in winter sorghum across varies slopes
Sharda *et al.* (2006)	Contour farming and inter crop + green gram	Increased yield of crops by 15.4% to 26% and reduced soil loss by 17.6% to 25%
Kannan and Madhu (2013)	Ridges and furrows on contour	Increased infiltration, reduced soil loss by 30% and potato equivalent yield by 8%

2.2 Compartmental bunding

Compartmental bunds convert the area square/rectangular compartment to impound rainwater. These are practices in medium and black soil area to store rainwater in the soil profile during monsoon for the use of rabi crop. Compartmental bunds provide greater opportunity, time for rainwater to infiltrate into the soil and wet the soil profile completely for early sowing of winter crops thus giving greater crop yields. The size of the compartmental bunding varies with slope and slope of the field. Compartments of 6m x 6 m upto 1% slope; 4.5 m x 4.5 m for 1-2% slope, and 3m x 3m for 2% slopes are recommended (Sharda *et al.*, 2006).

2.3 Ridges and furrows

Formation of fridges and furrows has been found most suitable for soil moisture conservation and to reduced runoff and soil loss, particularly in light soils. Open the furrows at 50 to 60 cm apart across the slope in medium to deep black soils, after completion of primary tillage, during the second fortnight of June to lay out the field into ridges and furrows. This can be done through a ridger/plough attached to either tractor or bullocks. Cultivation of crops under ridge- and furrow-system across the major land slope with a gradient of 0.2 to 0.4% in land having 1 to 3% slope will conserve more rainwater in situ. This is suitable for widely spaced crops with 60 cm or more row spacing. A field length of 60 to 90 m is optimum for cultivation of crops with ridges and furrows.

2.4 Broad-bed furrow system

The ridges and BBF developed by the International Crops Research Institute for semi-arid tropics (ICRISAT, India) for increasing the productivity of semi-arid poorly drained Vertisols, provide more opportunity for infiltration of rainwater and at the same time prevent water logging of the crop growing on the bed. The BBF system consists of a relatively raised flat bed or ridge approximately 95 cm wide and shallow furrow about 55 cm wide and 15 cm deep across the slope on a grade of 0.2 to 0.6% for optimum performance. The bed width also depends on the crops, soil type, and rainfall. The furrow act as drainage for removing excess water and broad bed stores rainwater. In block soil crops are sown in pre-formed beds made before the season and maintained year after year. This will save considerable cost as well as improve the soil health. This is suitable for narrow-spaced row crops. Even if a few rows are lost due to the furrow, the yields are made up owing to better in-situ rainwater conservation. There is no water stagnation in the bedding system. Hence this system acts both as disposal system during high intensity rains and as a conservation measure during low rainfall situations (Pathak *et al.*, 2009).

2.5 Conservation furrow system

The conservation furrow is a simple and low cost in-situ soil- and rainwater-conservation practice adopted in Alfisols and associated soils with problems of crusting and sealing for rainfed areas (400–900 mm rainfall) with moderate slope varying from 1 to 4%. Due to crusting early runoff is quite common in these soils. Furrows at 3–5 m apart on contour or across slope are opened either during planting or during intercultural operation using country plough in this system. These furrows harvest the local runoff water and improve the soil moisture in the adjoining crop rows, particularly during the period of water stress. The practice has been found to increase the crop yields by 10–25%.

2.6 Zingg terracing

Zingg terracing is adopted in low- to medium-rainfall areas in Vertisols with contour/ graded bunds. In Zing terrace nearly 30% of the area in the upstream side of the bund is levelled, so that in this levelled area assured crop yields are realized even during drought years. This is done by cutting 15 cm soil and putting it all near the bund to make flat land for 30% of the area in the upstream side of the bunds. Lower one-third portion of inter-bunded area is levelled to spread the runoff water in a large area. Usually water-intensive crops are cultivated in the levelled portion (receiving area), while dry crops are cultivated in the unlevelled (donor) area. In the levelled one-third portions, normal crop can be harvested even during severe drought year and it is possible to cultivate two crops during a normal year. This will increase both cropping intensity and crop yields in the region.

3.0 Mulching and Residue Management

3.1 Organic mulch

Mulching is the process of covering the soil between crops rows with the layer of crop residues, manures and other litter to reduce evaporation, increase infiltration, reduce runoff and control weeds. Mulches dissipate the kinetic energy of the rain drops, prevent soil erosion (splash erosion), facilitate infiltration, soil temperature regulation, improve the water-holding capacity of the soil. As a result, supplemental water demand of the crops is reduced. Mulching is a useful practice for controlling erosion, weed growth and conserve moisture as well as nutrient in the soil in rainfed hilly region (Sharma *et al.,* 2010). Application of mulch found to influence the soil physical characters positively. Kukman Nagaya Mulumba and Ratan Lal (2008) found that mulch rates significantly increased available water capacity by 18–35%, total porosity by 35–46% and soil moisture retention at low suctions from 29 to 70%. Chakraborty *et al.* (2010) reported that organic mulching using rice husk increased moisture (3%), produced more roots (25 and 40% higher root weight and root length densities compared to no-mulch) , increased wheat grain yield (13-21%) and water use efficiency by 25% in semi-arid environment. Wheat straw mulch(30 cm) application in maize crop significantly influenced soil properties, soil organic carbon (SOC), available nitrogen, available phosphorus, total nitrogen, total phosphorus, and soil water content and maize grain yield (7%) and water use efficiency (8%) and enzyme activity (Kashif Akhtar *et al.*, 2018). Further through organic mulching and residue incorporation the biomass is returned to the soil which help in organic carbon build up in the soil. More importantly, mulching improves the burrowing activities of earthworms and improves air-moisture balance in the soil. Besides improving soil physical properties, like better drainage in clayey soil, mulches improves soil micro-nutrients and microbial population. Further, the effect of mulch on soil prosperities and yield is enhanced when it is combined with conservation tillage.

3.2 Vertical mulch and live mulch

Vertical mulching involves opening trenches of 30 cm depth and 15 cm width across the slope at vertical intervals of 30 cm and stuffing sorghum stubbles vertically in these trenches, so that they protrude 10 cm above the ground. Vertical mulches of sorghum act as intake points and guide runoff water into subsoil layers thus, increases profile soil moisture and increased winter sorghum yields to a greater extent in a dry/drought year compared to wet/normal or above normal rainfall years. This technique in medium to deep stiff and clayey soils increased sorghum yield varying from 26 to 78% respectively. (Ramamohan Rao *et al.*, 1978).

Live mulch is a cover crop, preferably leguminous crop inter planted or under sown with a main crop, to serve the purposes of a mulch, such as weed suppression and regulation of soil temperature and other environmental benefits. The concept of live mulching is based on mixed cropping whereby fast growing legume is established before or simultaneously along with widely spaced season grain crops and returned to the soil at an appropriate stage. In an experiment conducted at Dehradun, sunhemp (*Crotalaria juncea* L.), dhaincha (*Sesbania aculeata* Pers.) and cowpea (*Vigna unguiculata* L.) as a live mulch in maize-wheat cropping system.

3.3 Plastic mulch

Plastic mulching is the process or practice of covering the soil/ground with plastic sheets of varying colours and thickness, with an objective to provide more favourable conditions for plant growth, development and efficient crop production. Plastic film mulching plays an important role in agriculture owing to its ability to improve grain crop yields and water use efficiency (WUE) by maintaining soil moisture, suppressing weeds and increasing soil temperature. Plastic mulches directly affect the microclimate around the plant by modifying the radiation budget of the surface and decreasing the soil water loss (Liakatas *et al.,* 1986). The colour of plastic-film mulch largely determines its energy-radiating behavior and its influence on the microclimate around a plan. Black plastic mulch, the predominant colour used in crop production, is an opaque black body absorber and radiator. The efficiency with which black mulch increases soil temperature can be improved by optimizing the condition for transferring heat from the mulch to the soil. Earlier harvest, reduced evaporation, fewer weed problems, reduced fertilizer leaching, soil compaction, elimination of root pruning, increased crop growth, and reduced drowning of crops were the advantages of the use of plastic mulches for vegetable production which is reported by the several authors. To overcome negative environmental problems caused by persistent plastic waste from Plastic mulch, biodegradable plastic mulches(BDM) have been developed as a promising alternative to Plastic films, providing a sustainable and environmentally friendly solution for agricultural activities. Biodegradable plastic mulch use is on the rise as it provides many of the benefits of PE mulch with the advantage of being tilled in or composted at the end of the season, avoiding the disposal problems of plastic mulch.

4.0 Conservation Agriculture

Conservation Agriculture(CA), comprising minimum mechanical soil disturbance and direct seeding, organic mulch cover from residues and cover crops, and crop species diversification through rotations and associations, is now practiced globally on about 125 M ha and worldwide. The technologies of CA provide opportunities to reduce the cost of production, save water and nutrients, increase yields, increase crop diversification, improve efficient use of resources, reduce runoff and soil loss and benefit the environment (Suraj Bhan and Behera, 2014). In India, CA adoption is still in the initial phases. Over the past few years, adoption of zero tillage and CA has expanded to cover about 1.5 million hectares (Jat *et al.,* 2012). The major CA based technologies being adopted is zero-till (ZT) wheat in the rice-wheat (RW) system of the Indo-Gangetic plains (IGP). In other crops and cropping systems, the conventional agriculture-based crop management systems are gradually undergoing a paradigm shift from intensive tillage to reduced/zero-tillage operations (Suraj Bhan and Behera, 2014).

Table 5 Benefits of conservation agriculture

Conservation agricultural practice	Author	Environmental benefit	Crop yield
No tillage with mulch	ZiyouSu et al(2007)	Increased soil moisture content	9% increase in rainfed wheat
No tillage with crop residue	Rafael et al(2021)	Reduction in soil loss by 58%	12% increase in Maize yield
zero till and residue retention	Govaert et al(2009)	After 15 years of practicing, im- proved the dry aggregate size distribution	
Reduced tillage and residue incorporation	Somasundaram et al.(2019)	Conservation agriculture increased % of water stable aggregates , SOC	Higher soybean yield under CA
Zero tillage direct seeded rice followed by zero tillage direct seeded maize+residue retention	Singh eta al.(2016)	Higher SOC content(27%), aggregates, root mass density	Higher maize yield
No-till rised bed with residue retention	Yadav et al.(2018)	Higher soil moisture content (17%)maize root mass density	higher yield of maize
Reduced tillage and residue retention	Anup Das et al. (2018)	Higher SOC(18%), soil microbial biomass carbon (SMBC) and dehydrogenase activity (DHA), and soil NPK	Higher pea(26%) and rapeseed(70%) yield

5.0 Cover Crops

Cover crops have been defined as crops grown to protect the soil from erosion losses and losses of nutrients via leaching and runoff. This definition was expanded in the *Encyclopedia of Soil Sciences* to those crops that are grown for improving soil, air, and water conservation and quality; nutrient scavenging, cycling and management; increasing populations of beneficial insects in integrated pest management; and/or for short-term (e.g., over-winter) animal-cropping grazing systems. Cover crops provide multiple benefits for erosion and runoff control, soil quality enhancement, nutrient scavenging, and pest suppression. Cover crops reduce sediment production from cropland by intercepting the kinetic energy of rainfall and by reducing the amount and velocity of runoff. Cover crops increase soil quality by improving biological, chemical and physical properties including: OC content, CEC, aggregate stability, and water infiltrability. Several researchers have reported the benefits of cover crops to *reduce sediment off-site transport* (Dabney, 1998; Delgado *et al.*, 1999). McFarlane *et al.*, (1991) reported that the cover crops of oats greatly reduced both sheet and rill erosion on post-harvest plots of potato. Additionally, several studies have reported the impacts of cover crops on *increasing nutrient use efficiencies and C sequestration* (Little *et al.*, 2004; Edgar *et al.*, 2009).

8.0 Vegetative Barrier

Vegetative barrier, also known as live bunds are closely spaced plantations usually of a few rows of grasses or shrubs grown along the contour for erosion control in agricultural fields. These vegetative barriers not only help in resource conservation, but also provide much needed biomass to meet the needs of rural communities. In higher slopes it can be combined small bunds for improving its effectives. Vegetative barriers technology is highly beneficial for marginal and small farmers since it is cost effective and easier to establish. In India, Different vegetative barriers have been identified for various agro-ecological regions and different soil (Sharda *et al.*, 2006). *Saccharum* spp. for alfisol of Orissa and Shivwaliks, *Cenchrus ciliaris* in dry vertisols, *Pennisetum hohenackeri* in dry Alfisols, *Pennisetum maximum* in the sub-humid lower wester Himalayas, *Panicum antidotale* and *Pennisetum polystachyon* for North Eastern Region were identified as effective or vegetative barrier. In an experiment conducted at Dehradun under rainfed condition, planting two rows of grass (*Cymbopogon martini*) at one meter vertical interval in 2% slope reduced runoff, soil loss and increased soil moisture availability and yields of maize-wheat cropping system (Gosh *et al.*, 2015).

9.0 Geo-textiles

Geo-textiles are woven nets of fibre made from jute, coir or any other natural fibre used in soil conservation or any other soil related constrains in crop production. Several studies reported the benefits of geo-textiles in river bank protection and slope stabilization. The benefit of geo-textiles in field crop production and soil conservation also reported by few writers. Adhikari and Shankar (2018) reported that application of jute geo textiles increased rainfed groundnut yield by 64.2% and soil organic matter by 53% under rainfed condition n West

Bengal, India. Field experiment conducted at Dehradun, on a 4% land slope in the Indian Himalayan Region (IHR) revealed that Agro Geo Textiles (AGT) prepared from giant-cane (*Arundo donax*) placed at 1 m vertical intervals recorded the highest ($p<0.05$) maize grain yield (2.8 Mg ha-1), which was 36% higher than maize crops raised without AGT (conservation agriculture only). This treatment also reduced runoff (24%) and conserved soil losses (8.22 t ha-1 year -1. Productivities of succeeding pea (*Pisum sativum var. hortense*) and wheat (*Triticum aestivum* L. emend Fiori & Paol.) crops were enhanced by 122 and 36%, respectively (Raman Jeet Singh *et al.*, 2019). Manivann et al.(2018) reported that that 700 GSM open weave JGT proved to be more effective in reducing runoff, soil and nutrient loss and increased soil moisture retention capacity of the soil

B. Soil and Water Conservation Measures at Terrace level

1.0 Contour Bund and Graded Bunds

Field bunding across the slope retains run-off in the cultivated field and facilitates its infiltration. Contour bunds are laid across the major land slope along the contour lines in the areas having 1.5 to 6% land slope and having less than 600 mm annual rainfall. The minimum height of contour bund is 50 cm with a cross section of 1.61 m2 having a vertical interval of 0.9 m and the horizontal interval between the bunds may vary from 50 to 70 m depending on the land slope. Bunds are stabilized in 2 to 3 years by growing local grasses on them and are particularly recommended for red soils. The surplus runoff is safely disposed through waste weirs. The graded bunds are constructed with a longitudinal grade of 0.2 to 0.4%, having a vertical interval of 0.75 m to divert the runoff from the fields. The cross-section area of the bund is 0.83 m2 and the horizontal distance is 60 to 70 m. These bunds are more suitable for black soils with greater water logging in the periods of intense rainfall. With adequate vegetation the height of the bunds can be reduced to 50 cm. These bunds are recommended for the soils having less than 6% land slope. The graded bunds are connected to the water ways or water-harvesting structures with waste weirs. In an experiment conducted at loamy soil of semi-arid region of Rajasthan, field bunding significantly increased mean mustard seed yield by 14.4% and biological yield by 15.3% over no bunding because of increased availability of soil moisture. Water-use efficiency also increased by 9.7 kg/ha-mm (Regar *et al.*, 2007). However, contour bunding is not always successful. Prolonged water stagnation near the bunds usually damages crops and prohibits timely cultural operations. Loss of productive land and frequent breaking of bunds have also been reported from some areas, particularly those on clay soils.

2.0 Bench Terracing

Bench terracing is widely practiced soil conservation measures in hilly areas having high degree of slopes. It comprises of transforming original steep land into series of level strips supported by risers. It breaks the length of slopes and reduces the degree of slopes as well thereby conserving moisture and soil for better crop production (Sharda *et al.*, 2006). Though it is recommended for 16 to 33% slope, bench terracing is being practiced up to 50% slope in Nilgiri and Himalayan hills owing to socio economic condition. Bench terraces may be outward sloping, levelled or inward slopping based on crops grown, rainfall and soil. Levelled or table top bench terrace is recommended for medium rainfall region with highly permeable deep soil. Inward sloping bench terracing is more effective in high rainfall are for vegetable crops which require good drainage and susceptible to water stagnation. High rainfall region like Nilgiri hills inward bench terracing with 2.5% and 1% longitudinal gradient is recommended for sae disposal of water.

3.0 Puertorican Terraces: Formation of bench terrace by conventional half cut and half fill method is expensive and if proper soil depth surveys are not conducted will result in exposure of sub-soil leading to reduced crop yields, in addition to the per cent area lost under risers which is equal to the per cent slope of land for 1.1 batter. To overcome these undesirable effects, studies on different types of terraces were conducted at ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Udhagamandalam to evolve a cheaper and effective method of developing bench terraces. It was found that Puertorican terrace with vegetative barriers using Guatemala grass (*Tripsacum laxum*) and Hybrid Napier reduced the cost of construction to one sixth and one third of the cost involved in the traditional method (Padmanabhan *et al*., 1988). Mixed vegetative barrier of two rows of pineapple and one row of Guatemala grass downstream at 1.0 and 1.5 m vertical interval also was successful in the formation of terraces at Gudalur. This technology is cheaper, easy to adopt, economical and eco-friendly. In the Western Ghats region, where majority of the cultivated area is highly sloping and the cultivation of annual crops and vegetable is underway in large areas, this technology is most appropriate in terms of both sustainable production and natural resource management. Vegetative barrier can be established with locally and economically suitable plants and additional income can be obtained from this also. Thus this technology can create revolution in the area of Natural Resource Management. The recommended soil and moisture conservation measures based on rainfall is given in Table 12.

Table 12 Recommended soil and moisture-conservation measures for different rainfall zones in India

Seasonal rainfall (mm)			
<500	**500-750**	**750-1000**	**>1000**
Contour cultivation	Contour cultivation	BBF (vertisols)	BBF (vertisols)
Conservation/ dead furrows	Conservation furrows	Conservation furrows	Field bunds
Ridges and furrows	Ridging	Sowing across slope	Vegetative barriers
Sowing across slope	Sowing across slope	Tillage	Graded bunds
Mulching	Vegetative barriers	Vegetative barriers	Vegetative bunds
Scoops	Scoops	Small basins	Chos
Compartmental bunding	Tied ridges	Vegetative bunds	Level terrace
Graded border strips	Mulching	Field bunds	
Tied ridges	Zing terrace	Graded bunds	
Off-season tillage	Off-season tillage	Nadi	
Inter-row water harvesting system	BBF	Zingg terrace	
Small basins	Inter-row water harvesting system		
Contour bunds	Small basins		
Field bunds	Modified contour bunds		
Khadin	Field bunds		
Graded bunds	Graded bunds		

C. Water Harvesting and Recycling for Climate Resilient Agriculture

Rainwater management is one of the critical components in rainfed farming and the successful crop production depends on *insitu* moisture conservation, surplus runoff water collection, storage and recycling (Rao *et al.*, 2017). Further, the importance of rainwater harvesting for agriculture is now more urgent with increased climatic variability and higher frequency of extreme weather events (Rao *et al.*, 2009; IPCC, 2014). Extremes, untimely and high intensity rainfall experienced in recent years are likely to continue and cause surplus runoff. There is a scope for utilize this surplus runoff water through storage structure for supplementary irrigation in semi arid region and increase the cropping intensity in high rainfall region. Over the recent decades, interventions around rainwater harvesting have been an important component of rural and agricultural development programmes in India and many water harvesting structures were created with the public funding from schemes like Mahatma Gandhi National Rural Employment Guarantee Scheme (MNREGS), Integrated Watershed Management Programme (IWMP), National Agricultural Development Programme (RKVY) and National Horticultural Mission (NHM) and Pradhan Mantri Krishi Sinchai Yojana (PMKSY). High rainfall variability (AICRPDA, 1991-2011) in the selected seven study districts further makes an important case for rainwater harvesting for agriculture. Research institutions have worked on designing efficient rainwater harvesting structures for different rainfall regions and soil types, effective storage of harvested water and methods for its efficient use in the Indian context (Kumar *et al.,* 2011).

Although rainfall in high rainfall regions is sufficient to meet the water demand of crops, its spatial and temporal distribution makes rainfed farming a risky proposition. Water harvesting can reduce the risk substantially by facilitating early planting by taking maximum advantage of the rainfall, thereby insuring the crop against rainfall aberrations. The proper design of a water harvesting system in a high rainfall region should take into account the spatial and temporal behavior of rainfall, water requirement of the crops, in addition to catchment characteristics.

D. Agro Forestry Systems for Resource Conservation

The extreme weather events occurred due the climate change impact during the last decade caused an enormous negative impact on agriculture in addition to the existing problems like water scarcity/stress, depletion of soil health and crop productivity stagnation. Traditional adaptations and management practice, such as agroforestry systems, may potentially offer options for improving farmer adapting to climate change through synchronised production of wood, food and fodder as well as moderation of the impact of climate change. The historical studies on agroforestry showed that, practice of agroforestry system (AFS) can maintain / improve the crop and land productivity level during the extreme weather events while sustaining soil health and maintaining ecological balance. Trees in the agriculture lands have multifunctional role like biodiversity and natural resource conservation, and these systems require less input and provide a more stable and diversified income due to provision of multiple goods and services for farmers (Tscharntke *et al.*, 2011).

Agroforestry practices are based on the idea that trees increases nutrient cycling, improves soil fertility and microclimate that support the growth of annual crops (Nair *et al.*, 1999). AFS provides more profitable and less risky than the traditional agriculture systems because of diversified products and services (Sollen-Norrlin *et al.*, 2020). The root systems of trees are capable to explore deep soil for water and nutrients, which will help in overcoming the droughts. Additionally tree increases through fall and soil porosity, increased soil cover and reduced runoff lead to increased water infiltration and soil moisture in the soil profile which can reduce moisture stress during less rainfall years. The advantages of AFS over mono agriculture have stimulated renewed interest in the practice of tree cultivation, particularly in areas where they had previously been removed (Beer *et al.*, 1998). The integration and management of trees in watersheds, cultural landscape, agricultural lands and degraded lands generates additional products and services to the rural farming communities.

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Chapter 2

Concept of community based watershed management and its components

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INTRODUCTION

The prime objective of integrated natural resource management on watershed basis is to minimize adverse effects on the natural and the social environment and actively pursue opportunities to manage the land resources for the benefits of the present and the future generations. Since climate, soil, water, plants (crops, forest, etc.), animals and human beings in a particular watershed, belong to an integrated ecosystem, if one component is disturbed the others will be automatically affected. Therefore for optimal management of any component of a watershed, the ecosystem should be considered as a whole. This requires the preparation of detailed inventories on the status of basic resources and their management which must be studied together for suggesting better options. Agriculture is the main stay of the economy of our country and only sustainable agriculture is likely to provide the long benefit required to achieve development and poverty alleviation. Proper planning and management of the available resources is necessary to ensure maintenance of their production potential, quality and diversity.

SIZE AND SELECTION OF WATERSHED

Generally a workable size of around 500 - 1000 ha watershed is preferred. Watershed selection is also governed by the objectives, problems and guidelines of the watershed programme/scheme. As per latest guidelines (NRAA, 2021), the watershed development projects will be broadly taken up in the most vulnerable rainfed districts by prioritization of micro-watersheds. However, the challenges and issues of North-Eastern and hilly States/UTs will be given due emphasis to accommodate the policies and thrust areas of the government for these regions. While prioritizing the watershed projects in the critical areas of the districts, the following criteria may be used in selection:

a) Frequency of drought occurrence.

b) Acute scarcity of drinking water Degree of over exploitation of ground water resources.

c) Preponderance of degraded lands/wastelands.

d) Decline in Normalized Difference Vegetation Index (NDVI).

e) Status of soil health, aquifer characteristics and topography.

f) Hydrological assessment of surplus runoff from watersheds. Contiguity to another watershed that has already been developed/ treated.

g) High proportion of population belonging to scheduled castes and scheduled tribes, and other socially & economically backward population.

h) Low productivity of major crops to that of District/State average.

i) Willingness of village community to make voluntary contributions, adopt regulatory norms for maintenance of common property resources, and ensure equitable sharing of the resources/benefits.

PARTICIPATORY RURAL APPRAISAL EXERCISES

WDT members need to conduct a series of Participatory Rural Appraisal (PRA) exercises separately in each of the selected villages. All the members of the team will move as one unit and use techniques like participatory mapping, transact, matrix ranking, timeline, seasonality, etc. to gather first hand information. The PRA exercises should initially provide data regarding details of land, water and human resources, soil types, severity of erosion, problem soils, rainfall, ground water levels, surface runoff, drainage lines, pasture land, forest species, grazing grounds, fuel, fodder and economic species, production systems in agriculture, horticulture, livestock, animal husbandry, village industries besides the socioeconomic realities such as demographic details, social and wealth ranking, migration, literacy, village crafts, skills, employment opportunities. After obtaining the above information, the PRA maps/visuals should be used for participatory analysis of present status, utilization pattern and maintenance of various natural resources (through water resource audit, land resource audit, social resource audit, perennial vegetation audit, etc). Further maps and visuals emerging out of above audit exercises may then be used for analyzing problems, reasons for the problems and possible solutions as understood by the participants. Collection of information is only one of the objectives of the PRA exercises. The equally important objective is to interact with the village community in small groups to facilitate their participation in the programme.

BASIC RESOURCE SURVEY

The information collected in the initial PRA exercises should be verified with secondary data available in the government departments, meteorological department, revenue records, village survey reports, etc. A part of the above information could be further supplemented with new primary data to be collected through conventional survey methods particularly for those items for which quantitative data would be required for comparison (as a bench mark) at the time of conducting the post project impact study. This will include items like area under irrigation, extent of private land lying fallow, number of functional and non-functional wells and tanks, present level of water table in the wells, present status of perennial vegetation in common land, average productivity of land and water based enterprises/commodities, income from non-land based enterprises, number and quality of social groups and organizations at the village level, extent of migration to urban areas, scarcity of drinking water for human beings and animals, etc. These surveys should be completed within six months of the commencement of the project so that they could be used as input for preparation of watershed development plan.

Details about ownership of land by each participating family may be collected from revenue records at the village level. Wherever available additional information about demarcation of boundaries of different owners within a particular survey number may also be collected as it would help in properly locating proposed measures for development of land and water resources.

Data related to the spatial features like physiography, soils, land use and vegetation and hydrology, etc. will have to be presented in terms of maps which can be extracted from different sources (Table 1), if available and should be finalized by ground truth verifications. In case, these sources are not available, then the data is to be collected through field surveys and analysed for preparing the watershed plan. This information can be supplemented with data collected through PRA exercise and remote sensing.

Table 1: Information/Data/Maps Needed for Planning (What, Why and From Where)

Items	Purpose	Source(s)
Base maps		
Cadastral/Village Map showing survey no. with boundary, roads, main *nallas* & other important features	To get spatial holdings and locations	Block office/ VAO Revenue department
Toposheets (1:25,000/ 50,000) showing physical features, drainage and contours	Topography i.e. elevations, drains, hillocks, watershed delineation as a base map	Survey of India, Dehradun or Regional Centres for reference from collectorate, PWD, AED, Forest, Department etc.
Note: In absence of high resolution map, portion of selected watershed may be exploded (i.e., enlarged), preferably to 1:4000 to 1:8000 scale. Also superimpose, survey no. details on this map by bringing both to same scale for effective planning and location of proposed measures.		
Derived maps, thematic maps for contours, soils, land use, vegetation, slope groups, geomorphology etc. derived from Remote Sensing & GIS and other field survey reports	Data layers pertaining to different physical features to help in planning	State Remote Sensing Agency (IRS, Chennai) & Reports of other related departments e.g. Agriculture, Forest, etc. Soil Survey Report, Agri. Department, Coimbatore.
General information		
Population (human & cattle) *Area & hamlets *Income level *Infrastructure facilities *Education	General socio-economic status. This can be later supplemented by detailed socio-economic survey of watershed	Village revenue Records, NIC Office at Collectorate Dist. Statistical Office
		Contd.
Items	**Purpose**	**Source(s)**
Meteorological Data		
*Rainfall (amount, intensity & distribution) *Temperature	Runoff estimation, crop planning	Local Revenue Dept. Research Institutes/SAUs, PWD (WRO), Forest

*Evaporation & other data		Department
Hydrological Data		
*Runoff & soil loss *No. of surface water bodies & storage capacity *Water table depth Perenniality of flow in streams Siltation in ponds/lakes	Runoff computation, water yield, available water resources, design of structures etc.	AED/RVP SMS Research Institutes PWD/WRO TNEB
Crops & Agricultural production		
*Area under different crops/ horticulture *Single, double or triple crops *Irrigated/rainfed *Average yield levels *In puts used & management practices adopted	Land use planning and suggest agronomical measures	Agril/Horticulture Department Research Institute
Vegetation		
*Major tree species their distribution *Density, canopy, biomass *Management level *Grasslands & their condition	Land use and vegetation planning	Forest Department Research Institutes Revenue Department
Note: Sample survey for detailed socio-economic conditions, vegetation and crop details to be taken up		

MAPPING FOR WATERSHED PLANNING

The primary object of a survey is the preparation of map or plan. The results of surveys when plotted and drawn on paper constitute a plan. A plan or map is, therefore, the representation to some scale, the details of the ground or site. The representation is called a map, if the scale is small, while it is called a plan if the scale is large. Since the Map is based on the field survey, the accuracy and precision depend on the survey conducted. A map should give the true representation of the details of the survey conducted for a particular plane. On the map, horizontal distances only are shown. Sometimes vertical distances are also represented by means of contour lines. For generating the maps on different aspects for watershed planning, it is suggested that the scale of mapping should be in the range of 1:4000 to 1:8000.

Scales

Drawings are not usually made full sized. For convenience, it is generally necessary to draw them to a reduced size, this operation being known as "Drawing to scale". The scale of a map or drawing is the fixed proportion which every distance on the map or drawing bears to the corresponding distance on the ground. Thus, if 1 cm on the map respresents 10 m on the ground, the scale of the map is written as 1 cm = 10 m. The scale of map is an important factor for the purposeful utilisation of maps. The scale of mapping depends upon the purpose to be served. The scale is also expressed by "Representative Fraction" (R.F.). It is the ratio of map distance to the corresponding ground distance. In forming the Representative Fraction both numerator and denominator should be reduced to the same denomination. For example, if the scale is 1 cm=10 m

The R.F. of the scale is -

$$\frac{1 \text{ cm}}{10 \times 100 \text{ cm}} = \frac{1}{1000} \quad \text{or } 1 : 1000.$$

The scale may be stated on the map graphically or by numerical relations. It should be shown near the title of the map, so that it will be readily seen. On a graphical scale the units of measurement should always be stated which will remain true even after reduction or enlargement of map by photographic process.

Enlarging and Reducing Maps

It is often necessary to reproduce plans or portions thereof to either an enlarged or a reduced scale. Plans may be enlarged or reduced by (1) The graphical method, (2) The mechanical method by using pantagraph or Ediograph and proportional compass and (3) The photographic method. (4) GIS

ENLARGEMENT OF DRAWINGS
Photographic Method

Example:
Scale 1:25000 (or) scale 1cm=250 M

1 time to 2 times enlargement (2/1=2)
Scale → 150% and 133%
1cm=125m 1.5 X 1.33=1.995 (or) 2 times / double the size

1 time to 3 times enlargement (3/1=3)
150% and 150% and 133%
1.5 X 1.5 X 1.33 =2.993 (or) 3 times / Triple the size

REDUCTION

2 times to 1 time reduction (1/2=0.5)
50%=0.5

3 times to 1 time reduction (1/3=0.33)
50% and 66%
0.5 X 0.66 = 0.33

Size of papers	Conversion
A4-210X297mm	141% - A4 to A3
A3-297X420mm	121%-A4 to B4
B5-182X257mm	71% - A3 to A4
B4-257X364mm	

The process of enlarging/reducing the maps is often essential to bring maps of different sources/scale to a common workable scale. This is also necessary for overlaying different thematic maps/layers in order to delineate homogeneous land units which require a particular set of treatments. Enlarging/reducing maps can be done away with if mapping is carried out in GIS environment wherein overlay of maps and calculation of area statistics become very simple and accurate.

Watershed Maps

Watershed maps on different aspects are prerequisite for a project and serve as important guide for scientific and systematic planning, implementation and monitoring of watershed programmes. The list of maps/drawings is given below.

Types	Source/Process of development
1. Topographical map	: Survey of India
2. Cadastral map	: Revenue Department
3. Location map	: Developed from Topographical map
4. Land use map	: Developed from field survey/data collected from other agencies
5. Soil map	: Soil Survey Dept./Developed from soil survey
6. Contour map	: Thematic/Topographical map/Developed from contour survey
7. Slope group map	: Developed from contour map/field survey
8. Land capability map	: Developed from soil survey report/field survey
9. Map showing existing structures	: Developed from field survey

10. Maps for proposed treatments : Developed by using thematic maps mentioned above and by including inputs from stake holders

Minor Instruments used in Surveying and Mapping

Minor instruments	Uses	Cost	Address for procurement
1.Hand level	• Rough work such as reconnaissance and preliminary surveys. • Locating contours. • Taking short cross sections.	Rs. 250-500	National Instruments Limited, 192, Mount Road, Hamid Building (Ist floor). Chennai-600 006. Chetak enterprises,178 (A) Maktoolpuri, Roorkee-247 667. Delite Engineering corporation, 49/1, Jamuna Bhawan Opp. Sultan Tower Roorkee-247 667 M/s Basic Engineering Company, 202, Balapama Bandra Kurla comlex, Bandava (East) Mumbai-400 005
2.Abney's level	• Measuring angles of elevation and depression. • Measuring the slope of the ground. • Tracing a grade contour	Rs.1500-2000	
3.Planimeter	• To measure the area of plan of any shape very accurately	Dial type Rs.2000-5000 Digital type Rs.30000-50000/-	

COMMUNITY ORGANIZATION AND PEOPLE INSTITUTIONS

Participatory approach is more pertinent in the planning and development of watershed management programmes, because it is basically the peoples' programme and the government agency should participate in that as a facilitator. This is so because it not only requires the resources to be developed or created or managed properly and equitably distributed among the stakeholders or beneficiaries but also requires that not only the Private Property Resources (PPR) but also the Common Property Resources (CPR) are developed, managed and maintained. For this to happen, it is highly necessary that every stakeholder in the watershed accepts and implements the recommended management plan and is very much involved into the planning and implementation process.

There are two basic points of consideration in this bottom up participatory development process. The first one is that the proposed development or plan should seem desirable to the people. To be desirable, the objectives proposed must be related to the local community's needs and interests. The second one is that it should seem possible.

Restructured latest watershed guidelines have lead greater emphasis on community involvement and allocated sufficient per cent of the total fund of the project for this vital component. Before commencing the developmental activities of the programme, sufficient attention should be paid towards generating awareness among the community members regarding the new strategy as well as main features of the "Latest Approach for Watershed Development". This paradigm goes well with the recommendation of the GoI Inter-Ministerial Committee on Doubling Farmers Income (DFI) that invites attention to the specific needs of three principal stake holders: (a) the consumers need nutrition security (b) the farmers need income security and (c) the production environment needs ecological security. For this purpose, repeated meetings in large and small groups may be arranged. It would be useful if traditional street plays, folk songs, etc., are adopted to communicate the spirit of the restructured watershed programme during large group meetings. If required summary version of the guidelines in local language may also be circulated/distributed to willing persons.

Meetings with the Watershed Community

Conduct regular meetings with the farmers in villages to clearly explain the purpose of the programmes, get their feed backs, develop contacts, gather Indigenous Technological Knowledge (ITK) and win their confidence and involvement.

Formation of Local Peoples' Institutions

Project level peoples' institutions such as Watershed Association, Watershed Committee, Farmers Producers Organizations (FPOs), Self Help Groups (SHGs) and User Groups (UGs) are formed, by laws framed and society is registered for day to day running, management and distribution of benefits and create working capital through revenue generation, people contribution, etc., for repair and maintenance of the works. This will create a self sustaining local institution to take over the activities after withdrawal of the Project.

As per latest guidelines (NRAA, 2021) the very purpose of forming people's institutions in watershed programme is to provide people the "ownership of the project by making them an integral part of decision-making, giving them control over their resources, autonomy to implement the project, capacity to use resources sustainably and carry on the process even after the completion of such projects.

These Institutions will bring cohesiveness within the community, introduce and nurture a culture of cooperative and coordinated use of natural resources and assets on a sustainable basis, and protect the project area resources from indiscriminate use, which was the primary reason for degradation and low productivity status seen before the treatment. The unstated spirit is to break the vicious cycle of overuse and degradation in post project implementation by developing sense of ownership among people. In the project area, small groups of the project communities shall be formed with specific roles and responsibilities. It is important to mobilise project stakeholders around common identities and interests as listed in the following sub-paras. Gram Sabha (GS), a Panchayati Raj Institution shall be an important peoples' body to be associated with the project.

Gram Sabha (GS)

Involvement of Gram Sabha (GS) in planning, sanctioning & execution of watershed projects shall be ensured. While approving the comprehensive action plan, the GS, ensure adequate biological activities find suitable place in it.

Watershed Committee (WC)

As per guidelines (NRAA, 2021), the Gram Sabha will constitute WC to take primary responsibility for executing project development. The Committee shall be registered as a Society under the Societies Registration Act, 1860. Alternatively, the WC shall be constituted by the GS as a sub-committee of GP chaired by the Sarpanch. In such case, no registration under Societies Registration Act, 1860 will be required. The Committee shall comprise a minimum of eleven members; five members representing various user groups and the SHGs; three from FPO (one member each representing the FPO itself, CHC, and such other unit, like at sale outlet set by it); one GP member; and one WDT. The Secretary selected will serve as Member-Secretary of WC. The eleven member committee (including the Secretary) shall have, at least two representations each, from among the women and SC/ST members. The Committee members in a specially convened meeting shall choose one among themselves to serve as the Chairperson and another as Co-Chairperson. Either Chairperson or co-Chairperson shall be essentially a woman. The Secretary of the Committee shall be a paid functionary, and his emolument shall come from the administrative component of the budget of watershed project. The Committee may approach the Gram Panchayat for a suitable space to set up its office or hire a building from where it can operate on a regular basis.

Farmer Producers Organization (FPO)

With the majority of farmers being small and marginal, both input and output management becomes inefficient, due to low scales of operational economy. As a result, mostly farmers may not be able to achieve high productivity and also stand to lose from not being able to integrate their produce with markets. One of the important objectives of the new generation guidelines is to help achieve higher economic growth for the project community, collectivization of farm operations, which can be realized through FPOs. Hence, from the stage of implementation of project itself, the PIA shall focus on forming FPO as an Entry Point Activity. In case it already exists in a project, the approach would be to strengthen it. The FPO shall be the member - owned and member - managed institution. Any household dependent directly or indirectly on the natural resources of watershed can join the FPO by paying prescribed share capital amount and membership fee as defined by the organization. The WDTs will initiate the FPO formation by mobilizing the people, creating awareness, and educating them about the need & advantages of forming such an organization. The Team may seek and avail support of GP members and others who can positively influence the community. The FPO will be registered once it reaches a threshold of 300 to 500memberships (with paid share capital) as a cooperative or a society or a company under the relevant Act, after detailing out its bylaws and governance structure. The Team may encourage existing SHGs to take membership in the FPO and expand its base. In respect of FPOs, Operational Guidelines of the scheme of "Formation and Promotion of 10,000 Farmer Producer Organizations (FPOs) issued by Department of Agriculture & Farmers Welfare, Govt. of India may be referred for guidance. (*https://dmi.gov.in/Documents/FPO_Scheme_Guidelines_FINAL_English.pdf*).

Self Help Groups (SHGs)

SHGs have proved successful across the country, particularly as centres of micro-credit. Further, they have also taken up variety of livelihood activities in diverse fields. Promoting alternate livelihood activities being an important objective of a watershed project, conscious efforts should be made to make the existing SHGs as active partners in development strategy within the project area. While strengthening the existing ones, need based/resource based new ones may also be formulated. Effort may be make to federate all SHGs to improve business opportunities. The WDT and WC should take this responsibility and create homogenous groups based on the common identity and interests of local people. The landless and weaker section members in particular will need to be mobilized. This initiative can be linked with the program of NABARD, MGNREGS, NRLM etc. The members of existing and new SHGs will need to be trained in different aspects of operations, credit management and livelihood activities. The NLNA/NLND may decide on the size of revolving fund to be made available to the SHGs in the Project area.

User Groups (UGs)

Watershed approach of development is a landscape approach, wherein resources like land, water, and assets thereon, are planned/utilized keeping conservation and regeneration in view. This warrants total involvement of the people in terms of ownership and management of the assets created. These assets include, soil & water conservation measures, water harvesting structures, pastures, horticulture & plantations etc. In this context ,promotion of collective effort of farmers & other stakeholders at planning, decision making, implementation and management stages would be useful. This can be achieved by creating and nurturing several „User Groups (UGs)" comprising of persons with common interest around different resources. The PIA shall focus on forming homogenous groups of different stake holders around various initiatives at the implementation stage. This will help in associating the potential users in deciding on the work details. For example, the decision for developing a pasture land may involve the ratio of fodder trees and grasses to be adopted, the species to be opted. Such an approach builds ownership and a stake in developing and maintaining it later. UGs may be encouraged to join FPOs and avail of various services offered by them. Further, the WC should roll out resource-use agreements among UGs based on the principles of equity and sustainability. These agreements must be worked out before the activity is undertaken. The UGs shall be responsible for adhering to the user norms, and upkeep of the concerned assets. The Gram Panchayat will need to take over these assets and provide operation and maintenance support. The WDF resources could also be made available for the upkeep of assets.

PREPARATION OF WATERSHED DEVELOPMENT PLAN

Based on the present land use, Land Capability Classification map, problems, needs and priorities ascertained through Participatory Rural Appraisal (PRA), watershed treatment/ development plan is prepared following a participatory approach for arable and non-arable lands including drainage lines and infrastructural development. Components of a typical plan may include the following:

Protection and Conservation Measures

Majority of the project experiences suggest that a blend of structural and vegetative measures is a better option. This will include all the measures/structures including in-situ soil and moisture conservation measures like bunding, leveling, terracing and vegetative barriers, water harvesting structures such as ponds, nalla bunds, small dams, percolation ponds etc., drainage line treatments (DLT) with engineering structures and vegetation for checking land degradation and conserving water; and repair, restoration/strengthening of existing common structures for sustained benefits from previous investments made, if any. For the location and design of DLT measure and water harvesting structures, contour and profile surveys have to be undertaken.

Production Measures

These include the activities that are required to make the efficient use of conserved soil and water resources in producing user products such as food, fodder, fuel, fruit, fibre, milk etc. on sustained basis. These may include improved crop cultivation and management practices, afforestation, alternate land use systems, cultivation/raising of industrial, medicinal and aromatic grasses and plants for providing alternate livelihood support system, development of livestock, dairying, poultry, sericulture, fisheries and other essential income supporting activities.

Latest guidelines have indicated that out of 79 percent allocated for works phase, 49, 15 and 15 percent are meant for natural resource mangement, production system and Livelihood Activities for the asset less persons and Micro Enterprises & Business Development, respectively.

CONVERGENCE APPROACH

Watershed management is a single window, integrated area development programme. Integrated watershed management cannot perhaps be achieved just by following integration of resources using multidisciplinary approach with the funding or support provided alone under any watershed programme. This may also involve harmonized use of resources available from other on going/existing sectoral and development schemes in the area/district. Such resources can be dovetailed with the watershed programmes that will not only help in useful convergence of various schemes and programmes for overall development of the area programmes for overall development of the area but also in effective monitoring. Some of these sectors may include education, health, sanitation, drinking water, roads etc and most of these can also be dovetailed with the entry point activities.

SOCIAL ACCEPTANCE AND APPROVAL OF PLAN BY WATERSHED COMMUNITY

The watershed development plan so formulated is summarised and presented in a general body meeting to invite discussions, suggestions and modifications, if any to seek social acceptance and approval of plan by the community.

INTEGRATION OF SOCIAL RESOURCE MANAGEMENT WITH NATURAL RESOURCE MANAGEMENT

Integration of Social Resource Management (SRM) with natural Resource Management (NRM) is crucial for achieving sustainable results. Such an integration would become easier if action plans of all components are developed separately within each SHG/UG; implementation of above plans are carried out by respective groups; adequate emphasis is given to production enhancement and livelihood support activities, combining short-term, medium-term and long-term gains to watershed community.

KEY ELEMENTS OF WATERSHED PLANNING (NRAA, 2021)

Participatory Watershed Development Plans (PWDP)

The vision of the new generation of watershed development projects will be achieved through PWDP prepared by the watershed community with technical guidance from the WDTs. The following constitute broader components of the watershed development plan:

i. Ecosystem Regeneration and Production.

ii. Natural Resources Management and Governance.

iii. Services & Livelihoods.

These three are organically linked and relate to development, management and governance of natural resources. The plan should focus on effective and efficient use of natural resources to realize better income for the rural people. In hilly regions, participatory approach should be adapted for springs rejuvenation with meticulous planning, involving communities in twin arrangements in upper and lower reaches.

Ecosystem Regeneration and Production Plan

a. Crops and the land use vary in accordance with the topography. Its characteristics and tenurial relations also determine the land use. The watershed landscape is first zoned into relatively homogenous units based on its physical characteristics, usage (crops, grasses, trees) and tenurial status (such as private/ commons/ forest department owned lands). The types of zonation vary across different agro-ecologies.

b. In addition to the physical watershed treatment plan covering *ridge to valley*, the ecosystem regeneration plan should look at the land use crops grown or types of grass lands or vegetation in each of the zones and the status of groundwater/ aquifers etc.

c. The plan should indicate the measures taken up for improving soil health in terms of soil organic matter, regeneration of vegetation, mitigation of climate risks in crop production, crop diversification including horticulture, approach to improve crop (soil) cover for longer duration in a year, arresting land degradation, harvesting rainfall and protective irrigation.

d. An important aspect of this plan is integration and strengthening of livestock production systems, integration of livestock feed and fodder into crop systems, promotion of fodder trees and regeneration of grass lands, as the broad components.

e. The plan for each of the zones must show measurable indicators for assessing the ecosystem regeneration and projected improvement in production of various crop systems as a result of interventions made. The change can be appreciated only when the baseline index of these indicators is included in the plan.

f. For comprehensive *ridge to valley* treatment is the watershed development approach. The forests and common lands on the upper reaches will necessarily constitute the first candidates for watershed activities. Well-treated upper reaches impact the lower reaches including the arable lands positively. The additional benefit of such a treatment would result in improvement in quality of forest, besides augmenting forest produce adding to supplementary income of the community.

Normally, the forest department has a working/management plan for its development, which it carries out through the Joint Forest Management Committees (JFMCs). It is important to plan/align all activities in forest areas in sync with watershed activities following *ridge to valley* approach. Since it may not always be possible to achieve such perfect alignments in the field, it would be necessary to fund this activity from Project development allocations itself. One may also explore scope for convergence of forest area treatment plan with ongoing afforestation programs and MGNREGS etc.

Natural Resources Management and Governance Plans

This component will have three parts as discussed below:

a) Maintenance of natural resources related assets

Natural resources related physical works need maintenance, and the bio-works such as plantation require strong protection measures and care. The watershed committee responsible for undertaking treatment works and asset creation should maintain a Watershed Assets Register, and the list of completed works recorded and updated continuously. The completed assets should be transferred to the Gram Panchayat for their continued maintenance at the end of each year of implementation.

A system of annual audit of natural resource assets should be taken up by the GP to assess their status and maintenance needs. These can be integrated into the MGNREGS by a resolution of the Gram Panchayats. The WDT should ensure that these processes are institutionalized into the functioning of Gram Panchayat and followed regularly from 2nd year onwards. The activities planned to achieve this should be submitted as a part of the overall Project development plan.

b) Water Budgeting, Management/Regulatory Norms and Governance

It is crucial for the community to establish reference sites of wells/ bore wells, and regularly monitor groundwater along with local rainfall, so as to arrive at regulatory norms on water extraction, type of crops to be grown and area coverage. The groundwater monitoring exercise may be taken up twice a year (April-May & September-October / before the crop season), and results be placed after analysis, before the Gram Sabha. The purpose should be to build a common understanding and consensus in the project community for sustainable use of groundwater. The community should be brought to agree on potential restrictions on new extraction structures, reducing area under water intensive crops and other such norms that economise on water use. These exercises are to be taken up twice a year and activities proposed should be part of the watershed development plan. A suitable arrangement for carrying out this exercise should be made by PIA in consultation with Watershed Committee and also provide requisite training for the same.

c) Protection and Regulation/Regeneration of Common Lands

Common lands that are typically in the upper reaches of the watershed slopes, including forests, pastures etc. should receive focused attention,along with identification of users, their needs and organizing them into user groups. The plan for regeneration and development should also enlist various products, usufructs arising out of the planned regeneration process, and their benefit sharing norms. Protection measures, norms and their enforcement mechanisms need to be arrived at and must have sanction of the Gram Panchayat.

Services and Livelihood Plan of FPOs

These are essentially *economic growth plans* of the watershed community building upon the social capital base and investments in natural resources. An FPO is formed from the beginning as a business entity that efficiently provides services, organizes inputs, promotes value added commodities produced by local enterprises, and undertakes aggregation and marketing, protecting the interests of small & marginal farmers, SC/ST members and women. The FPO shall start with organizing the three regular components:

Custom Hiring Centre (CHC)- renting out implements/ equipment/ small machines for use by small holder farmers, women and agriculture labour

Input Shop- where inputs required for farming, small implements, quality seeds (produced by its farmers or procured from outside) are readily available within close proximity

Information Centre- providing weather forecasts, weather advisories, crops and livestock related information, information on various schemes, hosting knowledge sources like videos, a library etc.

The plan for economic growth and livelihood activities ideally starts with assessment of the potential impact on crop, livestock, fish and other agricultural production system that comes from the investments made on natural resources. From the perspective of monetising the produce, attention is needed on post-production activities, including value addition & marketing. Hence, investments for creating/upgrading infrastructure, building human resources and skills, and working capital are assessed, and included in the watershed development plan. The FPO should be able to undertake these responsibilities by taking active support of Watershed Committees, Gram Sabha and Gram Panchayats.

Convergence Planning

Several government schemes can complement the watershed development initiatives. Once the overall project development plans is prepared, the WCDC will need to discuss with the PIA supported by its WDT and prioritise the activities. This should also involve exploration of scope for sourcing funds from various ongoing relevant schemes. The focus should be on supplementing project activities and funds by effecting convergence with relevant ongoing schemes. The final budget of the Watershed Development Plan will thus stand to include the list of planned activities, estimated costs, sources of funds (project fund, convergence fund etc.). The WCDC shall shoulder the primary responsibility for mobilizing convergence of resources from other schemes.

PROJECT PERIOD AND PHASING

In view of the expanded scope and expectations under the new generation watershed; development program, the project duration would be three to five years. The phases and duration of each phase is shown in the following table:

Phase	Name	Duration
I	Preparatory Phase	upto 1 Year
II	Works Phase	2 to 3 Years
III	Consolidation and Withdrawal Phase	upto 1 Year

LATEST UNIT COST

As per latest guidelines, the unit cost for watershed development projects under WDC-PMKSY2.0 is Rs.22,000/ha for plain areas, and Rs.28,000/ha for hilly & difficult areas (desert areas) and upto Rs. 28,000/ha for LWE/IAP Districts.

WATERSHED BUDGET

As per the latest guidelines (NRAA, 2021), the major head-wise distribution of budget for a specific watershed project would be as given in the following table:

Major Head	Sub Heads	% of Budget
Administrative	Management Cost	10
	Monitoring & Evaluation	2
Preparatory Phase	Entry Point Activity	2
	DPR Preparation	1
	Institution &Capacity Building	3
Works Phase	Natural Resource Management	47
	Production System	15
	Natural Resource Management & Governance	2
	Livelihood Activities for the asset less persons, Micro Enterprises & Business Development	15
Consolidation & Withdrawal Phase		3
	Total	**100**

WATERSHED DEVELOPMENT FUND (WDF)

One of the mandatory conditions for selection of villages for watershed projects is peoples' contribution towards the Watershed Development Fund (WDF). The contribution to WDF may be 10% of cost of NRM works when executed on private lands. However, in case of SC/ST, small and marginal farmers, the contribution may be 5% of cost of NRM works. These contributions may be acceptable either in cash (preferably transferred electronically) at the time of execution of works or in the form of voluntary labour. A sum equivalent to the monetary value of voluntary labour may be transferred from the watershed project account to the WDF bank account that may be maintained in a distinct and independent of the former account. User charges, sales proceeds and other contributions, disposal amounts of intermediate usufruct rights may also be deposited in the WDF bank account. Income earned from assets created under the project on common property resources constitute another source of funds that can be credited to WDF. Charitable institutions may also be legally facilitated to contribute generously to this Fund.

In case cost-intensive farming, system-based livelihood activities/interventions viz. aquaculture, horticulture, agro-forestry, animal husbandry, fishery, secondary agriculture etc. are taken up on private lands, directly benefiting the individual farmers, the project funds may only be spent on the condition of part contribution by the said beneficiary. Even under this condition, distribution of animals, machinery etc. must be avoided. Such individual benefitting activities may be taken up to support the poor households. The contribution of the beneficiary will be 20 % (for general category) and 10 % for (SC/ST members) of the total cost estimate of the activity. However, contribution from project fund shall not exceed two (2) times per hectare cost norm (Rs. 22,000 and Rs. 28,000 for plain and hilly areas respectively). The farmers" contribution i.e. 20% for general category and 10% for SC/ST shall be deposited into WDF, as the case may be.

END RESULTS

- Each of the Watershed Development project is expected to achieve following results by the end of project period:
- All planned works and activities have been successfully completed, and there is visible reduction in soil erosion, increase in ground water table, and enhanced green cover over both arable and non-arable lands surfaces in the project area.
- The Gram Panchayat has willingly taken over operation and maintenance responsibility of assets created and transferred to them.
- The community organizations namely, FPO, WDF, SHGs, User Groups etc. are operating well.
- The FPO has large number of shareholding members and a healthy capital base; and has well managed CHC, Input Sale Outlet, basic agri-logistic infrastructure and market facilitation for local agri-commodities.

- There are increase in productivity levels of various crops and livestock.
- There exist alternate livelihood options for all members of project community – farmers, landless agricultural labours, livestock keepers, artisans etc.
- The project community finds value in sustaining the treated land areas under projects and is well capacitated to manage it as a collective group.
- There is increase in cropping intensity, greater diversification of agricultural production system, and the total agricultural output rises substantively.
- Various regulatory norms for use of water (viz water budgeting) and access to usufructs rights over assets are in place, and are adhered to by the local communities.
- There is increase in average income of the project farming communities.
- The project communities adopt watershed project to ensure economic growth and ecological rejuvenation of the landscape.

Chapter 3

Common Property Resource Management in Watershed Areas

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Common property resources (CPRs) can broadly be defined as resources in which a group of people has co-equal user rights. Membership in the group of co-owners is typically conferred by membership in some other group, generally a group whose central purpose is not the use or administration of the resources. In India, these resources include community pastures, community forests, wastelands, common dumping and thrashing grounds, watershed drainages, village ponds, rivers, rivulets, etc. Even when the legal ownership of some of these resources rests with other agency or agent In *de facto* they belong to the village communities and continue to be significant component of the land resource base of rural communities.

CPRs are those resources in which a group of people or the villagers have co-equal user rights and they manage , maintain, utilise, protect and construct these resources with equal right and responsibility. CPRs like community forests, community pastures, wastelands are spread over a large area, so they play a pivotal role in livelihood of the community or the village. Even after catering to multiple needs, CPRs are facing crisis. They are now threatened by neglect, overexploitation, under investment and expropriation. CPRs are among the most neglected areas in development planning.

Salient features of CPR

CPRs are formed from amalgamation of land, forest, water, soil and many other natural resources.

CPRs are a central focus point of the livelihood and lifestyle of the villagers. They contribute in the agriculture production, livestock management, non farm activities, rural industries etc.

Everyone in the community has access to these CPRs

Social organization of the villages may not be effective and efficient in management, conservation, regeneration and utilisation of CPRs. Community understands and believes that CPRs are for them.

Role of the CPRs in rural livelihood

CPRs are categorised into natural and manmade. These are described as under

Natural CPRs

These are nature-gifted and include:

Land resources

Gochar (plot of land left vacant for livestock grazing).

Banjar (degraded and wastelands, under individual or group ownership but used as resting place by livestock of the community).

*Gkkkaura (*Plot of land where milking of milch cattle is done)

Khaliyan (land where all the members of the community store their crop produce together.

Nistar (Land reserved and left vacant for fairs, haat markets cultural ceremonies etc.

Forest resources

Kakad bani (plot of land with vegetative cover specially between two village boundaries.)

Devbani (plot of forest land left by the community in the name of god and used only in the event of natural crisis/disaster).

Rakhabani (plot of forest land left by consensual decision of the community used as the land resource).

Devaranya(Plot of forest land for god).

Waal (Forest land owned by Zamindars or temples, may be used for cultivation).

Beed (mostly private dense forests used by the community at the time of crisis)

Rundh (private dense forests which could b used by the community after paying taxes).

Water resources

These include ponds, tanks, bunds, checks, wells, canals, rivers, rivulets, etc.

Man made CPRs

These are created by the community for the community and include:

Village tanks,

Bavdi (traditional ponds),

Bunds/Dams,

Wells,

Chaupal (for community meeting)

Thanie (platform for judicial meetings),

Waterways, field channels,

Paths, roads,

Schools,

Play grounds,

Cemetery

Temple or worship place and

Dharmshala (community building)

Although CPRs contribute to people's employment, income generation and asset accumulation, they are seldom recognised and recorded. CPRs principally provide *Physical products* such as food, fibre, fodder, fuel, timber water, manure, silt, space, etc. *Income and employment opportunities* such as off-season activities, drought period sustenance, additional crop activities, additional animals, petty trading, rural industries handicrafts, etc. *Larger social and ecological gains* such as resource conservation, drainage/recharge of farming systems, renewable resource supply, better micro – climate and micro-environment, etc.

Depletion of CPRs

Despite their multifarious and valuable contribution to the rural economy, CPRs are the most neglected in development planning. Following are some of the factors causing deterioration and depletion of CPRs

Government Policies

Government programmes to increase productivity.

Failure of PRIs

Faulty education

Distribution in society

Biotic pressures

The functions of CPRs are threatened and their contributions to poor people's livelihood have declined. The decline in the quantum and quality of CPR has resulted in increased unsustainability of land based activities in dry region. The progressive decline in the value of CPR products, accompanied by equally increasing number o of people relying on them for sustanance has pauperised the community.

CPR management in watershed programmes

Management of CPRs is an important priority sector in watershed development. The emphasis is to reactivate the traditional informal management systems for CPR in watershed areas. The Jhabua model of Integrated Watershed Development Project has used the vehicle of such informal systems. As mentioned earlier, informal groups protecting, conserving and utilising CPRs (like pastures, vegetations and wastelands in degraded forest areas) were re strengthened. A new energy and dynamism in the form of JFM was introduced in them. It was consciously tried into to suffocate local initiatives by imposing plethora of JFM regulations. The physical and legal – cum- administrative interventions were focussed and sensitised with CPR perspective. Due to extensive exploitation of the CPRS Jhabua has over a periods of years, been converted into xerified degraded dry land with massive soil erosion and runoff. WA and WDC have been given primary role in accentuating the processes of CPR management. Enrichment and regeneration of CPR was planned, executed, managed, maintained and utilized by the WA in watershed areas. Institutional management in the form of formulation of numerous effective UGs has resulted in a major change in the perception. The users were made managers) for example fishermen's UG, for fishing tanks, water UG for irrigation tanks. VFC for degraded forests, handicrafts UG for non farm activities. The community is mobilised and encouraged to participate in CPR management by launching comprehensive multimedia campaign. The WDP ensured;

Fewer occupational changes (that is say shift from handicrafts to cultivation).

Promotion of occupation which can be supported by the existing CPRs.

Less factionalism in the village, implying greater degree of social cohesion, conducive to the protection of CPRs

Less patronisation of UGs/WDGs involved in CPR management, so as to decrease outside influence on the management systems and decreasing the dependence on external influences.
Equity of access and benefits from CPRs and ensuring equal stake in the maintenance of CPRs
Create forum for community to evict CPR-grabbers.
Promote indigenous and appropriate technology for CPR management and
Inculcate the feeling and atmospheric for cooperation and cohesive action.

At the planning stage, the DRDA or WAC has to earmark the approach of the programme
1)Investment needs: For sustained and effective management of CPRs increase in their productivity is essential. The requires rapid regeneration, through protection and regulated use and provision of substantial investments into CPRs.
2) *Positive approach*: Positive interventions, decided with the community, restricting the further decline of CPR areas, should be the major component of CPR development.
3)Technology focus: The rehabilitation of CPRs as productive social assets need a new technological focus in terms of species, inputs and technical methods of resource management. Besides productivity, emphasis on diversity and usefulness of products should be highlighted.
4) Management and regulations: It should be well understood that the rehabilitation of CPRs is less of an investment-cum-technological problem and more of a resource management problem. This cannot happen unless the CPRs are re-converted from open access resources to common property resources. In operational terms, usage regulations and user obligations towards CPRs should be re-established.
5) Traditional practices: Traditional practices regarding management conservation and utilization of CPR may be useful or harmful for the CPRs. Practices which positively promote CPR rehabilitation should be encouraged while others should be discouraged. The process has to be participatory and slow and should be handled with proper sensitivity. The traditional institutions should be revived and interwoven properly into the CPR management system.
6) *User groups:* The basic institutional arrangement to fulfil the objectives could be formation of CPR user groups. There are not unique methods to promote such groupings. The pattern of UG depends on the type of CPR and village-specific conditions. Uniform or static pattern should never be promoted. The key features of CPR-UG should be
Equity of access and benefits from the CPR for all its members.

UGs should have legal sanction but should remain outside the control of formal village institutions.

Membership of the group should include the whole village community or specific occupational groups.

A pre- condition for group membership should include a binding commitment to user obligations and regulations. And

Flexibility in exit an entry of members should be allowed with no right to break up the group

Grass land and degraded forest management, wasteland management, water conservation and harvesting management are some of the important areas of CPR management in watershed areas. The success of recent initiatives in the CPR management, specifically in watershed areas, inspires considerable hope for effective CPR management.

Case study on CPWR Management in Tamil Nadu

ICAR –IISWC, RC, Ooty conducted a study with reference to CPWR management in three tank intensive districts of Tamil Nadu. It was found that these tanks were mostly rainfed tanks and the people's institution involved in management of these tanks were WUA.They have formulated their own byelaws .They have engaged *Neerkatti*(person for equitable distribution water in command areas. Rotational irrigation was followed . They did crop planning based on availability of water in village tanks. Apart from irrigating the crops from these tanks , the other benefits that they could accrue are pisciculture, domestic use, industrial use like for making brick kilns, water for cattle, and grazing, fuel wood from tank fore shore plantations , etc.,

Sump Constructed at Senkulam Tank to use water for irrigation

Usage of Structure for Pisciculture – Omandur Tank

Usage of Structure for animals drinking – Omandur Tank

Use of the structure for washing- Keelpathi tank

Use of structure for cattle grazing and drinking- keelpathi tank

Usage of water from the structure for brick making - Kayalmedu tank

Excess Vegetation growth in Thamaraikulam tank

Damaged Weir – Kathatti Tank

Uneconomical vegetation growth – Kathatti tank

Based on this study the Centre has come out with following policy recommendations.

Measures for sustainability of community based water storage structures

<u>Policy Recommendations</u>

Removal of vegetation

Periodical desilting of the tanks

Farmers should be allowed for desilting the tanks and using the desilted soil in their fields wherever restriction is there.

Strengthening of bunds

Eviction of encroachment

Empowerment of the president and members of the WUA to take up regulatory mechanism in using the water and maintaining the structure

Generation of funds for maintenance by WUA

Involvement of NGOs in maintenance

In the tanks wherever surplus water is there the farmers may be encouraged to go for double cropping with short duration crops instead of single cropping with long duration crop.

Lining of common supply channels from the tanks may be done wherever the farmers have requested for.

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Chapter 4

AGROFORESTRY SYSTEMS FOR NUTRIENT CYCLING AND RESOURCE CONSERVATION

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Background

The developing countries witnessed an extraordinary phase of food crop production and productivity over the past 5 decades, despite increasing land shortage and rising land values. Agricultural intensification during recent decades is best considered as the level of human appropriation of terrestrial net primary production. Due to the intensification of agriculture through mechanization, use of chemical fertilizers and pesticides, irrigation, and development of high yielding crop varieties had resulted increased food production. This increased in food production is unprecedented and supports the world's growing human population. However, high intensity agriculture also comes with costs. Fossil fuel energy is relied upon to produce chemical fertilizers and pesticides as well as to power mechanical equipment. In some cases energy consumption exceeds food energy production by over ten to one. Such heavy reliance on non-renewable resources may be unsustainable over the long term. Pesticides and fertilizers used in crop production have entered the environment leading to groundwater and surface water pollution. This pollution has both human health and ecosystem health effects. When chemical nutrient inputs are combined with intensive tillage, soil organic matter (SOM) decreases. SOM is important because it increases the nutrient holding capacity and moisture retention of soil. As farming becomes more intensified, fields became larger and crop diversity declines. The decline in biodiversity along with other factors, including pest resistance, has led to increases in insect damage despite increases in pesticide use. Modern agriculture has large benefits, but it also has high environmental costs. Concerns about the high cost of intensive agriculture have led to increased interest in low-input or organic agriculture. Soil amendments are needed to sustain crop yields. Adding organic residues increases the retention of C and N in the soil. In recent years, due to the non-availability of residues and the higher transportation cost reduced the use of organic residues. All this resulted in the decrease of soil fertility and productive capacity of land in many regions.

A need for soil restoration

Soil degradation is a worldwide problem and much of the decline in soil quality is linked to human population growth. As populations increase during recent decades, demands for natural resources and agricultural products also increase. Population growth sparks several major trends including deforestation, high rates of urbanization, reduction of fallow periods, and increased cultivation of marginal lands. All of these trends lead to soil degradation. When forests are cleared, nutrients are removed, nutrient conserving mechanisms are lost, and soils degrade as nutrients leach out. Urbanization leads to the conversion of arable land to urban land and increases local demand for agricultural products. As the amount of high quality arable land decreases and the demand for agricultural products increases, external inputs are added to increase yields, fallow periods are shortened and marginal land are brought into cultivation. Marginal lands degrade quickly, and shortened fallow periods prevent soil nutrients from building back up. As crop yields on degraded lands decline, fallow periods are shortened even more, and additional marginal land is converted to agricultural land. Mechanization leads to erosion, pollution of rivers and streams with sediment, and filling reservoirs. Increased chemical use has led to pollution of water supplies, chemical residues on foods, and increased pesticide resistance. Nitrate, from fertilizers, animal wastes, and crop residues is the most prevalent chemical pollutant and it seeps into shallow and deep aquifers and pollutes ground water and contributes to eutrophication (Tilman 1998). Many of the costs of high input farming are societal costs that are not factored into the monetary cost of food or its production (Mäder et al. 1999). High input agricultural technology was inappropriate for farmers unable to afford the technology (Nair, 1993). In some cases the advanced technologies were made available through subsidies, but when these subsidies were reduced, agricultural costs increased dramatically for farmers (Matson et al. 1998). Changes in the crops grown put new strains on limited resources such as water and sometimes lead to aquifer depletion, salinization, or waterlogging (Matson et al. 1997). After the shine of the Green Revolution began to dull, system oriented, low-tech strategies were developed. One of the new emerging fields was agroforestry. Agroforestry techniques are based on the idea that trees increase nutrient cycling, improve soil fertility, and support the growth of crops (Nair et al. 1999).

Agroforestry – an alternative

Agroforestry practice is an important land-use management intervention which integrates trees into an agricultural land, which provides a unique opportunity to maintain the ecological balance while maintaining productivity of the land. Agroforestry systems (AFSs) are age old practices of growing trees and crops in interacting combinations with or without animals (Nair et al., 2010). It is essentially a mixed cropping system, implies co-existence of agricultural crops and tree species which can achieve both natural resources management and socio-economic benefits. Around the world agroforestry has been widely practiced for thousands of years. Agroforestry has been defined in various ways. The World Agroforestry Centre (www.icraf.cgiar.org) defines it as ‘‘a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels’’ (Nair et al. 2009). AFSs are structurally and functionally more complex than either crop or tree monocultures resulting in a greater efficiency of resource (nutrient, light, and water) capture and utilization, and greater structural diversity that entails efficient nutrient cycling. Hence, AFSs have advantageous over conventional agricultural and forest production systems through increased productivity, ensured economic benefits, sustainability, diversified products (e.g. wood, fruit and staple food), while simultaneously providing numerous other environmental benefits including maintaining biodiversity and soil health, microclimate modification and carbon sequestration (Lal 2007; Nair et al. 2009; Kumar 2011; Nair 2011; Hombegowda, et al. 2016). AFSs have higher SOC storage rate compare to agricultural systems (monoculture) due to the presence of trees. Trees provide a long-term biomass stock with high litter inputs to soil, and are capable of injecting carbon deep into the soil with their extensive root systems (Montagnini and Nair 2004; Takimoto et al. 2009; Adhikary et al., 2016; Hombegowda et al., 2020) and can reduce the C output (efflux) from the system through microclimate modification (Albrecht and Kandji 2003; Nair et al. 2009). The agroforestry practice with a suitable tree and crop combination ensures complementary use of water and other natural resources that enhances the performance of mixed species assemblage (Hombegowda et al., 2019). In India, AFSs are known for their insurance value in maintaining the rural livelihood security. Hence, today AFSs have been recognized as the integrated applied science that has the potential for addressing many of the land-management and environmental problems.

Agroforestry systems (AFSs)

There are many cropping systems that fall under the umbrella of agroforestry. Some of these systems are taungya, silvo-pastoral, improved fallows, shaded perennial-crop, parkland systems, and alley cropping. Taungya is a system developed in southeast Asia. Subsistence food crops are planted between juvenile timber trees, such as teak (Boonkird et al. 1984). More recently this system has been introduced into Latin America (Schlönvoigt and Beer 2001). Silvo-pastoral systems include planting leguminous trees and allowing animals to graze directly on the trees, or cutting and carrying the leaves from leguminous trees to animals (Cooper et al. 1996). Perennial crops such as coffee or cacao are planted under a canopy of trees, often leguminous, in a shade perennial-crop system. The trees may be coppiced periodically with the leaves used as mulch for the perennial crop or fed to animals (Beer et al. 1997). In parkland systems, crops are grown under an open, managed canopy of mature, often naturally occurring, trees (Rhoades 1997).

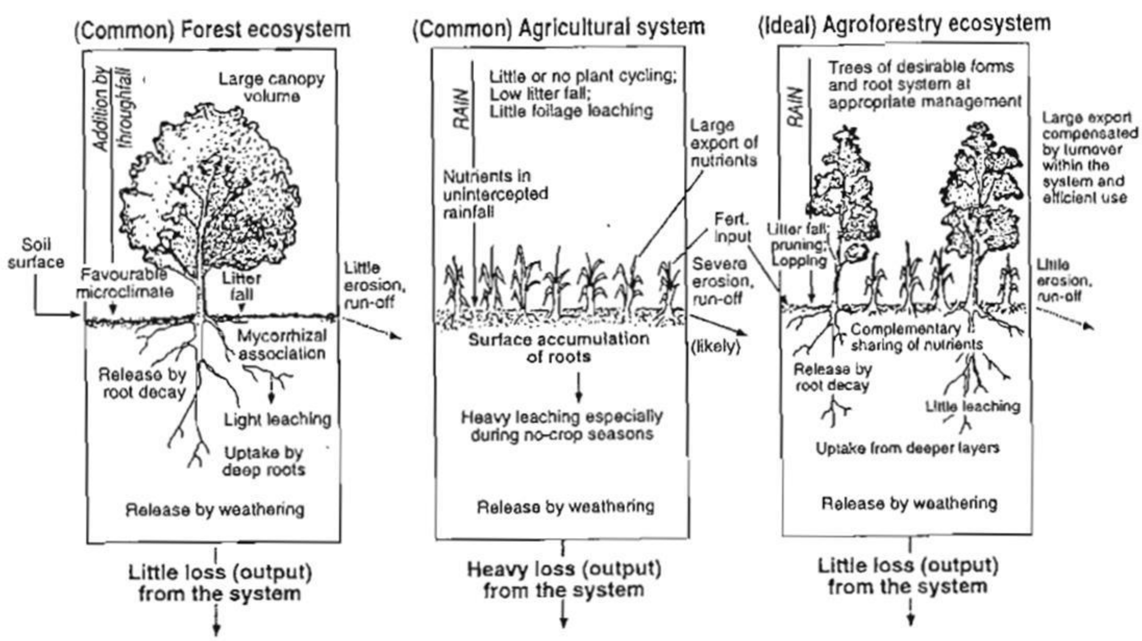

Fig. 1. Schematic representation of nutrient relations and advantages of ideal agroforestry systems in comparison with forest systems and agriculture (Source: Nair 1984).

Advantages from AFSs

The major environmental functions other than the food production of agroforestry can be enumerated as

- Control / reduction of soil degradation and rehabilitation of problem soils
- Control of desertification
- Flood and drought moderation
- Reduction in the pollution of groundwater resulting from high inputs of fertilizers
- Increasing biodiversity in the farming system and watershed scale
- Increasing food security and thereby reduce pressure on land resources
- Checking deforestation and its associated impact on environment
- Reducing pressure on forests through on-farm supply of fuelwood, fodder and other forest products
- Reduction in the build-up of atmospheric carbon dioxide and other greenhouse gases and mitigating adverse effects.

Table 1. Estimated agroforestry area in India

Category	Area (million ha)	Particulars
Agroforestry in rainfed areas		
Agri-silviculture	2.40	Scattered trees on fields, bunds, boundaries
Agri-horticulture	1.86	Fruit orchards/fruit trees based cropping systems
Trees on field boundary/bunds	0.74	Socail forestry, deliberate live fences, etc.
Silvo-pastoral	5.58	Trees on grazing/range lands
Homegardens	2..42[a]	Mostly in coastal areas and North Eastern states of Humid envirnment
Shifting cultivation	2.27 [b]	Mostly in NEH states and Orissa
Afforestation of problem soils	2.12	Plantation on salty soils, mine areas etc.
Trees on community /common lands	0.92	On panchayat lands, along roads, railways, etc.
Agroforestry on irrigated areas		
Agri-silviculture	2.63	Industrial use
Agri-horticulture	2.79	Fruit orchards/fruit trees based cropping systems
Total	25.31 [c]	Social forestry, live fences, etc.

(Source: NRCAF-2013: [a] Kumar (2006): [b] North Indian Council (1997): [c] FSI (2011))

Nutrient cycling – the general concept

In a soil plant system, plant nutrients are in a state of continuous, dynamic transfer. Plants take up nutrients from the soil and use them for metabolic processes. In turn, plants return nutrients to the soil either naturally as litter fall in unmanaged systems, deliberately as pruning in some agroforestry systems, or through root senescence in both managed and unmanaged systems. These plant parts are decomposed by soil microorganism, releasing the nutrients bound in them into the soil. The nutrients then become available for plant uptake once again. The term nutrient cycling, as used in most agroforestry discussions, refers to the continuous transfer of nutrients that are already present within a soil-plant system, such as farmer's field (Nair, 1993; Nair et al., 1995; Sanchez and Palm, 1996; Buresh and Tian, 1997). However, in a boarder sense, nutrient cycling involves the continuous transfer of nutrients within and between different components of an ecosystem and includes processes such as weathering on minerals, activities of soil biota, and other transformations occurring in the biosphere, lithosphere, and hydrosphere (Jordan, 1985).

The autotrophs (producers) component of an ecosystem (mostly plants) produces biomass through photosynthesis, a process which also involves transpirations of water and uptake of nutrients from the soil. Nutrients that are taken up are either stores within the plant or used in the production of new biomass. Some of these nutrients are subsequently returned to the soil through litter fall, root turnover, crown drip and stem flow. Decomposers in the soil mineralize nutrients back to inorganic forms that can be used again by autotrophs, but also use available nutrients, decreasing nutrient availability for autotrophs. Within-system movement of nutrients by water, wind and organisms as well as inputs to losses from the ecosystem, are essential processes (DeAngelis, 1992).

Natural forests ecosystems of the tropics represent self-sustaining and efficient nutrient cycling systems. These are "closed" nutrient cycling systems with relatively little los or gain of the actively cycling nutrients, and high rates of nutrients turnover within the system. In contrast, most agricultural systems represent "open" or "leaky" systems with comparatively high nutrient losses. Nutrients' cycling in agroforestry systems falls between these "extremes" (Nair et al., 1995). Figures 1, originally proposed by Nair (1984), presents a generalized model of nutrient cycling in an agroforestry system, in comparison to cycling in monocrop agricultural and natural forest systems. The figure emphasizes that the major differences between agroforestry and other agricultural production systems is the greater possibility of managing the AFS or its components to facilitate increased rates of nutrient turnover or transfer within different compartments of the system (Nair, 1993; Nair et al., 1995) (Figure 2). In order to exploit these nutrient-cycling advantages of agroforestry systems, we need to understand the processes involve. Several recent reviews have addresses the topic (e.g., Rhodes, 1997; Buresh and Tian, 1997; Mafongoya et al., 1997a). Based on the current level of understanding, there appear to be three main tree-medicated processes that determine nutrient cycling in tropical AFSs; (1) increased input of N through biological N_2 fixation (BNF) by trees; (2) enhanced availability of nutrients resulting from production and decomposition of substantial quantities of tree biomass; and (3) greater uptake and utilization of nutrients from deeper layers of soil by trees. Additionally, AFSs offers the possibility for reducing the loss of soil- and therefore nutrients–through erosion. This aspect, although relevant in the broad discussion on nutrient cycling, is not considered here. In some discussion, input, output, and turnover phases of nutrient cycling are discussed separately. We feel that it is more useful and realistic to include all three phases in a discussion organized according to the three main processes identified above.

Tree mediated processes that affect nutrient cycling in agroforestry systems

Biological nitrogen fixation (BNF) by trees

Both science and myth are involved in discussions on the role of BNF in nutrient cycling in tropical AFSs. The fact is that some trees that are, or potentially can be , used in AFSs have the ability to add N ot the soil through BNF. The main myth concerns the amount of N_2 fixed by treea and shrubs and the extent to which it is actually used or potentially available to the associated crop during various perios of time.

Among the 650 woody species beloning to nine families that are capable of fixing atmoshpheric N_2, 515 belongs to the family Leguminosae (320 in Mimosoidae, 170 in Papilionoideae and 25 in Caesalpinoideae). Several geera of non-leguminous N_2 – fixng trees (NFTs) are aso important in tropical AFSs; examples include Alnus and Casuarina. Among some 120 genera of NFTs (MacDicken, 1994), only a few are used directly as human food – fruits, floers, leaves (examples include the genera Erythrina, Inga, Leucaena, Parkia, Pterocarpus, and Sesbania): many are used for timber, fuelwood, or fodder; and most, if not all, for soil improvement. This last aspect soil improvement is achived throuh several processes: (1) the direct contributon by trees to the soil N pool through transfer of biologically fixed N, (2) increased nutrient turnover and availability due to increased production and decomposition of biomass, and (3) improved erosion control via appropriate tree plant of arrengements and mulching with tree prunings.

Among the various AFSs in the tropics, the most widely studies in terms of N_2 fixation are two simultaneous systems: alley cropping and shaded perennial- crop systems. Lastly, sequential systems such as improve fallows are also being studied more rigorously (Rao et al., 1997). The presnet knowledge of BNF in the two simultaneously systems has been reviewed extentisively by Sanginga et al., (1995) (alley cropping) and Beer et al. (1997) (shaded perennial–crop systems).

Some early reports on alley cropping climed that enormously large quantities of N were fixed by some fast growing tree species used as hedgerows, especially *Leucaena leucocephala* and *Gliricidia sepium* (Figure 2). Sanginga et al. (1995), in their review, cited N_2 fixation levels of 100 to 300 kg and some times up to 500 kg N ha^{-1} yr^{-1}. But such estimates are subject to a numbe of variables such as soil, climate, and plant management conditions. Furthermore, it has lately ben found that high variability exists among provenances or isolines of NFTs in the percnetage total plant N deived from atmospheric N_2 (Sanginga et al. 1995). Yet another problem is the difficulty in assessing the extent to which the N_2 fixed by NFTs becomes available (N recovery rates) to crops that are associated with the NFTs during current and subsequent seasons. The extent of N recovery is ependent on the rate of organic matter decomposition and mineralization (section: Tree biomass and its decmposition)

Nitrogen fixation has been evaluated in a nuber of studies involving sghaded perennial-crop system as well. Studies during the 1980s in unfertilied coffee a cacao palnatations shaded with *Inga jinicuil*, *Gliriridia sepium*, and *Erythrina poeppigiana* and in fertilized plantations under *E. poeppigiana* (Lindblad and Russo, 1986) estimated N_2 fixation levels to 35 to 60 kg ha^{-1} yr^{-1}, using acetylene reduction assay. These could well be underestimates because the acetylene reducton method measures only short-term nitrogenase activity (Peoples and Herridge, 1990). Comparin nutrient balances of leguminious and non-leguminous shade-tree/ coffee associations, Fassbender (1987) aso estimated 60 Kg ha^{-1} yr^{-1}as N_2 fixation by *E. poeppigiana.* Nygren and

Ramirez (1995) found that *E. poeppigiana* nodules disappeared almost completely for 10 weeks after pruning, which suggets that there may be 20 weeks in the year during which these es biannually pruned treees would not fix N_2 and hence compete with the assocaiated crop for soil N.

The mixed plantating of leguminous and non- leguminous, fastgrowing tree species, such as *Acacia* and *Eucalyptus* species, in short–rotation industrial plantations bacame another simultaneous important system involving perrinials species. This practice is gaining popularity in some parts of the tropics, especially in southest Asia. Comparing nutrient cycling under such mixed stand with nutrient cycling under pure stands, Khannna (1997) concludes that the addition of NFTs to pure stands on non-NFTs may alter nutrient cycling in the systems through (1) direst effect from the addition of N by NFTs, (2) indirect effects due to interactions caused by the addition of N by NFTs, and (3) increased competitions for nutrients. In six year old ixed plantatings of Eucalyptus sp. And Albizia sp. In the proportion of 34:66 in Hawaii, Binkley et al., (1992) observed higher biomass production, above ground net primary productivty, and annual growth increment in the mixed species stand than in the respective single species stands. Similarly, in Thailand, Foelster and Khanna (1997) observed higher mand tree basal area and basal area increments in four year old mixtues of *Eucalypts globulus* and *Acacia mearnsii* than in the pure stands of these species. Both studies concluded that N contribution from the NFTs in the mixtures was substantial enough to not ony compensate for, but even to outweigh the determental effects of possible competation between the species for lights, water and other nuteirents, especially P. Although detailed studues that describes the processes leading to such enhanced growth of species in mixtiures are lacing, faciliation through N additions to the systems iss trongly suggested. NFTs are a valuable resources in AFSs. If the N is trnasfered continuously from the NFT to the soil, the inclusuon of the NFT should enhance the soil N status in the long run.

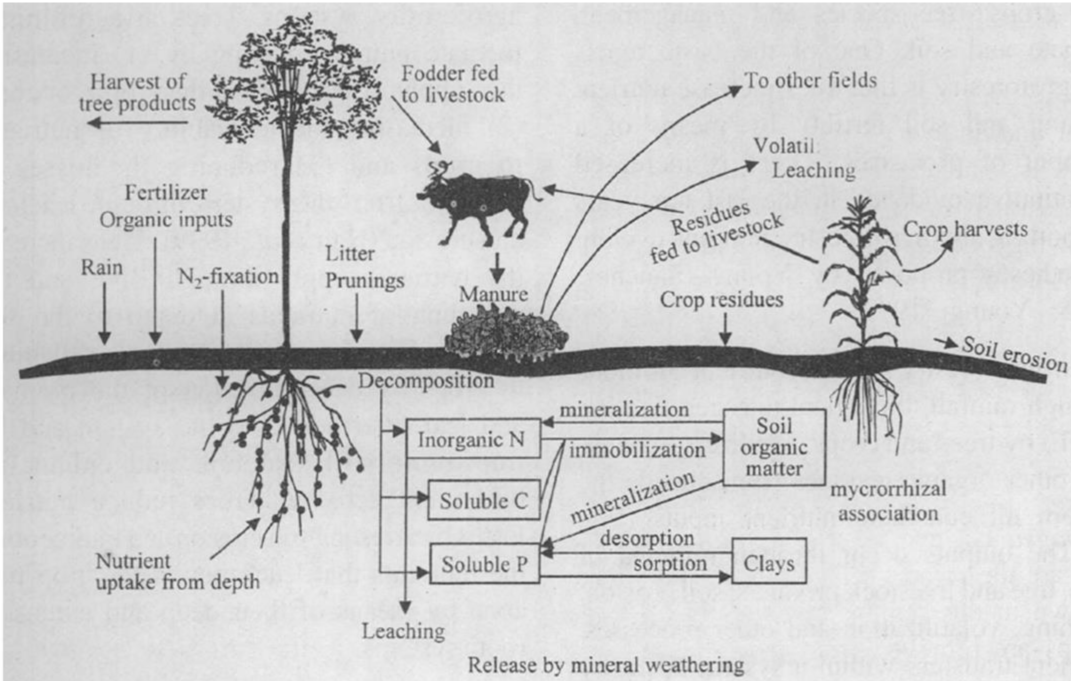

Fig. 2. Main pathways of nitrogen and phosphorus cycling in agroforestry systems (adapted from Sanchez et al., 1997). Fertilizer inputs are neglible in smallholders farms in the semi-arid Africa and Asia

Tree biomass and its decmposition

One of the major recognized avenues of soil fertility improvement in tropical AFSs is the recycling of nutrients hrough decomposition of tree biomass–mainly leaf litter or prunings, but also roots–that is added to the soil. Obviously, the extent of benefits derived will depend on the quantity and nutrient content of the biomass added, and the rate at which it is decmposed. Voluminous information is available on the nutriet systems under a variety of conditions, especially in systems such as alley cropping and improved fallows where soil fertility improvement is a major objectve. As is to be expected, considerable variation exists in such data. Most reports on nutrient content of tree bimass deals with N; other elements such as P and K are less commonly reported. The C to N rations of the leaf biomass of 17 N_2 fixers range from 10 to 25, whereas the 10 non- N_2 fixing species, the range is from 14 to 32. If the C content of the leaf biomass is assumed to range from 45 to 50 %, the N content of leaf biomass will range from 2 to 5 % for these N_2 – fixing species and 1.4 to 3.5 % for the non- N_2 fixers. As for P and K, information of general nature available in the literature shows a range of 0.15 to 0.29 % for P and 0.9 to 0.152 % for K in leaf biomass of common agroforestry tree species (Nair, 1993; Palm, 1995). Added to these variations in nutrient content of the materals, there is enormous variation in the reported quantities of biomass roducton by different species under various situations (Table 2, 3 & 4). Therefore, the extent of soil fertility improvement caused by nutrient ccycling via tree biomass decomposition in AFS is very site specific.

While trees in AFSs may supply N to associated crops, but their ability to supply P is very limited. Many tropical soils have very low native P levels (Sanchez and Palm, 1996; Buresh et al., 1997). Indeed, the low native soil P, high P fixation by soil with high iron and aluminum contents, and the nutrient–depleting effects of long-term cropping without additons of adequate exterenal input have contributed to P deficiencies in many topical soils (Jama et al., 1997). Nevertheless, applications of tree biomass to the soil has been shown to increase crop avaialble P especially in the highly weatehered tropical soil. This is achieved either directly by the process of decomposition and release of P from the biomass or indirectly by the production of organic acids (by products of decomposition) that chelate iron and aluminum, reducing P fixaton. However, as reported by Palm (1995), the quantity of P cntained in the biomass of most multipurpose tree species used in AFss is insufficient to supply tge crops's P demand, through the biomass may contain sufficient N to meet the integrate an inorganic crop N requirements. Jama et al. (1997) concluded that it could be economically attractve to integrate and inorganic P source wih the organic material, whereby the organic materail would provide the requiremennt N for the crop and the inorganic P source would meet the aditional requirement of P.

Widely varying estimates of root biomass addition have been reported from different AFSs. Fassbender et al. (1991) reported that in a five year old stand of *Theobroma cacao* and *Cordia alliodora* in Costa Rica with an above ground biomass store of 4.9 Mg ha^{-1}, The fine and small root biomas constituted 4.2 Mg ha^{-1} (9 % of above ground biomass). The corresponding figures for a 10 year old stand were 95.4 nad 9.8 Mg ha^{-1} (10%). These percentage figures are on the lower end of the range (3-33) reported by Vogt et al, (1997) for a wide variety of tropical forests and forest plantations ecosystems, Schroth and Zech (1995) reported that an alley cropping system involving *Gliricidia sepium* with maize (*Zea mays*) and groundnut (*Arachis hypogaea*) in the West African rainforest zone produced 1.1 Mg ha^{-1} yr^{-1} of root biomass in the 0-50 cm soil layer, equivalent to 8.8 % of the above ground biomass (13.6 Mg ha^{-1} yr^{-1}). Govindarajan et al. (1996) reported from semiarid highlands of Kenya that in an alley cropping system of *Leucaena leucocephala* and maize, fine root biomass production by *L. leucocephala* was only 510 kg ha^{-1} durg a cropping season of about 120 days.

It is belived that root tissues are continuously sloughed off and replaced, and that these sloughed off tissues, along with senescent and dead roots constirute a significant avenue of addition of organic matter (and nutrient) addition to the soil ecosystems. Furthermore, above ground management of plants (such as prunings in hedgerow intercropping systems) might influence root dynamics. Studies on these aspects have been very limited and inconclusive. Deconposition of organic materaisl and the rate at which their nutrients are released are determined by the "quality" of the materails, the environment, and the decomposer organisms that are present. Since many recent studies have focused on the quality of palnt biomass avalable in AFSs, a iscussion on the current status of this topic will be useful.

Plant litter quality

For this discussion, the quality of an organic materail referes to its (organic) constituents and nutrient conent (Mafongya et al., 1997c). Organic constitutes are important bacause the energy available to decomposer organisms depends on the proportion of soluble C, cellulose and hemicellulose, and lignin. Soluble C includes metabolic and storage C, and is primarily responsible for promoting microbial gowth and activity. Green foliage usually contsins 20 % to 30 % soluble C. Cellulose and hemicellulose, which constitutes 30 % to 70 % of plant C (12 % to 30 % of total palnt mateial) are structural polysaccharidies of "intermediate" quality; they are attacked ny the decomposer microbes after soluble carbohydrates have been and other cell wall constitutes from degradation (Chesson, 1997), is the lowest – quality. C constituent, prviding little or no energy to the decomposer untill the last stages of decompostions. Thus, the lignin conent of the organic material is considered to be the most important factor detemrining the rate of decomposition (Megendi and Nair, 1997). Lignin content of AFS tree species varies from 5% to 20 % of dry weight in green foliage abd 10% to 40% in senescent foliage or leaf litters. It has been suggested that 15% is a critical level, above which decmpoition is impared (Mafongoya et al., 1997C). Many recent studies with agroforestry tree species have shown that polyphenols and condensed tannins, which cmprise a relatively small percentage of the organic materail, have a disprootionately large negatibve influence oc decompostion and N relaese (Mafongoya et al., 1997 a;b). The effect of the bound condensed tannins (insoluble) is similar to that of lignin: they make the call wall and proteins physically or chemically inaccessible to decomposer organisms and thus decomposition. In geneal, total soluble polyphenols content of green foliage of agroforestry species can be as high as 10 %, but is usually less tha 5%. In addition o=to the C quality, nutrient especially N content of plant materials is a major determinant of litter quality. Generally, materials with N content higher than 20 mg g^{-1} are considered to be of high quality, although this can be modified by lignis and polyphenols contents (Mafongoya et al., 1997a:c).

Amount of nutrients

Before knowing the AFSs the important question arises it that, do tree prunings contain enough nutrients to meet crop demand, it is necessary to know the amount of prunings produced and their nutrient concentration, as well as the nutrient requirements of specific crops. A large number of biomass production screening trials and alley cropping trials have been conducted in a range of climate and soil environments with a variety of leguminous trees, and even a few non-leguminous trees. Reviews indicate that leguminous trees in alley cropping systems produced up to 20 t ha^{-1} yr^{-1} dry matter of prunings, containing as much as 358 kg N, 28 kg P, 232 kg K, 144 kg Ca, and 60 kg Mg (Young, 1989; Szott et al., 1991), more than enough to meet most crop requirements. In situations where trees are inter planted with crops, fine roots can also supply nutrients to crops through root turnover and root dieback, caused by pruning above- ground biomass.

There is little data on the amount of nutrients supplied through roots in AFSs so this paper will focus on aboveground inputs. It is, however, important to note that fine root and mycorrhizal turnover in forest systems can contribute two to four times more nitrogen and six to ten times more phosphorus than aboveground litterfall (Bowen, 1984), so tree roots in agroforestry systems are likely to contribute a considerable amount of nutrients to intercropped plants. Despite the large number of biomass screening trials, it is difficult to make recommendations for a given environment as to which trees produce sufficient pruning biomass. The nutrient content of the prunings depends on many factors, including tree species and the relative proportions of leaves and stems in the prunings and their respective nutrient concentrations. Even among leguminous trees the N concentration of the leaves varies from 1.5 to 3.4% (Young, 1989), or more. Within a species nutrient concentrations can vary by a factor of two or more as shown in Budelman's (1989) review of the information on nutrient content of leaves of *Leucaena* *leucocephala* and *Gliricidia sepium*. Despite the higher nutrient concentrations in *G. sepium*, *L. leucocephala* produced more pruning biomass and therefore served as a better source of nutrients for crops (Budelman, 1989), showing that the combination of factors is important. Differences in nutrient concentrations within a species can be due to a number of factors, including differences in provenances, soil fertility, climate, season, age of leaves or plant, frequency of pruning, or even differences in the laboratories or methodologies used to analyse nutrients. Budelman (1989) suggests that soil nutrient status is the most important factor influencing nutrient concentrations within a species. The magnitude of the effect, however, varies among species. There is currently no way to predict the biomass and nutrient production for a particular species for a given soil, climate, and management practice, and there is not likely to be in the near future, except for a few well-documented species such as *L. leucocephala* and *G. sepium*. Fernandes et al. (1994) and Young (1989) have recommended several species with high biomass production and nutrient content for use in different environments. Given the constraints of the existing data for making recommendations, examples are given to illustrate the amount of nutrients provided in the leaves from tree prunings and other organic inputs compared with the nutrients required by a maize crop (Table 2 & 3). The nitrogen (N) content of 4 t ha^{-1} of leaf material from a variety of agroforestry trees, except for the two non- leguminous species, is sufficient to meet the demands of 2 t of maize (plus 3 t stover). Whereas N was the focus of early studies in agroforestry and alley cropping in particular, in general tree prunings can meet crop N requirements, even though as little as 14% and often less than 50% of the N in prunings is from N fixation (Giller and Wilson, 1991). Calcium demands were met by all the species and magnesium demands were Close to being met. Potassium was not supplied in sufficient quantities by many of the species but if crop residues are recycled the nutrient balance is positive. Phosphorus (P) was not provided in sufficient quantities to meet crop demand by any of the species. Even if crop residues are recycled there is still a negative P balance.

In order to meet P requirements, either more pruning biomass must be applied or the concentration of P in the prunings must be higher both of these options are somewhat limited. When discussing nutrient balances and nutrients applied via prunings of agroforestry trees, it is necessary to make an important distinction between nutrients recycled within a system and nutrients added to the system. Prunings added to inter cropped plants are recycling nutrients within the soil-plant system, they are not a nutrient addition to the system. Some of the N may be added to the system by N fixation but the amount of N fixed varies greatly depending on the trees used and the environmental conditions (Giller and Wilson, 1991). Some nutrients, otherwise considered unavailable to crops because they are below the rooting zone of the crops, might be brought into the system from deeper layers in the soil by trees with deeper roots but the magnitude of this 'input' is not known. If crop products are harvested, then there is a net loss of nutrients from the system. Recycling of nutrients through prunings does not offset those losses. Eventually a decline in productivity of the systems would be expected, unless external nutrient inputs are supplied in the form of inorganic fertilizers or organic amendments.

Litter (Biomas) decomposition

It is possible ot make reasonably accurate predictions about decompostion rates of plant materails that are commonly used in AFSs. Mafongoya et al. (1997c) summarized these for a number of agroforestry speices, as reported in table 2, 3 & 4. They concluded that leaves that are high N, llow in lignin, and low in polyphenols (e.g., those of Gliricidia sepium and Sesbania spp.) wi decompose quickly and release large proportion of their N. Well lignified leaves (e. g. those of *Dactyladenis barteri* and *Fleingia macrophylla*) will decompose slowly and may cause immobilization of soil N for da fairly long period (several weeks) after they are added to the soil. The decompositon pattern of biomass of species with high N and polyphenols contents may be goverened by the protein binding capacity of the polyphenols: decomposition will be slow when protein-binding capacity is hgh (as in *Calliandra calothyrsus*). Furthermore, even species with narow C to N ration and low lignin and polyphenol contnents may decompose slowly if large amount of N are bound to condensed tannins, as if the case of Senna siamea. Thus variations in decomposition patterns for biomass for several AFS species can be handled with appropriate management practice.

Table 2. Nutrients required by a crop of maize compared to the nutrients contained in 4 t of organic inputs. (adopted from Palm, 1995)

A. Nutrients required by a crop maize					
	Nutrients kg ha^{-1}				
	N	**P**	**K**	**Ca**	**Mg**
Maize					
Grain (2 t)	50	12	30	6	4
Stover (3 t)	30	6	36	9	6
Total	80	18	66	15	10
B. Nutrients added in 4 t of leaves of various organic input					
Species	N	P	K	Ca	Mg
Leucaena leucocephala	154	8	84	52	13
Erythrina poeppigina	132	7	46	61	-
Inga edulis (fertile soils)	142	11	40	45	6
Inga edulis (infertile soils)	127	9	50	30	7
Senna siamea	105	6	44	110	7
Dactyladenia barteri	60	4	31	40	8
Grevillea robusta	52	2	24	60	7
Maize stover	40	8	48	13	8

Table 3. Percent added N released from leaves of agroforestry trees during eight weeks of incubation from various studies.

Material added	**Oglesby and Flowers, 1992**	**Constantinides and Flowers, 1994**	**Tian et al., 1992**	**Handayanto et al., 1994**	**Kachaka et al., 1993**
Gliricidia sepium	60	70	42	31	-
L. leucocephala	35	25	23	16	58
Calliandra calothrysus	11	28	-	18	-
Senna siamea	30	38[a]	10[b]	-	40[b]
Inga edulis	11	28	-	-	

[a] Used leaves and stem; [b] Denotes initial immobilization

Table 4. The % N mineralization, % recovery to the total N added, % recovery of the N mineralized, % remaining in undecomposed plant material, and the % of that is un accounted for following the addition of leaves of several agroforestry tree to crop. Values within a study are comparable but not among studies.

Source on N	% Mineralized	% recovery of total N	% recovery of the N mineralized	% remaining in much	% Lost or in SOM	References
L. leucocephala	76	4	5	24 [b]	71	1
Sesbania sesban	89	31	35	11 [c]	58	2
L. leucocephala	88	10	12	12 [c]	78	
Calliandra calothrysus	40	-3	-	60 [c]	>40	
Acacia cunninghamii	66	2	3	34 [c]	64	
L. leucocephala	47	11	23	53 [d]	36	3
G. sepium	48	13	23	52 [d]	35	
Peltophorum dasyrachis	24	8	32	76 [d]	16	
C.calothrysus	32	7	22	68 [d]	35	
G. sepium	100	21 [a]	21 [a]	0 [e]	79	4, 5
L. leucocephala	90	26 [a]	28 [a]	10 [e]	64	
Inga edulis	68	12	18	32 [f]	56	6
Erythrina Sp.	94	21	22	6	73	
Cajanus cajan	73	20	27	27	53	

[a] Compared to fertilized control; [b] 84 days; [c] 70 days; [d] 64 days; [e] 100 days; [f] 4 rice crops

Refferences: 1. Mulongoy and Van meersch (1988); 2. Gutteridge (1992); 3. Handayanto et al., (1994); 4. Tian et al., (1992b); 5. Tian et al., (1993)

Management of decomposotion and nutrient-use efficiency

Biomass decomposition can be manipulated to improve the efficiency of uptake and utilization of nuteents by growing palnts, especially in simultaneous AFSs. Mafongoya et al.(1997c) suggest two strategies for this: (1) regulate the rates of relaese of nutrients to improve the synchrny of nutrients supply with plant (crop) demand, and (2) provide a more favorable environment for pant growth. While the former is of immediate (short term) nature, the atter invlves longer term improvements, often mediated through improvements in soil organic amtter (SOM) status. Green foliage composes the bulk of plant biomass that is available for decomposition in AFS, as opposed to senescent material (litter) that dominates the biomass input in natural and agricultural systems. Beacause mobile nutrients are translocated from senescent leaves to oter plant parts before ltterfall, litter differs from green foliage in quality and, therefore, decomposition rates. Conditions prevaling during tree growth can aso results in plant biomass of different quality. Incrased N concentration and reduced polyphenols concentration in leaves consequent to enhanced N supply to the plants resulted in fatse decomposition and uptake of released N by maize (Handayanto et al., 1997a;b). These resuts indicate that higher N_2 fixation by trees could result in the production of better quality leaf biomass compared with biomass from trees growing under N- starved conditions.

A number of field management operations can alter biomass quality or the rate of its decay: (1) the duration and temperature of drying the materials before applying it to the soil (fresh prunings decompose faster than sun-dried prunings), (2) the physical size of the material (smaller sized materials decompose faster than larger and coarser materials), (3) the mixing of biomass of differing compositions, and (4) the menthod of applying the materials (incorporating materials into the soil results in faster decomposition than surface palcement) (Mafongoya et al., 1997b;c).

When tree biomass is used as a source of nutrients for crops, it is important to ensure synchrony between the release of nutrients (*via* decompositions) and their uptake by the crop (Nair, 1993). Improved synchrony will enhance nutrient for eficiency by minimizing the loss of nutrients (Myers et al., 1994). Synchrony can be achived (1) by manipulating the crops's demand for nutrients through adjustments in the time of planting and crop selection, and (2) by manipulating nutrient release through adjustments in biomass management, as described in this section. A schematic representation of manipulation of synchrony is provided in Figure 3. An imortanr point to consider in this context, as in the case of biological N_2 fixation, is the so called nutrient recovery, which indicates the extent to which the nutrients that are released from biomass decomposition are taken up by the current (and subsequent) season' crops. Many leguminous tree species used in AFSs, especially alley cropping and biomass transfer systems, are capable of producing substancial quantities of biomass (see table 3), through which nutrients, with the notable exception of P, are recycled in quantities sufficient to support crop growth (Palm, 1995). In sub humi Kenya, Mugendi et al., (1997b) used ^{15}N to estimate N recovery from tree biomass applied to the soil in an alley cropping experiment. Only 9 % to 13% of the initial ^{15}N was recovered by the first season's maize crop, while 55% to 69% was recovered in the soil organic N pool after the cropping season. The remaining 20% to 30% of the ^{15}N could not be accounted for (Table 5). Hagger et al. (1993) also reported the amount of N left in the soil after the first crop to be as high as 80% of the initial N applied in the tree biomass.

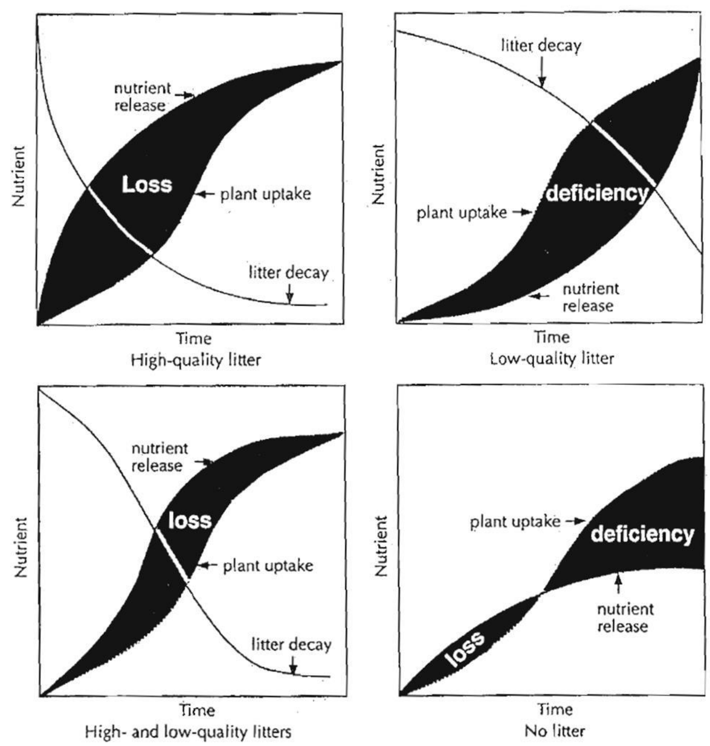

Fig. 3. Hypothetical patterns of nutrient availability in four treatment of an experiment to test the synchrony principle. Source: Myers et al., (1994).

Although low recovery by a crop of N released from decomposing organic material des not necessarily imply a corresponding build-up of SOM, these studies suggest that a considerable portion of N added as tree biomass to crop production filed can be retained in SOM. In shaded perennial crop systems, transfer of N from the N_2- fixing leguminous shade trees to non-N_2-fixing associated crops has generally been assumed to occur largely through the decomposition of aboveground pruning residues and litter fall. Studies carriedout in latin Americal coffee and cacoa plantations, with 120 to 560 leguminous shade trees per hactare pollarded 0 to 3 times annually, showed that these inputs could vary from 3 to 14 Mg ha^{-1} yr^{-1} fo 57 to 66 kg ha^{-1} yr^{-1} was released through nodule senescence and decomposition, with no difference in nodule N content (22 to 23 kg ha^{-1} yr^{-1}) between the fertilized and unfertilized plots. Nygren and Ramfrez (1995) found a turnover of 6.8 to 35.4 g N $tree^{-1}$ in a 23 week pruning cycle (9.6 tp 50.0 kg N ha^{-1} $yr^{-1)}$ through *E. poeppigiana* nodule senescence and decomposition. These studies suggest that a significant proportion of N_2 fixing plants. As regards the extent of N cycling, Babbar and Zak (1995) found higher rates of N mineralization in Costa Rican coffee plantaiton shaded by *E. poeppigiana* (148 kg ha^{-1} yr^{-1}) than in plantations without shade trees (111 kg N ha^{-1} yr^{-1}; both sites were heaily fertilized with mineral N at rates up to 300 kg N ha^{-1} yr^{-1}). They conculuded that N cycling was more efficient in shaded plantations because, despite the grester availability of minerilized N, less N was lost through leaching.

Tree urake of nurtients from deeper soil layers

It has long been recognized that in some tree species, roots extend far deeper into the soil than the rooting depths of common agricultural crops (Stone and Kalisz, 1991). Recent research on AFS trees has focsed on this dep rooting attrbutes of tree, with a view to understaning the spatial distribution and temporal patterns of root growth (van Noordwijk et al., 1996) and relating such information to nutrient uptake by tree roots from deeper soil layers (Buresh and Tian, 1997). Reviewing the current level of knowledge in this area of research. Buresh and Tian (1997) concluded tat the potential of trees to take up subsoil nutrients is generally greatest when the trees have dep root systems and a high dend for nutrients, and when they are grown in locations with water and/ or nutrients stress in the surface soil but considerable reserves of plant-available nutrients or weatheable minerals in the subsoil.

In western kenya , researchers have noted the accumulation of fairly large quantities of nitate (70 to 315 ka N ha^{-1}) I acid soils at 0.5 to 20 m depth under unfertilized maize and have attributed it to the formation of nitrate by mineralization of SOM and the sorption and retention of nitrates by clay minerals. Fast growing trees such as C. calothyrsus, Sesbania sesban, and Eucalyptus grandis grown in rotation with maize rapidly root into this nitrate accumulation zone and take up the sorbed nitrate that is inaccessible to maize (Jama et al., 1998). Mekonnen et al., (1997) observed that nitrate N to 4 m soil depth was only 51 ka N ha^{-1} in a 15 month S sesban fallow, as copard to 199 kg N ha^{-1} under fertilized maize. The maximum rooting depth was 1.2 m for maize, where as of 15 month old *S. Sesban* extended to below 4m. In another study on an acid soil in western Kenya, Jamma et al. (1998) further showd that fast growing trees with high roor length densities can rapidly utilize sub-soil nitrate on soil no chemical and physical barriers to rooting. Fats growing S. sesban and C. calothyrus rooted to >4 m depth in 11 months, but slower growing G. robusts had few roots below 3 m depth. *S. sesban* and *C. calothyrsus* and root length densities of >0.1 cm cm^3 ro below 1.5 m depth, and they reduced soil nitrate throughout the 2 m deep soil profile. The reduction in soil nitrate in the top 2 m (150 to 200 kg N ha^{-1}) correspnded to large accumulation of N in aboveground biomass for *S. sesban* (336 kg N ha^{-1}) and *C. calothyrsus* (312 kg N ha^{-1}). Slower growing G. robusta only accumulated 107 kg N ha^{-1} in aboveground biomass, and soil nitrate increaed rather than decreased duriing the 11 months after establishment.

The potential for nutrient uptake from deeper soils is much greater for water soluble nutrients such as nitrate than for immobile nutrients such as P. There is typicaly lttle potential for trees to take up and recycle P from below the rooting depth of annual crops because plant extractable P is normally low in sub oil and the posphate ion is realtively in soil Buresh and Tian, 1997). The role of trees in nutrient uptake from deeper soil layers for nutrients other than N and P is, general, little studied. Soil physical and chemical barriers to rooting will reduce the potentail of trees to retreive and take up subsoil nutrients. Mobile nutrients in acis soils of the humid tropics can be leached by high rains into subsoil where high aluminium ssturation retricts the rooting of crops. In such systems, the roots of trees with a horizontal spread in the sub soil may act as a safety ney, which intercepts nutrients as they leach own the soil profile (van Noordwijk et al., 1996). In semiarid areas, the lateral extentions of tree roots is considered to be more important in nutrient uptake than the penetration of roots to deeper soil horizons. As noted by Sanchez and Palm (1996), nutrients taken up by trees roots from beow or beyond the root zone of interpalnted annual crops can be an important input in AFSs when these nutrients are transferred to the crop rooting zone and made available to crops through biomass addition and decomposition.

Agroforestry for Soil Conservation and Amelioration

Agroforestry plays a key role in keeping the soil resource productive, which is one of the major sustainability issues. Closely spaced trees on slopes reduce soil erosion by water through two main processes: first as a physical barrier of stems, low branches, superficial roots, and leaf litter against running water and secondly as sites where water infiltrates faster because of generally better soil structure under trees than on adjacent land. Agroforestry played a major role in the recent past in rehabilitation of wasteland such as desert and lands that have been degraded by salinization and ravines, gullies and other forms of water and wind erosion hazards. These aspects have been discussed in detail in earlier chapters. Agroforestry systems on arable lands envisage growing of trees and woody perennials on terrace risers, terrace edges, field bunds, as intercrops and as alley cropping in the shape of hedge row plantation. Integrating trees on the fields act as natural sump for nutrients from deeper layers of soil, add bio-fertilizer, conserve moisture, and enhance productivity of the system.

In a study on an acid soil in Eastern Ghats India, Hombegowda et al. (2020) verified the effectiveness of two hedge row systems with trench planting for minimizing run-off, soil and nutrient loss, improving soil moisture, and SOC sequestration, while maintaining higher grain yield of finger millet. In this study the treatment Gliricidia + Trench planting (G + TP) reduced run-off by 29%, soil loss by 45–48%, and loss of soil organic carbon (SOC), N, P and K by 42–47, 62–65, 54–58 and 51–56%, respectively over control. Similarly for Leucaena + Trench planting (L + TP), the values were 17–19, 27–40, 28–37, 42–50, 39–49, and 37–46%, respectively, over control. Reduced run-off in the G + TP treatment increased soil moisture storage by 11–29%. Alley cropping with *Leucaena leucocephala* was effective for erosion control on sloping lands up to 30 %. Reduction in crop yield could be minimized by shifting the management of trees as contour hedge rows. The sediment deposition along the hedge and tree rows increased considerably with consequent reduction in soil loss. Improvement in the organic matter status of the soil can result in an increased activity of the favourable microorganisms in the root zone. In addition to the nutrient relations, such micro-organisms may also produce growth-promoting substances through desirable interaction and result in better growth of plant species. Inclusion of trees and woody perennials on farm lands can, in the long run, result in marked improvements in the physical conditions of the soil, e.g., its permeability, water-holding capacity, aggregate stability, and soil-temperature regimes. Although these improvements may be slow, their net effect is a better soil medium for plant growth. Experimental evidences give a very clear picture about agroforestry system that increased soil organic carbon and available nutrients than growing sole tree or sole crop (Hombegowda et al., 2016). An increase in organic carbon, available N, P, and K content in Khejri based silvopastoral system over no-Khejri soil, advocating retention/plantation of Khejri tree in pasture land to get higher fodder production and to meet requirement of food, fodder, fuel, and small timber is one such example. Similarly, an increase in soil organic carbon status of surface soil under *Acacia nilotica Sacchram munja* and under *Acacia nilotica Eulaliopsis binata* after 5 years was observed. It was found that *Acacia nilotica Eulaliopsis binata* are conservative but more productive and less competitive with trees and suitable for eco-friendly conservation and rehabilitation of degraded lands of Shiwalik foot hills of subtropical northern India. Rehabilitation of degraded forests is possible through afforestation by adopting integrated land use planning with soil and water conservation measures on watershed basis. NRCAF observed that in agrisilviculture growing of *Albizia procera* with different pruning regimes, the organic carbon of the soil increased by 13–16 % from their initial values under different pruning regimes, which was five to six times higher than growing of either sole tree or sole crop.

Agroforestry systems have been developed using local resources and conservation-based measures in the North Eastern Hill (NEH) region. Suitable alternate land use systems involving agriculture, horticulture, forestry, and agroforestry have been designed with the support of local natural resources for almost identical hydrological behaviour as under the natural system. The model land use suggests utilizing slopes below 50 % toward lower foothills and valley lands for agricultural crops and pisciculture, middle slopes between 50 and 100 % for horticulture and top slopes over 100 % for forestry/silvopastoral establishment. Under agrihorti-silvopastoral systems, the reduction in runoff was 99 % and in soil loss 98 %. Combining fine-root system of grasses and legumes, such as *Stylosanthes guyanensis*, *Panicum maximum*, Setaria, etc., and deep-root system of fodder trees, such as alder (*Alnus nepalensis*) in a silvopastoral system stabilizes terrace risers and provides multiple outputs. In-depth evaluation of soil chemical properties of traditional agroforestry system in north eastern region indicated a spectacular increase in soil pH, organic C, exchangeable Ca, Mg, K, and build-up of avai1able P under different agroforestry practices (AFP) within 10–15 years of practice. The exchangeable Al, potential cause of infertility of these lands disappeared completely within 10–15 years of agroforestry practice. Therefore, the agroforestry practices were found to have built in dynamism for the restoration of soil fertility and sustained yield. Similar results were obtained when multipurpose trees were evaluated in an extremely P-deficient acid Alfisol in Meghalaya. The use of trees as shelterbelts in areas that experience high wind or sand movement is well established example of microclimate improvement that resulted in improved yields. Increased agricultural production due to windbreaks and shelterbelts in India has been well demonstrated. Establishment of micro-shelterbelts in arable lands, by planting tall and fast-growing plant species such as castor bean on the windward side, and shorter crop such as vegetables in the leeward side of tall plants helped to increase the yield of lady's finger by 41 % and of cowpea by 21 % over the control. In general, the use of shelterbelts brought about a 50 % reduction in the magnitude of wind erosion.

Conclusions

Many leguminous agroforestry trees produce sufficient pruning biomass and contain enough nutrients, except for P, to meet crop demand in intercropping systems. The nitrogen release patterns, or quality, of the prunings differs greatly, from 100% mineralization to net immobilization during the course of crop growth. These patterns are reflected in differential crop growth in pot studies but not in field studies. In general, only 10 to 20% of the N released is taken up by the first crop and a large portion is in the soil organic matter, indicating that the N benefit of the pruning additions is in the long term rather than immediate. The effect of different quality inputs on the various soil organic fractions and their N supplying capacity is not known.

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Chapter 5

SOIL MANAGEMENT INTERVENTIONS FOR CLIMATE CHANGE MITIGATION THROUGH CARBON SEQUESTRATION

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Introduction

Soil is a storehouse of nutrients and water essential for crop production, hydrological cycle and atmospheric gas exchange. It is the foundation for plant establishment, growth, agriculture, and forest and livestock production. The soil's biodiversity and abundance of biological activity are more incredible than in any other terrestrial ecosystem. Soil contributes about 98% of our food directly or indirectly (Lal et al., 2021). Climate change, variability, and mismanagement or misuse of resources lead to soil degradation and vulnerability. The SOC pool in 1 m depth of soil is 30 tons ha^{-1} in arid regions, whereas in organic soils of temperate areas, it is 800 tons ha^{-1}. But it is also an alarming message that most agricultural soils have lost 30 to 75% of the soil organic carbon pool that accounts 30 to 40 t C ha^{-1}. This carbon loss is more significant in soils prone to accelerated erosion due to human activities, resulting in soil quality degradation and productivity decline. The optimum organic carbon level is necessary for the soil to hold water and nutrients, decrease soil erosion and degradation risks, improve soil structure, and provide energy to soil microorganisms.

In contrast, soils have more potential to store carbon than other terrestrial ecosystems as agriculture, deforestation, and other anthropogenic activities have reduced their organic carbon content. Practices like intensive agriculture, high chemical input farming, and clean cultivation have drastically depleted the soil's organic carbon content and adversely affected soil health. The critical limit of SOC concentration for tropical soil is 1.1%, but they have a very low organic carbon content level of 0.1 to 0.2 %. Accomplishing the critical organic carbon content level in these regions will be arduous for farmers and scientists. But agricultural soils have the potential to sequester carbon to their original capacity. The effect of carbon sequestration is more prominent in degraded soils regarding soil health improvement. Soil C sequestration is an effective food and nutrition security strategy through soil quality improvement. SOC sequestration in soils is an effective climate change mitigation option (Lal 2004), and the 4 per 1000 initiative suggested that 20–35% of global anthropogenic greenhouse gas emissions could be reduced by increasing global SOC stocks in the top 40 cm by 0.4% per year (Minasny et al. 2017). Therefore, every step towards sustainable soil health management in the climate change scenario should focus on soil carbon sequestration.

Climate change challenges on soil

Climate change is an essential factor in the planning and management of natural resources. Climate change, land degradation and biodiversity loss made the soil one of the world's most vulnerable natural resources. Projected temperature changes and rainfall patterns are likely to affect the SOC stock directly and indirectly. Directly, the temperature and moisture regime will affect microbial decomposition. Indirectly, plant growth, net primary productivity, above and below-ground biomass, and the type and amount of residues with differential materials recalcitrance will be affected.

Due to global warming, rainy days are expected to decline in many regions with more extreme events, and evaporation and transpiration rates are projected to increase. These changes may reduce the soil moisture availability for plant growth. The higher temperatures will also accelerate the rate of soil organic matter decomposition (mineralization), especially near the soil surface, which will affect the soil's potential capacity to sequester carbon and retain water. Many experiments showed that an increase in soil temperature would result in a significant loss of organic matter in agricultural and forest soils (Heikkinen et al., 2013; Melillo et al., 2017).

Higher soil temperatures increase the microbial decomposition and control of SOM storage in soil. Moist but well-aerated soils support microbial activity, and decomposition rates decrease as soils become drier. Flooded/submerged soils have lower rates of organic matter decomposition due to restricted aeration and thus, with very high amounts of soil C. High precipitation will transport the carbon down to the soil profile as dissolved or particulate organic matter. During drought, SOM decomposition may initially decrease but subsequently increase after rewetting. Soil physical properties are crucial in deciding the soil response or resilience to climate change. The inherent soil property, like texture, is resistant to change or changes very slowly over time, but soil organic carbon content, structure, CEC, nutrient availability, soil biodiversity and pH are more easily affected by climate and management practices. The proper soil management practices that keep the ideal soil's physical properties are inevitable to deliver soil ecosystem services, such as storing water, supplying nutrients to plants, sequestering carbon and reducing greenhouse gas emissions. Understanding these properties will enable the farmers to adapt to climate change and mitigate its impacts.

Sustainable Soil Management

Sustainable soil management aims the supporting, provisioning, regulating, and cultural services provided by soil are maintained or enhanced without significantly impairing either the soil functions that enable those services or biodiversity. The four types of ecosystem services and the soil functions explained are (FAO, 2015)

- Supporting services - primary production, nutrient cycling and soil formation
- Provisioning services - supply of food, fibre, fuel, timber and water; raw earth material; surface stability; habitat and genetic resources
- Regulating services - water supply and quality, carbon sequestration, climate regulation, control of floods and erosion
- Cultural services - aesthetic and cultural benefits derived from soil.

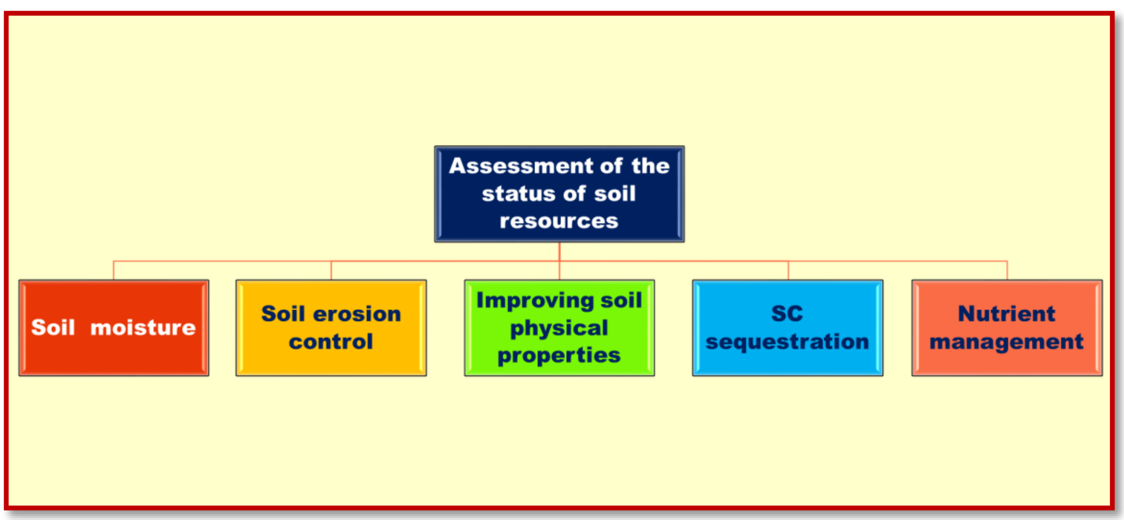

Fig 1. Sustainable soil management strategies

Soil Management interventions for carbon sequestration

Carbon sequestration in soils will contribute directly to climate change adaptation and mitigation. This will also make agricultural production systems more sustainable; increase the overall resilience of agricultural ecosystems; and maintain the ecosystem services of soils. Sustainable soil and land management practices adapted to the local biophysical and socio-economic conditions can enhance the interactions among soil, water, plants and livestock which can prevent, slow or stop soil degradation as the impacts of climate change (Lal, 2013). The ninth principles from the World Soil Charter (FAO, 2015) say that soils that degradated can, in some cases, have their core functions and contributions to ecosystem services restored by applying appropriate rehabilitation techniques. This increases the area available to provide services without necessitating land-use conversion. Many already proven soil management practices can help farmers to mitigate the adverse effects of increasing weather variability and climate change. The widespread adoption of these practices can contribute to the global carbon sequestration and maintain the soil health.

The soil carbon sequestration depends on a number of factors like

1. **Abiotic** - clay content, mineralogy, structural stability, land slope, soil moisture and temperature regimes
2. **Biotic –** land use, management practice, activities of soil organisms

The best management practices should consider all these biotic and abiotic factors for improving the efficiency

Some of the best management practices for agricultyural lands to improve the carbon sequestration potential are listed below

- Organic Manure application
- Balanced fertilization
- Conservation tillage (minimum, zero/no-till)
- Mulching
- Crop residue management
- Cover cropping

Organic manure application

The application of organic manure add carbon and other nutrients in the soil. The addition of organic manures in agricultural lands increases SOC stocks. Carbon stocks in the world at 0–20 cms depth improved 240–460 Kg C $ha^{-1}yr^{-1}$ after ten years of manure addition (Gattinger *et al.,* 2012). Further, a 30% increase in SOC at plough layer (0-15 cm) due to organic manure addition (Zavattaro *et al.,* 2017). Manure application could further add SOC concentration due to added organic C inputs in manure (Zhao *et al.*, 2014). Continuous addition of manure for four years, a 25% C was stored in the soil carbon pool (Eghball, 2002).

Balanced Fertilisation:

The Green Revolution transformed India into self-sufficient in food grain production; no other activity had such an immense impact on the country's economic development. The fertilization approach was one of the best field management practices to achieve high crop yields in intensive agriculture with high yielding varieties. But recently, farmers forgot the 4:2:1 ratio of NPK application and urea as a nitrogen fertilizer is used much more than the recommendation. Indiscriminate application of fertilizers also degrades the soil quality (Lin et al., 2014). Hence balanced nutrient application combining chemical fertilizers and organic manures will help enhance microbial activity and carbon sequestration.

Conservation Agriculture

Intensive and conventional agricultural practices challenged agriculture's sustainability through soil degradation, declining soil organic matter, loss of soil biodiversity, depletion of groundwater, and greenhouse gas (GHG) emissions (Parihar et al., 2018). Decreased land availability and increased cropping intensity, urging the farmers to remove the crop residues from the field immediately after harvest. Intensive cultural operations with farm equipment break the natural soil aggregates and modify the soil structure. This practice leaves the soil surface bare and highly prone to erosion and soil degradation (Doraiswamy et al., 2007). Minimum soil disturbance and maximum crop residue returns will improve soil organic carbon (SOC) storage and maintain soil health. Conversion to no-till practice on the lands under corn-soybean cropping rotation could sequester about 2% of the annual anthropogenic emissions of CO_2 emissions in the United States (Bernacchi, Hollinger, & Meyers, 2005). Conservation agriculture supports soil in adapting to climate change by improving its resilience against extreme climatic situations (Maity et al.,2021).

Mulching

Mulching with organic materials can effectively change the soil microclimate, enhance microbial activity, and release soil nutrients to plants (Vogel et al. 2015). Mulching will changes the nutrient cycle and energy flow between the soil and plants and alter SOC dynamics. It improves soil properties by adding carbon and nutrient sources through the decomposition of organic matter; and directly increases SOC.

Crop residue management

Crop residues contribute to the maintenance of soil organic carbon (SOC), a key component of soil fertility and soil-based climate change mitigation strategies. Crop residues are essential for maintaining soil organic matter content and sustaining crop production. They are also a vital energy source for soil macro- and microorganisms, stabilizing soil aggregates, enhancing nutrient cycling, and improving soil physical properties (Canqui and Lal 2009). In regions with >20°C annual temperature decomposition rate of crop residue is higher than in the cooler regions. Hence , a threshold level of residue retention in soils of the tropics to increase the SOC pool should be determined. Crop residue retention in fields should be an integral part of crop cultivation to increase the soil's organic carbon level

Cover cropping

Cover crops are an important soil carbon sequestration strategy usually used as green manure and ploughed into the soil before the subsequent crop is sown Important cover crops belong to cereals, brassicas, and legumes to fit almost any cropping system. Apart from reducing the erosion and carbon loss cover crops enhance the growth of soil organisms, which increases soil carbon levels over time. Nine years of cover crop addition contributed 10–20 Mg C ha^{-1} organic carbon in soils compared to no cover crop experiment (Chahal et al., 2020). Cover crops should be fast growing and produce higher biomass for serving both the purpose of erosion control and soil carbon sequestration.

Involving farming community

The farming community's involvement is essential in achieving the potential soil carbon sequestration rate. Government initiatives to sequester the soil carbon will motivate the farmers to recognize the importance of carbon in sustainable soil health management

- **Incentives:** Farmers applying all best management practices to improve the soil carbon have to be given incentives such as money or inputs
- **Priority in subsidies and insurance:** The farmers who sequester carbon on their farm should be given preferences in subsidies and crop insurance claim
- **Recognitions and awards:** Farmers should be recognized with awards and certificates for their contribution to carbon sequestration
- **Community Carbon parks:** The establishment of village level carbon parks with carbon sequestering potential fast growing tree and grass species in community lands
- **Convergence with Corporate social responsibility:** Corporate sector can adopt a village under CSR to improve the carbon status of degraded land
- **Carbon tax:** Farmers who are not improving the carbon status of their land should be taxed
- **Creating awareness:** Awareness to sequester the carbon in soil and farm through mass awareness and skill development programmes.

Conclusions

Soil health management will continue to play a prominent role in agricultural production systems. Healthy soil is more resilient against fluctuations of climatic parameters. Resiliency of the soil eco system needs to be enhanced to cope with climatic variations. Building and improving the soil health through SCS in agricultural lands will ensure continued productivity, enhance farmers' incomes, and promote food security in holistic manner. Building and maintaining a healthy soil is not an easy task especially in the arid and semi-arid regions. Carbon sequestration is the global need to combat the climate change impacts through greenhouse gas emissions. Achieving this global mission is possible only through local vision involving the farmers, as agricultural soils and trees have the tremendous potential to sequester the atmospheric carbon.

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Chapter 6

RAINWATER HARVESTING TECHNOLOGIES FOR WATER SECURITY AND CLIMATE ADAPTATION

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INTRODUCTION

The burgeoning population and their impact on every sphere of development, viz., agriculture, industry, and urbanization, depend primarily on water resources, leading to ever increasing water demands. Increasing water demand, over-exploitation of groundwater resources, and inefficiency of tapping the surface water and harvesting rain water created an imbalance resulting in a shortage of water availability for sustainable food production and domestic usage. FAO has reported that the global water withdrawal increased from less than 600 km^3 $year^{-1}$ in 1900 to almost 4000 km^3 $year^{-1}$ in 2010. Further, it will increase to 5100 km^3 during 2025, with a rise of 8.4 % to 12.2 % from the current withdrawal rate. In 1995, 76% of the world population had water availability of less than 5100 m^3 per annum per capita. It is predicted that in 2025, most of the Earth's population will be living under a low water supply. It is projected that water user categories in the world will not shift much excepting an increase in water consumption due to urbanization in developing countries. The water consumption for agriculture will be around 70%, industry around 20% and residential and commercial around 10%. Due to the effects of climate change and uncertain rainfall, water use in agriculture will increase with the expansion of irrigated land. By late 1970, almost all developed and developing countries started intensive irrigation development to ensure increased crop production. Subsequently, the global rate of increase in irrigated areas has slowed down primarily due to the very high cost of construction of irrigation systems and soil degradation problems. Thus, lots of efforts are required to harness the water resource potential and combat extreme climatic events like drought and flood. The management of soil and water resources needs a holistic approach by linking socio-economic developmental activities with an eco-friendly environment.

I. RAINWATER HARVESTING

Geddes (1963) first defined water harvesting as the collection and storage of any form of water; either runoff or creek flows, for irrigation use. In many parts of the world, the collected rainwater from natural precipitation is the only source of water supply and it is considered an economical and useful method. Proper water harvesting techniques will mitigate the problems of soil erosion and flood to a large extent. It will also enhance the agricultural productivity in the region. The water harvesting can be done through the following techniques

- Harvesting the surface runoff from the land surface
- Diversion of surface/subsurface water sources
- Direct rainwater harvesting in undulating topography and hilly region
- Subsurface water harvesting
- Rooftop water harvesting

1. HARVESTING SURFACE RUNOFF FROM THE LAND SURFACE

a. Dug out or excavated farm ponds

Dug out or excavated ponds are the most common and simplest farm ponds for locations with relatively small water requirements. It can be designed to fit into an individual farm or number of farms or as a village/community pond. These are usually constructed in a relatively flat area by excavating a pit or deepening/widening a natural depression and forming an embankment-cum-dugout. Surface water ponds are most common while groundwater fed ponds can also be located where shallow sub-surface flow exists, as in the case of valley portions of mid slopes in the hilly terrains.

b. Embankment-cum-dugout ponds

It is a dugout pond with an earthen embankment to be constructed in natural nallah or depression with deepening of 3 to 4 m and excavated soil should be used to construct the earthen embankment. A suitable surplus weir has to be provided.

c. Larger Farm Ponds

Larger farm pond in the dimensions of 40 X 20 m has to be excavated in trapezoidal manner and fine sand has to be placed to a depth of 30 cm followed by spraying of weed control chemicals. The silpaulin sheets having 250-300 GSM thick has to be placed and completely covered. The sides of the farm pond have to be prepared in step by step enable to withhold the plastic sheet. In high porous soil the farm ponds have to be lined with low cost poly films.

Farm pond with down side lining

Lined Farm Pond

2. DIVERSION OF SURFACE / SUBSURFACE WATER SOURCES

a. Earthen embankments

It is an embankment construction across a watercourse for diversion (i.e. diversion dam) or storage (i.e. storage dam to store surface runoff for irrigation, groundwater recharging, or other useful purposes or store silt). These are suitable for harvesting and collecting water across nalla in common lands for multiple uses in promoting wasteland development and enhancing the productivity by conserving moisture and creating local water resources.

b. Bandharas

Bandharas are the small diversion structures constructed across the streams and drainage line and the stored water is irrigated to the near by fields by gravity flow. There are two types of bandharas based on the type of materials used for construction viz. earthen dam and concrete masonry dam. The height of such structures varies from 1m to 1.5 m. A sluice gate is provided in the centre of the structure to facilitate draining water completely during the heavy rains and flood season that avoids damage of the crops during peak water flow. These bandharas serve the purpose of storage and cater to the needs of both water supply and irrigation. These structures existed since Portuguese regime. These structures are found to be quite cost effective and yielding quick benefits to the farmers. Large numbers of bandharas have been constructed by Water Resources Department under minor irrigation scheme. The bandharas of Sanquelim, Bicholim, Maulinguem, Assonora and Koperdem were constructed many years ago and they need modernization.

3. DIRECT RAINWATER HARVESTING

a. Farm Ponds

A farm pond may be constructed where the largest storage volume of water can be obtained with the least amount of Earth filled within or close to the point of use. In general the farm ponds are constructed in rectangular or trapezoidal shape. Depending on the soil conditions, these ponds may be constructed with or without lining. Polythene sheets may also be used for lining to minimize percolation losses. Pollution of farm pond water should be avoided from drainage, farmsteads, sewage lines and mine dumps. Where this cannot be done successfully, it is recommended that water from such areas should be diverted from farm pond.

i. Smaller farm pond (Jal Kund)

Smaller farm ponds are designed to harvest the rainwater from the self-catchments area of pond during the rainy season. The harvested water can be used to irrigate to the mango, cashew and any other similar type of plants for their initial establishment. Smaller size ponds having the dimension of 2m (L) x 2m (W) x 1m (D) or 4m (L) x 1m (W) x 1m (D) to be excavated in the center of the area having about 8 to 10 plants at the field. The dimensions can be decided depending upon the soil depth. If the soil depth is deep and enables to excavate up to 2 m deep, the pond dimensions having 2 m X 2 X 1 m may be adopted. If the soil depth is shallow and the soil above one-meter is too hard, it is better to go for a 4 m X 2 m X 1 m size pond.

4.a. SUB SURFACE WATER HARVESTING

a. Sub-surface water harvesting pond

Some specific locations in the valley portions of undulating topography in the hilly region yield sub-surface runoff due to different monolith layers of soil profile. This provides ample scope for harvesting sub-surface flow, free of sediments. Constructing diaphragm ponds and/or sub-surface barriers to arrest and store sub-surface runoff for storage and recycling can achieve this. Springs constitute the major source of water supply in the hilly regions, especially in uplands. Springs are the manifestations of the groundwater hydrology of hilly areas. These springs are frequently found on the hill slopes and in the valleys of Western Ghats. There are small or large springs depending upon the degree of concentration and seasonal or perennial springs in nature depending upon whether the supply is variable or constant. Most of the springs in Western Ghats valley are perennial and will supply water for small land holdings throughout the year.

b. Sunken wells

Smaller shallow wells from 2 to 3 m deep with 2 to 3 m diameter which has to construct where the springs or sub surface flow is available. The subsurface water can be harvested and can be used for irrigation.

4.b SUBSURFACE WATER HARVESTING IN HILLY REGIONS

Subsurface water harvesting is the method of harvesting base flow water stored in shallow or subsurface aquifers.

a. Springwater harvesting

Springs constitute the primary source of water supply in the hilly regions, especially in valleys. They are the manifestations of the groundwater hydrology of hilly areas frequently found on the hill slopes and in the valleys of Western Ghats. Small and large springs depend on the degree of concentration and seasonal or perennial springs. Most of the springs in Western Ghats valley are perennial and will supply water throughout the year for small landholdings.

b. Subsurface shallow pond

A shallow pond is for harvesting base flow water stored in hilly terrain. These ponds can be designed in smaller sizes within a one meter depth. Terraced lands can be excavated one such pond per terrace and can be utilized for irrigating downside terraces.

c. Shallow well

Shallow well is also called sunken or collection well, which is being dug into the ground for less than 50 feet. The source for well is an aquifer, an underground layer of permeable soil containing water and allowing water passage. These aquifers are frequently replenished as rainfall percolate down through the soil column. Groundwater travels through permeable soil on top of hard or impermeable layers. The depth of the shallow wells is enough to intercept the uppermost perched water table, and the diameter is decided as per requirement.

5. ROOF TOP WATER HARVESTING

Rooftop water harvesting is in practice in parts of Rajasthan, Gujarat and North East hill region for domestic needs. It is an effective means of runoff harvesting from the rooftops. The rainwater falling on the roofs of a building is collected and stored in the cisterns. The cisterns are the tanks constructed below or above the surface. It may be used for domestic consumption by purifying if necessary. It has great potential to meet part of domestic needs in water scarce areas of the hill region. Roof water harvesting system could also be used for community water supply by collecting runoff at a centralized tank and network distribution system near the cluster of houses.

II. ARTIFICIAL RECHARGE METHODS

The artificial recharge structures are helpful in ground water reservoir augmentation by modifying surface water's natural movement. Artificial recharge techniques enhance the yield in areas where over-development has depleted the aquifer, conserve and store excess surface water for future requirements, and improve ground water quality. The primary purpose of artificial groundwater recharge is to restore supplies from aquifers depleted due to excessive groundwater development.

1. Percolation ponds

Percolation ponds are small storage structures constructed across natural streams and nalas to collect, spread and impound surface runoff to facilitate infiltration and percolation of water into the sub-soil for augmenting ground water recharge. The site should have highly porous soil and sites with heavy soils or impervious strata should be avoided. There should be a number of irrigation wells in the zone of influence upto about 1 km from the pond to benefit from the ground water recharge. The ponds may be designed to store about one-third of the annual water yield from the catchments and 1 ½ to 2 fillings during the monsoon are assumed.

2. Sunken ponds

These are small water harvesting pits sunk in gully bottoms. These pits are made to capture rainwater for recharging ground water. These are usually created in small gullies where sediment discharge is less. It can be also created upstream side of the wells in either common or private land. But, side of the drainage lines on the bunds should be avoided. The depth of pits is limited to 2.00 m, in most cases only 1.00m. The width of pit depends upon gully bottom may

vary from 1 m to 3 m. The length of pit may be 4.00 m or 2 m diameter in case of circular shape. The excavated soil is deposited in thin layers at down stream leaving provision of surplus arrangements. Suitable vegetation is planted around the pit. Silt trap is provided at upstream. Revetment is provided an inlet side. These are usually made in series.

3. Percolation trenches

A percolation trench/ infiltration trench is a recharge structure that is used to harvest runoff water, prevent flooding and downstream erosion,
and improve water quality in an regions. Medium size of trenches with a length of 4 to 6 m, width of 0.5 to 1 m and depth of up to 1 m can excavate at up streamside in common and community lands. These trenches will recharge the groundwater at down streamside.

SUMMARY

India's water resource potential is to the extent of 187 M ham of which utilizable water resource potential is only 110 m ham, including surface and groundwater resources. In the acute shortage of water during the post rainy season, water should be harvested either on the surface or subsurface by various technologies. Direct rainwater harvesting in smaller ponds and recycling is the solution for providing protective irrigation. The lining of ponds is recommended where the percolation losses are very high. The harvested water should be used efficiently by adopting advanced irrigation technologies *viz*. Micro-irrigation methods, mulching etc. Rooftop water harvesting technique should be introduced in all the metropolitan cities of major buildings to meet daily water requirements. Artificial recharge systems have to be constructed wherever required to increase the groundwater recharge. Artificial recharge of groundwater should be entertained by constructing percolation ponds and check dams in watercourses and it should be promoted in all watershed development programmes in the region. Creation of inventory on soil and water resources, development of indigenous sensor based instruments for monitoring hydrological parameters, use of modern technological tools for developing conservation strategies, changes in policy to protect natural resources, development of location specific soil and water conservation measures and participatory approach in conserving the soil and water resources are the future challenges for the scientists and policy makers.

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Chapter 7

Innovative Initiatives in Livelihood Promotion of Farmers and Entrepreneurs through Institutional Approach

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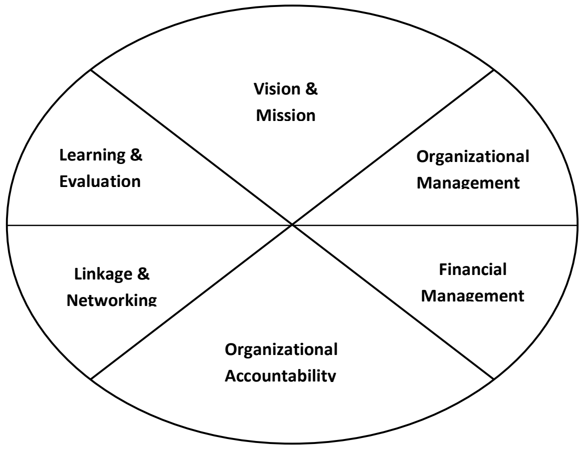
The functioning institution (established by people) at the village, form one of the major pillars of a healthy and sustainable democracy. These are the civic institutions at the base. MYRADA'S experience indicates that "participation", which like God is interpreted differently by each one depending on his or her needs and biases, is necessary but not enough; it must lead to institution building. Participation is a means to build an appropriate institution with a vision and mission of its own; it is also an end in itself, since people are empowered in the process.

Our experiences in rural areas provides sufficient evidence that a "People's institution" which is structurally appropriate to the resource to be managed, (be it credit, agri – commodities, forests or milk) provides an instrument through which people can acquire, increase and sustain ownership of any investment from outside. This is why effective participation is so critical; it questions the tendency to standardize and to overload every institution. Evidence also indicates that the sense of ownership derived from an "appropriate institution" provides the basis for SUSTAINABILITY of the objectives of the intervention which are increase in productivity and in equity.

The words "group", "institution" and "organization" are often used interchangeably. A group is a gathering at one end of the spectrum, while an institution is an entity with particular features at the other end. The "organization" comes in between. A group, is often a temporary gathering to achieve a particular purpose; it can develop (and does on occasions) into an organization which has rules and regulations and defined functions; in most cases, however, these rules and functions are largely imposed from outside. An organization develops into an institution when its members have full ownership of the body; where they have interiorized to a large extent the culture and systems that they (or others) have established. This is more easily achieved when the members have an active and effective say in drawing up the rules and regulations, in setting the agenda and building the culture that enables them to perform the functions that they choose.

When the rules are drawn up by outsiders, the organization can interiorize them adequately provided adequate training is provided to help it to develop its own vision and mission, and above all if the original rules are open to modification, addition and rejection; in most cases this is not the case.

The Features of an Organization/Institution



An institution, therefore, grows over a period; it requires at least two to three years before a group begins to develop clear signs of an institution. It is also quite possible for a functioning institution to loose its culture and undermine its systems through external or internal causes. An institution therefore requires both times to develop as well as constant commitment of all its members to remain healthy. In short, it must develop its own vision, its own financial and organizational management systems, its own learning mechanisms and the confidence required to link up with others to protect its identity and independence.

Since independence, community based institutions promoted in the development sector have created positive impact on people's lives. Difference types of people institutions promoted in the field of development such as;

a. Institution based on self-help and credit management
b. Focus on Natural resource management
c. Producers and commodity based institutions

a. SELF HELP GROUP

Development organizations adopted the self-help group as the appropriate people's institution which provides the poor with the space and support necessary to take effective steps towards greater control of their lives in private and in society.

The self-help group is not a static institution; it grows on the resources and management skills of its members and their increasing confidence to get involved in issues and programmes that require their involvement in the public and private spheres.

The SHGs provide the benefits of economies of scale reducing costs in certain areas of the production process which the members may decide to undertake as a common action. The group also provides a cost effective credit delivery system, as the transaction costs of lending decrease sharply both to the banks and the borrowers. The groups provide a forum for collective learning which rural people find more "friendly" and which is consequently more effective than the individual or classroom approach that is commonly adopted. The groups promote a democratic culture and provide the members with opportunities to imbibe norms of behavior that are based on mutual respect. The SHGs foster an" intrapreneurial" culture where each member realizes that while she/he needs the support of the group to achieve her/his objectives, the group also in turn requires her/his support in adequate measure. The groups provide a firm base for dialogue and cooperation in programmes with other institutions like Government departments, cooperatives, financial and Panchayat Raj institutions; if the groups are functioning well; they have the credibility and the power to ensure their participation in identifying, planning, budgeting, and implementation of Panchayat Raj programmes for the empowerment of the poor.

COMMUNITY MANAGED RESOURCE CENTER (CMRC):

CMRC is a self-run institution which provides essential quality services to its member institutions and the community and thereby supporting them to grow as sustainable institutions, empowering its members. The CMRCs are the federated structure of local level institutions which includes SHGs, Federations, WDAs etc. and other CBOs in their locality. The local level institution understands the importance of establishing a Resource Center managed by the community themselves in catering their own needs and requirements.

The objectives are;

- To provide necessary information on developmental programmes
- To promote linkages with banks for loans and with government line departments for pro-poor programmes
- To solve the groups problems
- To strengthen institutional capacity of sags
- To promote livelihoods through skill improvement training
- To promote insurance services
- To provide legal services

b. FOCUS ON NATURAL RESOURCE MANAGEMENT:

WATERSHED DEVELOPMENT ASSOCIATION:

Where a watershed is coterminous with a Village Panchayat or its area is confined within the boundaries of a Village Panchayat, the Gram Sabha of the Panchayat concerned will be designated as the Watershed Development Association. However, where a watershed comprises of areas coming under the jurisdiction of more than one Panchayat, members of the community who are directly or indirectly dependent upon the watershed area, will be organised into a Watershed Development Association. Such a Watershed Association should be registered as a Society under the Registration of Societies Act, 1860. The key objectives of WDA are:

- Create awareness among the sub-groups on the importance of ecological balance of the watershed as an ecological unit which needs to be properly managed.
- Co-ordinate and integrate the efforts of all the sub-groups; so that all the sub-groups work towards the same goal, namely the integrated development and management of the resources of the MWSs.
- Work out systems to ensure that common resources and assets like nala-bunds, gully checks, grazing lands, drinking water resources etc., are managed by the sub-groups in a manner where rights and responsibilities are shared appropriately.

- Provide the necessary support to the weaker members of each group to develop and participate effectively.
- Co-ordinate, lobby and bargain with the Government, contractors, financial institutions, Mandal Panchayats, MYRADA (as long as we are there) and other interest groups so as to mobilize, plan and manage programmes offered by these institutions for watershed development and for the development of weaker sections.
- Network with other WMAs and institutions involved in similar programmes so as to help the sub-groups to develop appropriate skills etc.

Watershed Committees: Subject to the overall supervision and control of the Watershed Association, a Watershed Committee shall carry out the day-to-day activities of the Watershed Development Project.

The Watershed Committee at the 500 ha level is done away as far as its roles in a) managing funds, b) monitoring the programme and c) working on common land is concerned. The standard watershed for operational purposes in Government Programmes covers an area of 500 ha in which over 100 families cultivate. There are too many to form a watershed group which promotes effective participation. As a result, they elect representatives and form a Committee to implement the programme.

Watershed Users Groups: In most watershed projects, the management of an irrigation tank if it exists is not included as a component. Most watershed management projects focus on the catchment where the poorer farmers cultivate mainly drylands. However, there are some projects where the management of irrigation tanks is included in watershed programmes. In such cases, Water Users Groups are formed which focus on the command area of an irrigation tank. The members comprise all those farmers with lands in the command area. Each UG shall consist of the persons who are likely to derive direct benefits from a particular watershed work or activity. The UGs should actually take over the operation and maintenance of the completed community works or activities on common property resources.

VILLAGE FOREST COMMITTEE:

Village Forest Committee which are widespread and which are expected to participate in regenerating and managing all degraded forest lands and to be involved in managing non timber forest products. The VFCs include one man and one woman from each family. The forester is the secretary and signs all cheques. The meetings are usually called by the forester. The VFC concept has introduced to manage degraded lands and forest products.

The VFC also shares the strengths of the PRI since it covers the whole village and is able to coordinate activities. The VFC makes a bow to gender issues by including women as members in equal numbers as men.

c. PRODUCERS AND COMMODITY BASED INSTITUTIONS:
FARMER PRODUCERS ORGANISATION / COMPANY:

Twelfth Plan working groups set up by the Agriculture Division of Planning Commission have strongly recommended that the Twelfth Plan should put special focus on building capacity that encourages group formation and collective effort by small, marginal and women farmers, rather than simply provide additional subsidy to individuals in these categories. Existing group activity takes many forms depending on purpose. From lower tiers of formal cooperative structures in credit, marketing, dairy and fishery, extending to self-help groups, farmer clubs, joint liability groups (JLGs) and, more recently, to producer companies. For simplicity, these can all be termed Farmer Producer Organizations (FPOs).

Small and marginal farmers face problems not only with shrinking land assets and with credit; they have difficulty in accessing critical inputs for agriculture such as quality seeds and timely technical assistance. In this situation, FPOs offer a form of aggregation that leaves land titles with individual producers and uses the strength of collective planning for production, procurement and marketing to add value to members' produce through pooled resources of land and labour, shared storage space, transportation and marketing facilities. These also improve bargaining power of small farmers and, most importantly, reduce transactions costs of banks and buyers to deal them. Investing in such group efforts has strong externalities. The Twelfth Plan Working Group on Agricultural Marketing, Infrastructure, Secondary Agriculture and Policy for Internal and External Trade has in fact suggested that an institutional development component, along lines of NABARD's farmer club scheme, be introduced in all centrally sponsored schemes to specifically target FPO formation among small producers, especially tribal, dalit and women. It notes that a majority of FPOs that are likely to emerge as a result of such an intervention will remain focused on addressing issues of crop planning, technology infusion, input supply and primary marketing.

The formation and development of FPOs will be actively encouraged and supported by the Central and State Governments and their agencies, using financial resources from various centrally sponsored and State-funded schemes in the agriculture sector agencies. This goal will be achieved by creating a coalition of partners by the concerned promoter body, involving civil society institutions, research organisations, consultants, private sector players and any other entity which can contribute to the development of strong and operations for various crops.

The objectives are;

- Mobilizing farmers into groups of between 15-20 members at the village level (called Farmer Interest Groups or FIGs) and building up their associations to an appropriate federating point i.e. Farmer Producer Organizations (FPOs) so as to plan and implement product-specific cluster/commercial crop cycles
- Strengthening farmer capacity through agricultural best practices for enhanced productivity
- Ensuring access to and usage of quality inputs and services for intensive agriculture production and enhancing cluster competitiveness.
- Facilitating access to fair and remunerative markets including linking of producer groups to marketing opportunities through market aggregators.

The poverty in the rural area will not reduce unless farmers move to other sectors which give more money. If they remain in agriculture, they must diversify and shift from only concentrating on producing food grains.

Small producer farmers produce 41% of the total grain and more than half of the total fruits and vegetables in the country. This can continue only if;

a) They earn an adequate income from these products. This can only happen if they are organized, and they own and manage an institution.

b) If they have a development fund to pay for training staff, management, Maintain officer etc. till they become viable after 3- 4 years.
c) Portfolio of loans- which include working capital. Term loans and revolving funds and low cost for production, aggregation, for value addition and for marketing. (financial scaffolding)
d) They are assured a minimum support price thorough regular procurement. The government can give this protection.
e) Support to develop and introduce appropriate technology to improve tools and implements that will raise productivity. These can be owned by a few and rented out to smaller farmers Instruments and tools related to preparing the land; as well as post-harvest processes- grading, shelling, husking, packaging and storage.
f) Insurance for crop failure schemes which are friendly to the small producer.

In order for them to earn a proper income, the farmers will need to get organized and own and manage institutions – called **Second Level Institutions** (SLIs). These institutions will **aggregate** (collect), **add value** and **market** the products of the farmers. These SLIs will have a small management body of elected representatives and need support from other institutions.

The biggest competition is the private companies that have entered the agribusiness sector. They own or control all parts of the business value chain (except production) from the lower links right to the market link. The small producer's institutions should at least control the lower links of the value chainlike aggregation, husking, quality grading etc. The large companies will source products from abroad unless our farmers are able to aggregate, add value, and maintain quality and time.

AGRI-ENTREPRENEURS SERVICE CENTER – New Initiative

AESC is an institution established to provide handholding support for farmers and entrepreneurs. The center extends mentoring support to budding entrepreneurs for sustaining their enterprises with appropriate services through collective action.

After more than 25 years of its own experience and of looking at the experiences of other partners both within and outside the ICAR network, came to realize that training in skills would necessarily result in some drop outs but for the others who wanted to continue, a few important forms of support had to be immediately available and well-positioned, and they included;

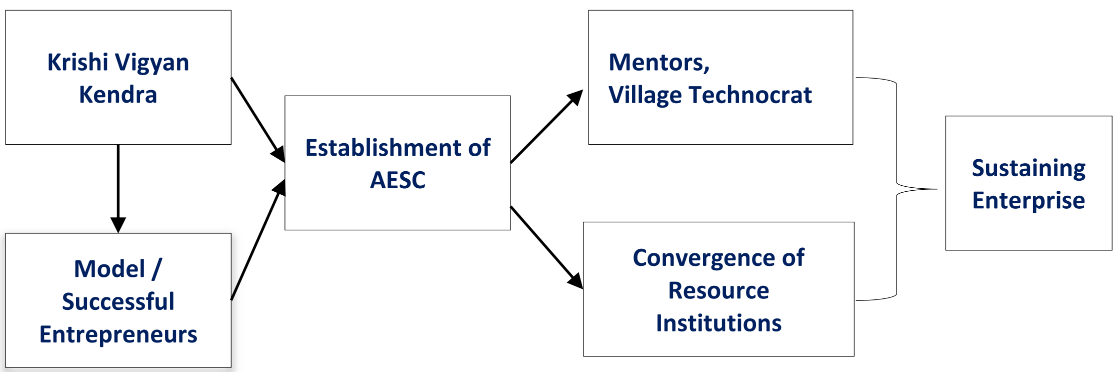
- Access to adequate investment credit to establish and run entrepreneurial ventures
- Space to incubate certain types of businesses
- Support to negotiate the complexities of getting legal clearances, product certification, GST number, etc.
- Networks for transport pooling and accessing markets
- And above all, regular mentoring support to solve day-to-day problems, understand changes in markets, improve quality on an ongoing basis, and build the business.

KVK organize and conducts skill-based training programmes for farmers, rural youth and entrepreneurs on a regular basis. Between 2017 and 2019 (3 years) 184 such training programmes were conducted in which more than 6,500 persons participated. The programmes covered a range of subjects from organic farming practices to mushroom growing to honeybee keeping to poultry and livestock management, to value additions to farm products. Experienced training institutions are well aware of the fact that not everyone who participates in such programmes practices the skills learnt. Some do farming as a matter of habit and some love to connect with their lands and livestock but few take farming to a professional level where it becomes a viable business despite its multifarious risks and challenges. For those who are inclined to take this plunge, professional handholding support is essential to navigate the complicated path. KVK has conceptualized and promoted the Agri Entrepreneurs' Service Centre to provide such support through which networks can be established and enterprises can be sustained.

KVK have come out with farmers' participatory approach to sustain the marketing initiatives of farmers and entrepreneurs with the establishment of AESC center. It is a registered body with a locally constituted Board of farmers, entrepreneurs, and representatives from resource institutions. There is a note that follows, that explains the objectives and services of the AESC.

Mentoring is an important service offered by the AESC, and it is truly remarkable that close to a hundred successful and public-minded local men and women have come forward to offer their services to build and grow other people's businesses. Goodness is expressed through helping one another. Happiness comes from sharing. This publications is a listing of all such Volunteer-Mentors who can be reached through the AESC or even contacted directly. It is the first time that such a listing has been compiled and published, and it is hoped that more and more people will come forward to make use of the AESC. If it serves as a model that can be replicated and further improved by other organizations as well, this initiative will have been well worth the effort.

The organogram of the AESC:



Need for AESC:

KVK conducts skill-based training programmes for farmers, rural youth and entrepreneurs. The fact that, not everyone practices the skills learnt. The reasons are;

- Lack of information on resources and marketing institutions
- Lack of mentoring support for budding entrepreneurs
- Lack of networking among the youths to develop the enterprise
- Absence of grass-root level Institutions for sustaining their initiatives

Objectives of AESC:

- To enhance existing skills, explore potential skills, and introduce new skills in the farming community with a view to promoting agri-preneurship.
- To provide all forms of mentoring support to budding entrepreneurs in the field of agriculture and allied activities. (Quality improvement, Packaging and Marketing)
- To establish appropriate technical, financial, and other resource-related linkages for business improvement purposes.
- To document the processes and derive lessons that can be shared with others similarly involved in agri-entrepreneurship development.

Services anchored in the AESC:

- Conducting skill-based training programmes in agriculture and animal husbandry.
- Linking new and budding entrepreneurs to established and successful entrepreneurs for experience-based and in-depth learning through mentoring processes.
- Helping entrepreneurs to develop bankable project proposals and connecting them with resource institutions for technical and financial support
- Enabling entrepreneurs to link with Resource Institutes / Departments / Regulatory bodies to obtain the requisite certification for their products.
- Honouring outstanding entrepreneurs and also linking such persons with other institutions offering awards and recognitions
- Publishing impactful experiences and popularizing them through print and electronic media

Compendium of Mentors:

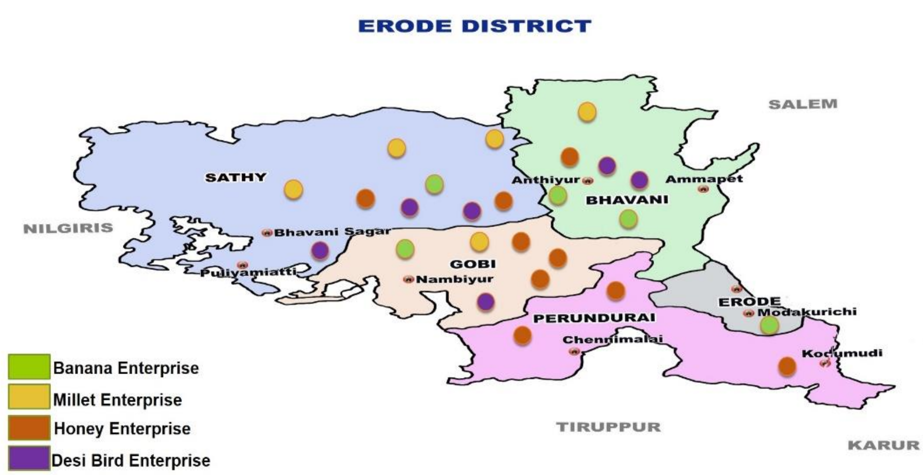
The AESC has 436 mentors enrolled in three categories such as (i) Farm based enterprises – 143; (ii) Livestock enterprises – 82 and (iii) Value added products enterprises – 211, and provides handholding support to budding entrepreneurs.

AESC - Functional Models:

The AESC have a functional models on different enterprises in Erode district. In which the four major enterprises are given below;

1. Banana enterprises
2. Millet enterprises
3. Honey enterprises
4. Desi Bird enterprises

Model Enterprise Unit in Erode District:



1. **Banana Enterprise:**

KVK involving in software programme like conducting skill based capacity building, organizing exposure visit, support for establishment of value added production unit, motivate to develop innovative products, validation of products and support for networking with markets.

For the past 5 years, KVK organized and conducted 94 skill based capacity building programme in banana enterprise by covered 1307 youths in the district. The youths equipped knowledge and skills in the banana enterprises. 37% of the youths are involving in different activities such as value added food products, banana fibre extraction, produced rope from fibre, handicraft materials and pith blocks. Also producing bio growth promoter for crops and cleaning material for floor and cloth wash from sap water.

Mentor in Banana Enterprises:

	•	**Name**	**:**	**Mr. M.Prasath**
O	•	Address	:	20 Madeshwaran kovil street, Gobi – 638452,
u				Mobile No. 9790039998
t	•	Expertize	:	Banana fibre, Fibre mat, Pith, Block, Sap water,
c				Natural Dye and Handicrafts
o	•	Brand Name	:	SP GRACE Natural
m	•	Experience	:	8 years
e	•	Annual Income	:	Rs.17,00,000

& ImImpact:

- Cluster level 3 production units established
- Developed 174 entrepreneurs in banana fiber production and value addition Banana fiber extracted 16 ton/year
- 6000 liter /year SAP water based value added produced
- Mat produced and marketed by youths 40,000 mts./year
- 2000 Nos. Handicrafts/year produced and marketed
- Network with international market outlets (Japan, Sri Lanka)
- Technology expertize provides to other district farmers

2. Millet Enterprises:

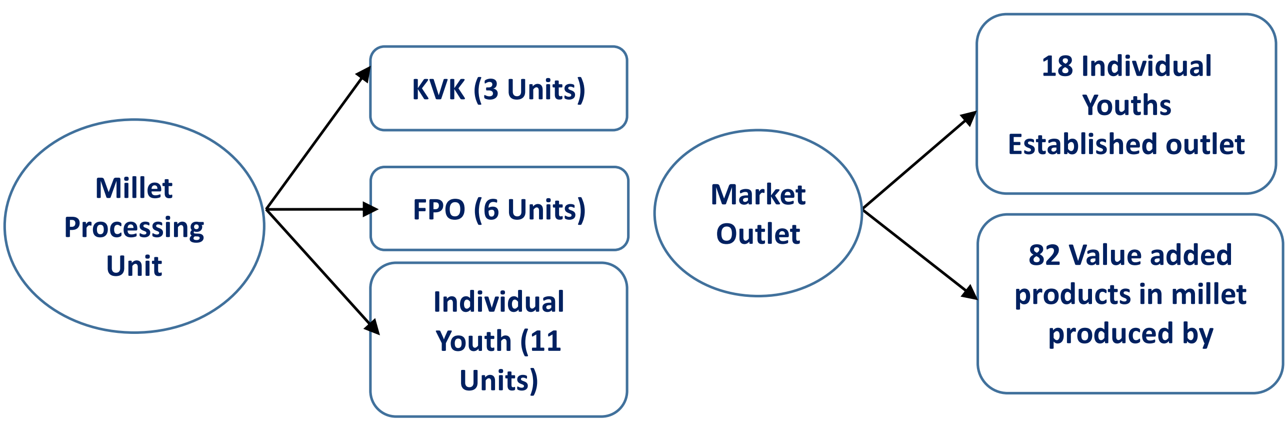
KVK involving in software programme like conducting skill based capacity building, conducting varietal demonstrations, organizing exposure visit, establishment of value addition unit with the support of Government institutions, standardization of value added products. Product development is concern primary products like grains from millets and Secondary products like flour, nutri mix, biscuit, flakes and other confectionaries.

Mentor in Millet Enterprise:

Outcome

• Name	:	**Mr.K.R. Murugesan**
• Address	:	Near Abhi Hospital, Nallagoundenpalayam, Gobi, Mobile: 9364104534
• Expertize	:	Millet based products ○ (Nutrimix and Biscuit)
• Brand Name	:	NAMNA
• License	:	FSSAI
• Experience	:	07 years
• Annual Income	:	Rs.12,65,000

Impact:



3. Honey Enterprise

KVK conducted 41 skill based capacity building on Bee keeping and value addition in honey for the past five years by covered 1456 farmers and youths in the district. In which, 790 youths are adopting this technology and established bee colonies on their farm. The youths are involved in producing the honey and making value added products from honey. Based on the experiences of KVK in honey bee rearing, established 4 cluster units viz. Gobichettipalayam, TN Palayam, Anthiyur and Perundurai with 22 youths.

Cluster Area	No. of Youths	No. of Boxes	Average Production / Month
Gobichettipalayam	7	240 Boxes	205 kg
TN Palayam	9	102 Boxes	87 kg
Anthiyur	4	60 Boxes	35 kg
Perundurai	2	30 Boxes	23 kg
TOTAL	22	432 Boxes	350 Kg

M

- **Name** : **Mrs. Manjula Parthiban**
- Address : Kolapalur Post, Gobi Taluk, Erode Dt,
  Mobile: 9442171818
- Expertize : Honey, Value Added Products & Accessories Manufacturing
- Brand Name : *Manjari*
- License : EO License, FSSAI approval, Approved Trade Mark
- Experience : 12 years
- Annual Income : Rs.8,25,000
- Recognition : Member in National Bee Board

Boxes Supplied to Other District:

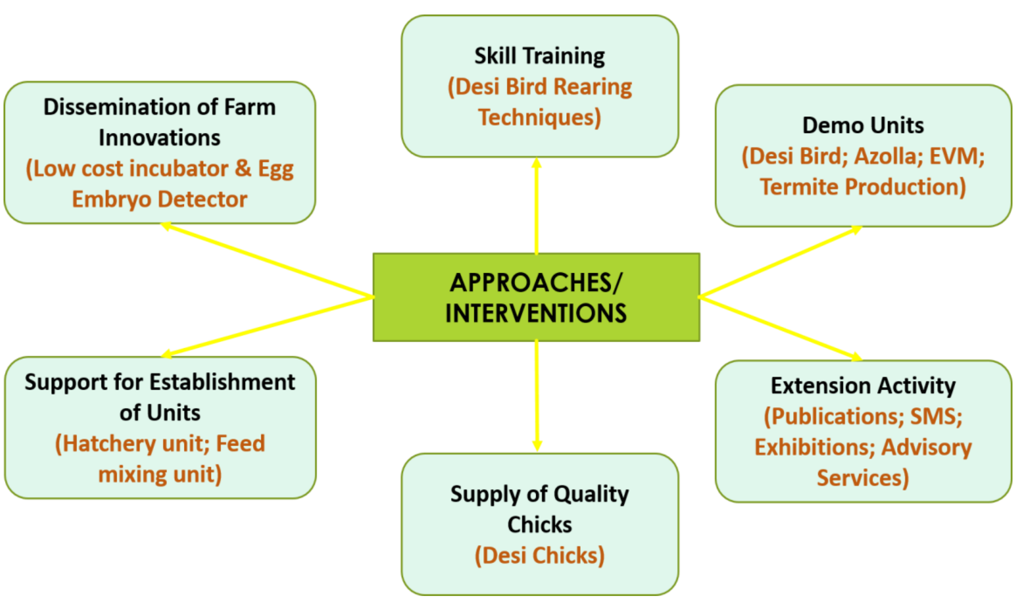
Name of the District	No. of Boxes Supplied
Krishnagiri	75
Dharmapuri	25
Vellore	100
Thiruvannamalai	120
Exhibitions & Stalls	890

Outcome & Impact:

- 27 units established in the district which covers 1200 boxes
- 32 branded value added products developed
- 6 Model farms established for providing training and technical guidance
- Promoted 22 youths as Mentors in bee rearing for budding youth entrepreneurs in various districts
- Technology disseminated through National Level Exhibitions
- Promotion of bee keeping activities to other districts through technical expertize services

4. <u>Desi Bird Enterprise:</u>

KVK conducting 68 skill training on Desi Bird Rearing techniques by covering 1449 youths in the district. 179 youths are adopting this technology and established desi bird rearing unit on their own in the respective villages.



Mentor in Desi Bird Enterprise:

Name	**:**	**Mr.Natarajan**
Address	:	Uthandiyur Post, Bhavanisagar, Sathy Taluk, Mobile: 9842490174
Expertize	:	Egg, Meat ,Desi Bird Rearing, Dog Breeding, Azolla Cultivation, Hatchery unit
Experience	:	06 years
Annual Income:		Rs.13,00,000
Recognition	:	Mahindra Samriddhi Award

Spread of the technology:

Name of the Intervention	Method of Approach	No. of Units Established	No. of Youths Covered
Hatchery Unit	Group	3 units	75 youths
Feed Mixing Unit	Group	2 units	60 youths
Azolla / Termite Production	Demonstration / Individual	110 units	110 youths
Egg Embryo detector	Individual	-	75 youths
Ethno Veterinary Garden	Demonstration / Individual	6 units	30 youths
New Variety – Desi chicks	Demonstration	40 unit	40 youths
Desi bird production	Individual	75 units	75 youths

Outcome & Impact:

- 465 youths involving in Desi Bird Production enterprises in Erode District
- Community incubator in 3 clusters - 310 rural youths benefited and sustain their Desi bird production
- 47 youths providing employment and mentoring support for budding entrepreneurs
- Feed Mixing unit in 2 clusters – 85 youths benefited
- Additional income Rs.12,000 to Rs.15,000/month realized by individual youths

Towards sustainable livelihood of youths through ENTREPRENEURSHIP…

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Chapter 8

Socio-economic impact assessment of watershed programmes

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Introduction

The word 'Impact' refers to lasting effect or influence, whereas impact assessment is evaluation of the extent of effect made. Whereas, impact evaluation is evaluation designed to identify and measure the consequences resulting from a programme or project or policy interventions. Impact assessment of watershed programmes or projects which measures the extent of contribution made towards fulfilling the following goals,

1. Economic benefits: individual benefits accrued to the stakeholders, be it a farmer/producer/consumer/trader/processor.
2. Societal benefits: benefits for the society and in welfare of the community
3. Environmental services: contribution made towards providing environmental services or conservation of natural resources.
4. Sustainability: long term benefits from the developed technology for future generations.

Advantage and benefits attributable to watershed interventions are quantified and evaluated for its performance in reaching its goals. Social and economic transformations made are considered in case of assessing larger impacts.

Any investment made on watershed development cannot yield the benefits immediately as there is a time lag which is a gestation period of planning and implementation where the investments made is been utilized and resources are used for developing a watershed. Like how the development and validation of a novel technology through research takes initial time period where there is zero economic benefit and the research starts accruing economic benefits only when the successful adoption of the technology begins. This reaches maximum where there is adoption ceiling limit and over the period of time, the technology depreciates and economic benefits are lowered accordingly. Similarly investments made on developing a watershed will have a time lag in yielding benefits to the stakeholders.

There are two broad approaches for impact assessment, Firstly, before and after where the conditions and situations before the implementation of the watershed interventions and after the watershed interventions are compared and the difference is attributed to the technology development and adoption. This approach can be misleading sometimes as there is a time gap between the two periods of comparison and many factors may change during this time gap. Hence, the most valid and widely used approach is with and without watershed approach where the farmers in the treated area and the farmers of the untreated/control area are assessed for various parameters at the same period of time and the difference is attributed to the watershed activities/interventions/development.

There is a thin line difference in research outputs, outcomes and impacts. Outputs are concerned with immediate results of a project/programme like knowledge generation, technologies developed; research methods, recommendations made and varieties/hybrids developed etc., Outcomes of the programme/project deals with technology adoption, initial impacts of the project/technology, institutional development etc. Impacts are of long term benefits of technology/watershed projects/programmes spread over a larger area. Contributions of watershed interventions towards achievement of economic, social, environmental and institutional goals are measured in case of impact assessments.

Levels of impact assessment

There are usually three different levels at which the impact analysis is carried out,

1. **Farm level:** The performance of the watershed interventions on the farmer’s field or at the farmer’s level is being assessed. The change in yield levels, income of the farmers, employment status, household food security, input saving, risk reduction, reducing gender disparity and the effect on increasing overall welfare of the farmer.

2. **Regional/sector level:** Contributions made by the technological interventions to the performance of the sector, market arrivals and prices, production levels, employment, inter-state or inter market trade, conservation of natural resources, reducing poverty and regional or income disparities are quantified at this level.

3. **Economy/National level:** Contribution made by the watershed development project or programme in performance of the economy, its share in national income, national savings, international trade, reducing poverty, hunger, malnutrition are assessed at the country's level.

Some of the data required to measure impacts can be directly observed and other data must be estimated indirectly from other sources/evidences. Choosing and using the data as required is very crucial for the researcher conducting impact assessment study. Accordingly, there are three important categories of impact assessment when the analysis can be made using different forms/types of data. Ex-ante analysis is carried out before the watershed implementation. These types of analysis mostly rely on researchers' trials and extrapolations. Concurrent analysis is carried out during the watershed development and implementation phase, this analysis gives feedback for the planner or implementing agency and within the timeframe, the necessary improvements may be done. Lastly, ex-post analysis which is done after watershed development/adoption of watershed activities or interventions is made and its effect on different parameters of the stakeholders is studied.

There are simple indicators to quantify the effect made by the technology at very first level like improvement in yield and productivity levels of the crop, cost saving over the inputs used, any improvement in product quality and nutrition levels, enriching or saving of natural resources, building system's resilience, reducing risk and reduction in regional and inter-personal disparity. In overall those parameters can be considered which directly or indirectly contribute in achieving the institutional goal.

Types of data and sampling

The original or first-hand information collected by the planner/researcher or his agents from the sample units for statistical analysis, interpretation and publication are called primary data. They are in the form of raw material. The data which are primary at one time may become secondary at another. The methods used for collection of primary data are PRA, direct personal interview method, indirect or oral examination method and through schedules/questionnaires/google forms or telephonic conversations. Secondary data consists of already collected data but available in various published forms and at various places. It includes records, documents of various central, state departments, universities and study groups etc.

Estimation of sample size and sampling

For collection of data, an investigator has to select samples out of a population called sampling. If the data is collected from each and every individual stakeholders of the entire population where sampling is not required is known as complete enumeration. Sampling procedure is a technique of selecting a sample from a given population. The most important consideration in selecting a sample is to see that it closely represents the total population. There are many techniques of selecting sampling units, they are:

- **Simple random sampling**: It is the simplest and most common method of sampling where each unit of population have equal probability of selection in each draw. The selection of sample units is done by lottery method or by using random number tables or by advanced version of these methods. This method is applicable when population understudy is homogeneous.
- **Stratified random sampling**: When the project area is large and/or population is heterogeneous, stratified random sampling technique is used. In this, the whole population is divided into sub-groups called strata and the sampling is done independently from each stratum. There should be minimum heterogeneity within a stratum and maximum between the strata. It ensures the better cross section of population and makes possible to use different sampling techniques in different strata.
- **Multistage sampling**: When the area to be surveyed is very large, then we divide the whole project or population and select some cluster/group from it called primary sampling unit. Selecting sample unit from this or sampling with proportional to size. These sample units are called secondary sampling units.
- **Snowball sampling**: is defined as a non-probability sampling technique in which the samples have traits that are rare to find. This is a sampling technique, in which existing subjects provide referrals to recruit samples required for an impact study.

The impact assessment of watershed program can be measured using the following impact indicators:

1. Improved cropping intensity
2. Equity: benefit sharing, access to resources
3. Additional employment generation
4. Additional farm and non-farm income
5. Extent of cultivation of wasteland
6. Income from different sources
7. Availability of fodder/grazing lands
8. Permanent improvements on the farm (farm mechanization, fencing etc.)
9. Improvement in farm assets and non-farm assets
10. Improvement in technology adoption in agriculture
11. Access to different markets and for better prices of farm produce
12. Access to better market information
13. Sustainability of watershed treatments
14. Poverty alleviation
15. Estimation of ground water recharge
16. Estimation of spillovers due to watershed development benefits outside the watershed.

Methodologies used for impact assessment:

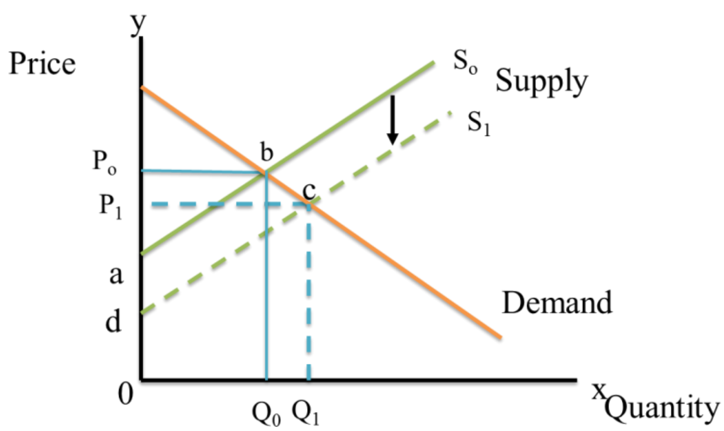
Field data can be used to do impact assessments using a variety of methods. Generally these are divided into three main groups:

- Econometric method: this method estimates the marginal productivity over a long period of time. Example: Cost functions, production functions and Total factor productivity (TFP).
- Programming method: this method aimed at identifying one or more optimal technological interventions or resource use from a set of options. Example: Linear programming, mathematical programming

- Surplus method: This method aims at measuring the aggregate social benefit of a watershed project or programme. Example: Economic surplus model.

Economic surplus model

The economic surplus model tries to quantify the aggregate social benefit of the watershed or technology being assessed. The social benefit can be received by the consumers or producers or any number of stakeholders in the economy. Economic surplus is not, of course, a monetary value that can be measured in anyone's bank account. It circulates throughout the economy, representing consumers' well-being from the consumption of this and other goods. The surplus earned in one market is quickly spent in another. For clear understanding of the same let us consider a typical market for an agricultural commodity whose price is given in y axis and the quantity demanded and quantity supplied in x-axis.



Considering relatively elastic demand and supply curves, we have the initial equilibrium point at b where the equilibrium price and quantity of the commodity if at P_0 and Q_0. With the introduction of new variety as a result of research which is high yielding, disease resistant variety in the market. This variety being popular and adopted by the farmers will slowly increase the quantity supplied in the market, as a result of which the supply curve slowly shifts towards right increasing the quantity supplied in the market from Q_0 to Q_1. At the same time decreasing the price for the commodity from P_0 to P_1 due to increasing quantity supplied. Here the consumer gains the maximum due to price reduction in the market and also increased quality produce, while the producers gain from the increasing demand at later stages for decreased prices and increase in the production levels. At the same times producers also lose some of the gains due to decrease in prices in the market due to increase in quantity supplied. Therefore, the net gain to the society is calculated by adding the gains of both consumer surplus and producer surplus which comes to the area abcd in the above figure. The purpose of the supply and demand curves is simply to establish clear scenarios for what would happen with or without research; economic surplus permits us to evaluate the difference between those two situations using a single measure. Any change in economic surplus is a measure of the social benefits derived from research. It is these gains that we intend to measure.

These effects can be expressed algebraically as follows:

$$\Delta PS = P_0 * Q_0 (K - Z) (1 + 0.5 Z n)$$

$$\Delta CS = P_0 * Q_0 * Z (1 + 0.5 Z n)$$

$$ES = \Delta TS = \Delta CS + \Delta PS = P_0 * Q_0 * k (1 + 0.5 Z n)$$

Where, K is the vertical shift of the supply function expressed as a proportion of tin: initial price, n is the absolute value of the elasticity of demand, e is the elasticity of supply and Z= KE I (E + n) is the reduction in price, relative to its initial (i.e. pre-research) value, due to the supply shift. The basic economic surplus model that considers a single market in a closed economy however the model will be extended to consider various multi market settings, mainly to disaggregate the measures of benefits that are obtained from the basic model (to allocate the producer surplus" among individual productive factors as quasi-rents and to allocate consumer surplus among different group of consumers).

The elasticity of demand and supply are considered based on the literature survey of the crop. Whereas, reduction in marginal cost is the ratio of relative change in yield to price elasticity of supply. Reduction in unit cost is given by change in cost of inputs per ha / (1+change in yield) Net cost change is given by the difference between reduction in marginal cost and reduction in unit cost.

Net Present Worth (NPW)

It is the incremental net benefits or incremental cash flow stream. It can be calculated by finding difference between the present worth of the benefit stream less the present worth of the cost stream of the project over its life period. This is the most widely used measure. The decision rule is to select the projects when NPW is greater than zero, otherwise reject. Higher the NPW better is the project. We have to select such projects which have highest NPW.

$$\text{NPV} = \sum_{t=1}^{n} \frac{(Benefit - Cost)^t}{(1+i)^t}$$

Internal Rate of Return (IRR)

This is the discount rate that makes the net present worth of the incremental net benefit stream or incremental cash flow equal zero. It is the maximum interest that a project could pay for the resources used if the project is to recover its investment and operating costs and still break even. This is the mostly used measure. The decision rule applied is to select the project if calculated discount rate IRR is greater than predetermined discount rate, otherwise reject it.

$$\text{IRR} = Lower\ discount\ rate + \text{Difference between the two discount rate} \times \frac{(NPV \text{ at the lower discount rate})}{Sum\ of\ absolute\ NPVs\ at\ two\ discount\ rates}$$

Benefit cost ratio

The ratio obtained when the present worth of the benefit stream is divided by the present worth of the cost stream. The decision rule applied is, if the B: C ratio is greater than unity, select the project otherwise reject it.

$$\text{BCR} = \sum_{t=1}^{n} \frac{Bt/Ct}{(1+i)^t}$$

Circular Economy

A circular economy model holds significance, relevance, and applicability since a long time. The focus and mind-set started shifting toward a circular economy model from 2005 onward mainly because of the increasing evidence of future demand–supply mismatch and realization regarding finite nature of available resources. A circular economy involves creating a closed-loop ecosystem for effective consumption and utilization of resources. This implies reconfiguring the material flows from a linear approach (resource-product-waste) toward a closed-loop approach (resource-product-waste new resource). The new reconfiguration model creates an ecosystem that is resilient and waste free owing to the adoption of reduce, reuse, and recycle paradigms.

There are 9R frame work strategies in circular economy which is given below,
R0 Refuse: Make product redundant by abandoning its function or by offering the same function with a radically different product
R1 Rethink: Make product use more intensive (E.g. By sharing product)
R2 Reduce: Increase efficiency in product manufacture or use by consuming fewer natural resources & materials
R3 Reuse: Reuse by another consumer of discarded product which is still in good condition and fulfills its original function
R4 Repair: Repair & maintenance of defective product so it can be used with its original function
R5 Refurbish: Restore an old product and bring it up to date
R6 Remanufacture: Use parts of discarded product in a new product with different function
R7 Repurpose: Use discarded product or its parts in a new product with a different function
R8 Recycle: Process materials to obtain the same (high grade) of lower (low grade) quality
R9 Recover: Incineration of material with energy recovery

Indicators of circular economy

- Resource output rate : Rate of output to input
- Resource consumption rate: Energy consumption per unit of output
- Integrated resource utilization rate: Waste recycling rate, Reuse ratio
- Waste disposal and pollutant emission: Total amount of waste generated & its disposal, CO_2 emissions

Ecosystem services

An ecosystem consists of all the organisms and the physical environment with which they interact, for example agro-ecosystems, forest ecosystems, grassland ecosystems and aquatic ecosystems. Ecosystem services are outputs, conditions, or processes of natural systems that directly or indirectly benefit humans or enhance social welfare.

The six major methods for valuing ecosystem services in monetary terms are

1. Avoided cost: Health cost
2. Replacement cost: Water purification plant
3. Factor income: quality of water increase income of fishers
4. Travel cost: Ecotourism
5. Hedonic pricing: Value of land/houses
6. Contingent valuation: Willingness to pay & Willingness to accept

Measuring Ecosystem services

There are four types of ecosystem services classification. They are:

1. Provisioning services: Food production, water, wood & fiber, fuel

2. Supporting services: Nutrient cycling, soil formation, primary production and habitat provision

3. Cultural services: Spiritual, Aesthetic, Educational & Recreational

4. Regulating services: Climate regulation, flood regulation & water purification

Risk and Uncertainty

Risk can be defined as imperfect knowledge where the probabilities of the possible outcomes are known and uncertainty exists when these probabilities are not known. Risk is a measurable uncertainty, whereas uncertainty is an unmeasurable risk. As we all know, agriculture is a gamble of nature hence risk and uncertainty becomes part and parcel of agriculture. Risk and uncertainty has a very thin line difference in agriculture. Many a times they are used as synonyms in agriculture research. Income loss due to decrease in price/wages, economic slowdown/financial crisis, government policies, etc. are examples for risk where the probability of loss or events can be measured to certain extend and also measures can be taken up in anticipation of them. Similarly, human, economic and infrastructural losses due to occurrence of natural calamities, fire, theft etc. come under uncertainties wherein the probability of occurrence of these events are unknown and the impact or the results are shocking and unbearable. Still the risk and uncertainty at an individual level, depends on the person's perception and his/her risk bearing ability.

Major types and their sources of risks and uncertainties in agriculture.

According to United States of Department of Agriculture (USDA) classification:

- **Production risk:** derived from the uncertain natural growth processes of crops and livestock. Weather, disease, pests, and other factors affect both the quantity and quality of commodities produced. This risk also includes timely availability of inputs, technology failure etc.

- **Market/price risk:** refers to uncertainty about the prices producers will receive for commodities or the prices they must pay for inputs. The nature of price risk varies significantly from commodity to commodity. Market intermediaries, lack of market infrastructure, grading and handling losses of the produce etc.

- **Financial risk:** results when the farm business borrows money and creates an obligation to repay debt. Rising interest rates, the prospect of loans being called by lenders, and restricted credit availability are also aspects of financial risk. Borrowing loan from money lenders etc.

- **Institutional risk:** results from uncertainties surrounding Government actions. Tax laws, regulations for chemical use, rules for animal waste disposal, and the level of price or income support payments are examples of government decisions that can have a major impact on the farm business. Further changes in the government policies and acts, subsidies, price support mechanism etc.

- **Human/personal risk:** refers to factors such as problems with human health or personal relationships that can affect the farm business. Accidents, illness, death, farmer suicides and divorce are examples of personal crises that can threaten a farm business.

All these types are interrelated and mixed and hence a careful analysis is to be made considering all types of risk including their sources to follow the relevant risk management strategies.

Risk attitudes

Risk attitude of an individual depends on his risk bearing ability which directly deals with the liquidity and solvency measures at short and term periods respectively. Risk attitudes can be divided into three types: risk averse, risk preferring and risk neutral

- **Risk averse:** Risk averters, or avoiders, are characterized as more cautious individuals with preferences for less risky sources of income or investment. In general, this individual will sacrifice some level of expected return in order to reduce the possibility of a loss. A person who is considered risk averse likely will also have a low risk bearing ability. Their situation would be such that a large income loss would seriously disrupt or end the business.

- **Risk preferring:** Risk preferring individuals are characterized as more adventuresome with a preference for more risky business ventures. Risk preferrers will select the alternative with some probability of a higher outcome. In order to get this higher income, this person must also accept a probability of a lower outcome compared to the risk averter. This person likely has a greater risk bearing ability and therefore is less concerned with the increased probability of a lower outcome and primarily focuses on the higher outcome potential.

- **Risk neutral:** The risk neutral person is the limiting case between the risk averse and risk preferring individuals. This person will have acceptable levels of risk bearing ability such that large losses are not of concern but at the same time, achieving the highest outcome is not the focus either. The primary concern is to achieve a sustainable outcome over time.

Decision making criteria under uncertainty

- **Maximax (Optimist):** The maximax criterion indicates that the decision-maker should choose the alternative which maximizes the maximum value of the outcome. This optimistic approach implies that the decision-maker should assume the best of all possible worlds.
- **Maximin (Pessimist):** This pessimistic approach implies that the decision-maker should expect the worst to happen. The maximin person looks at the worst that could happen under each action and then choose the action with the largest payoff. They assume that the worst that can happen will, and then they take the action with the best worst case scenario.

- **Regret criterion:** The regret of an outcome is the difference between the value of that outcome and the maximum value of all the possible outcomes, in the light of the particular chance event that actually occurred. The decision-maker should choose the alternative that minimizes the maximum regret he could suffer.
- **Utility criterion:** The utility criterion approach implies that the farmer is a risk averter. A risk averter is someone who prefers a more certain return to an alternative with an equal return but which is more risky.
- **Laplace criterion:** This is when the probabilities of several chance of events are unknown, they should be assumed equal, and the different actions should be judged according to their payoffs averaged over all the states of nature.

Risk management strategies

For an individual farmer, risk management involves finding the preferred combination of activities with uncertain outcomes with varying levels of expected returns. Risk management strategies can be grouped into three categories: risk prevention, risk mitigation and risk coping strategies. Prevention and mitigation strategies focus on income smoothing, while coping strategies focus on consumption smoothing.

Risk prevention strategies

They are intended for reducing the probability of a downside risk. They can also be called “risk reduction strategies”. These are introduced before a risk occurs. Reducing the probability of an adverse event occurring increases the producers’ expected income and reduces the income variance with a positive impact on wealth. These strategies primarily include market price support measures (through price stabilization), market interventions such as private storage support (financing for producers to build or upgrade farm storage and handling facilities), non-marketing of agricultural products, support to production techniques such as water management (irrigation, drainage, flood control etc.), the purchase of certified seeds and animal breeds, pest and disease control, technical assistance and extension, and the inspection of agricultural products and food safety measures. Whereas preventive strategies reduce the probability of the risk occurring, mitigation strategies reduce the potential impact if the risk were to occur.

Risk mitigation strategies

They have an ex-ante effect. They can take several forms, for example, payments with a variable rate (or countercyclical payments) compensating for all or part of the income losses suffered according to a pre-established formula, subsidies for risk management tools (insurance systems, futures markets), income tax smoothing systems, income diversification support, support of vertical integration, contracting etc.

Risk coping strategies

They can relieve the impact of the risk once it has occurred. They include mainly ex-post measures. The main forms of coping consist of disaster relief payments, ad hoc assistance, individual dis-saving/borrowing, migration, selling labour or the reliance on public or private transfers. In this case, the important role of the government lies in providing agricultural support programs such as calamity funds and other measures to manage sanitary or phytosanitary crises, safety nets, ad hoc state aid, social assistance etc.

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Chapter 9

Techno-social interventions for enhanced resource use efficiency, crop productivity and livelihood security- A case study in Ayalur Watershed, Distt. Erode, Tamil Nadu

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1. The Key Problem

The watershed lies in the tropical zone characterized with scanty rainfall (600mm) and dry climate. Most of the annual rainfall (about 51%) is received during the North-East monsoon (October to December) accompanied with high intensity storms. The watershed also receives good rains (about 30%) during South-West monsoon also. The uncertainty of North-Eastern monsoon and not too favorable contribution from the South-West monsoon make the plight of local agriculturists miserable. Lack of water resources for agricultural needs and low water yield in the bore well are the major problems due to less rainfall, increased water demand and more dependence on ground water leading to faster ground water depletion in the watershed. For want of irrigation facilities and less number of rainy days during NE monsoon, most of the land will be kept as fallow. Crops which are partially irrigated through bore wells often suffer from severe moisture stress and limits yield. Soils of the watershed have low water holding capacity and low nutrient status especially micronutrient. Low yield of crops and crop failure due to late onset of monsoon and long dry spell are the common problem in the watershed. This requires a careful crop management programme ideal for shallow red soils and also soil fertility maintenance measures in an integrated manner. In irrigated areas, efficient water use management practices need to be advocated to save scarce water resources. A sizeable area in the watershed with least productive soils was put under occasional crops. This could be considered for alternative land use including agri-horticulture, agro-forestry, horticulture with *micro-site improvement*. Availability of green fodders in the watershed is a serious problem which limits the milk yield. Landless labourers form a significant part of population and need employment or other income generation activities.

2. The Solution

Maximum stream flow could be expected during October-November as watershed receives 51% of rainfall in less number of rainy days. Hence, the major opportunity of harvesting rainwater for storage and /or ground water recharging exists during this period. There also exists ample scope to check and store runoff in the watershed by constructing a series of check dams, percolation tanks and ponds. Keeping these points in view, water harvesting activities like, series of check dams, percolation ponds, dugout ponds, farm ponds and desilting of existing percolation ponds had been taken up in arable land for recycling of harvested water and in non arable land for increasing water level in the open and bore wells for supplementary irrigation during *rabi* period.

The ground water resources were depleting in the watershed as a result of deficient recharge and increased dependence on groundwater. As a result, farmers in the watershed are going for the bore wells to a depth greater than 200 meter to get water. The low discharge from bore wells is not adequate for direct surface (flood, furrow or basin) irrigation, hence the farmers first pump the water from bore wells either to open wells or to an open unlined small surface storage pond for temporary storage from where it is pumped through centrifugal pump or under gravity flow to irrigate fields. In this method lot of seepage losses are encountered due to the prevalence of coarse textured soil. Hence, demonstrations on lining of surface storage ponds were taken up using silpaulin sheet in farmers' field. Following the success of silpaulin lining of ponds, these demonstrations were further up scaled to 7 farmers.

To further increase the water use efficiency, micro-irrigation techniques were propagated by way of installing 40 drip irrigation units and 5 units of sprinkler covering an area of 32 ha for crops like sugarcane, coconut and banana with 40% contribution from farmers.

Cultivation of groundnut and maize is the major land based activity in the watershed. Increased use of chemical fertilizer as source of major nutrients, combined with the declining use of organic sources of nutrients over time, has led to deficiency of micronutrients in soils, and reduction in beneficial microbes resulting in poor soil fertility. Nutrients such as boron and zinc are important to plant growth and yield of groundnut and maize respectively. Hence 32 number of crop demonstrations on INM with improved drought resistant varieties have been taken up in the watershed.

Alternate cropping system viz., dryland agriculture (*high density mango plantation with micro-site improvement*), agri-horticulture, silvipasture, commercial forestry, floriculture and site specific Integrated Farming System was introduced to increase the overall farm income. To reduce the drudgery for women engaged agriculture, improved implements were introduced. For creating livelihood and employment generation for land less labours self help groups (men and women) were formed for taking up various activities.

3. The Impact

A. Water harvesting/efficient use of irrigation water for increasing farm income and livelihood

A total of 18 water harvesting and gully control structures had been constructed and 4 existing structures were rejuvenated in the watershed through which 60749 m^3 storage capacities had been created. As a result of water harvesting through these activities a total of 242 ha-cm water have been harvested (Jan. to Oct., 2010) and the impact on ground water recharge was visualized by a rise in ground water table ranging from 2.3 to 13.9 m with average of 8.0 m in the vicinity of the structures in the watershed(Table 1). Because of increased water availability in the bore-well, farmers switched over to cultivation of commercial crops during *rabi* and they could give more irrigation to *kharif* groundnut which resulted in additional yield and income in the tune of 20% and 47%.

Table 1: Total water harvested through WHS and their impact on GW table

Details of WHS	Cost (Rs)	Capacity (cum)	No. of fillings	Total storage (cum)	No. of wells in vicinity	Depth to Water table (m)		Max. Water table rise (m)
						Before	After	
PP(M)C.Thotam	239,981	541	5	2705	3	13.9	1.8	12.1
PP(S)Murugesan	132,435	1016	4	4064	4	12.3	3.3	9.1
PP(M)Subramani	170,099	550	3	1650	2	14.9	7	7.9

PP(S)-Ramasamy	182,154	780	4	3120	3	6.2	2.9	3.4
Rej PP-Natraj	39,934	23612	5	118060	2	13.2	1	12.2
Rej PP-Murugesan	29,434	5980	2	11960	4	12.3	1	11.3
Rej PP-Palani	72,502	10575	4	42300	3	14.5	0.6	13.9
Rej CDs	8,463	114						
CD-Chi.Pal.	36,508	76	4	304	1	14.1	4.1	10
CD-Nataraj	107,278	257	4	1028	2	16	4.8	11.2
CD-Rajamani	110,866	280	3	840	3	13	5.5	7.5
DP-Samyappan	20,047	252	4	1008	2	23.3	12.6	10.7
DP-Rajamani	30,484	427	3	1281	4	12.6	3.5	9.1
DP-Pongiannan	26,104	338	4	1352	3	15	8.6	6.4
DP-Senthil	27,433	365	6	2190	2	17.2	11.5	5.7
DP-SP Raju	27,360	308	3	924	4	14	4	10
FP-Thangavelu	12,474	324	2	648	1	16.5	14.2	2.3
FP-Ganesan	14,419	306	3	918	2	13.2	6	7.2
PP-S. Palayam	69,677	1620	5	8100	4	15.3	2.2	13.2
PP(L)Mallipalayam	354,735	11420	3	34260	6	14	7	7
PP(M)-Odaimedu	217,177	952	3	2856	4	15	8	7
PP(S)-Kannan	152,112	656	4	2624	3	16.2	10.4	5.8
Total/Average	208,1676	60749		242192	36	14.1	4.1	8.0

PP: percolation pond; Rej PP: Rejuvenation of PP; CD:Check dam; DP: Dug out pond

Lining of surface storage pond resulted in 60% water saving. The water thus saved by provision of the lining was used by the farmer to increase the cropped area under irrigation (44%). The increase in irrigated area (0.8 ha) had fetched the farmer a handsome additional return of nearly Rs. 40,000/year. The simple technology of lining the ponds with *silpaulin* has earned the appreciation of the farming community in Ayalur watershed which has responded with a huge demand for this technology(Table 2, 2a, 2b and 2c) The impact of introduction of micro-irrigation shows that 17% to 50% water saving has been realized through this micro irrigation technique which resulted in additional area under cultivation(Table 3)

Table 2. Impact of lining surface storage pond in Ayalur watershed

Details of pond	Pond size	Average losses through seepage and evaporation (m^3/day)	Amount of water saved (m^3/day)
Control pond with no lining	17 m x 7.5 m x 0.55 m	2.62	-
Pond with silpaulin lining	23.8 m x 7.8 m x 0.75 m	1.04	18.96

Table 2.a. Water saved during crop period due to lining of surface storage pond

Crops	Area irrigated (ha)	No. of irrigations	Total number of pond fillings*	Amount of water saved (m^3)
Groundnut	1.3	10	65	1232.4
Tobacco	1.1	15	83	1564.2
Fodder sorghum	0.2	2	2	37.9
Total	2.6	27	150	2834.5

*Water filled one time in pond can irrigate 0.2 ha

Table 2.b. Irrigated area before and after lining of surface storage pond with groundwater

<table>
<tr><th rowspan="2">Crop</th><th colspan="4">Irrigated area before intervention (ha)</th><th colspan="4">Irrigated area after intervention (ha)</th><th rowspan="2">Increase in irrigated area (ha)</th><th rowspan="2">% increase in irrigated area</th></tr>
<tr><th>Kharif</th><th>Rabi</th><th>Zaid</th><th>Total</th><th>Kharif</th><th>Rabi</th><th>Zaid</th><th>Total</th></tr>
<tr><td>Groundnut</td><td>0.8</td><td>-</td><td>-</td><td>0.8</td><td>1.3</td><td>-</td><td>-</td><td>1.3</td><td>0.5</td><td>62.5</td></tr>
<tr><td>Tobacco</td><td>-</td><td>0.8</td><td>-</td><td>0.8</td><td>-</td><td>1.1</td><td>-</td><td>1.1</td><td>0.3</td><td>37.5</td></tr>
<tr><td>Fodder sorghum</td><td>-</td><td>-</td><td>0.2</td><td>0.2</td><td>-</td><td>-</td><td>0.2</td><td>0.2</td><td>-</td><td>-</td></tr>
<tr><td colspan="4">Total area (ha)</td><td>1.8</td><td colspan="3">Total area (ha)</td><td>2.6</td><td>0.8</td><td>44.4</td></tr>
</table>

Table2.c. . Crop production and returns before and after lining of surface storage pond

Crop	Before intervention			After intervention			Additional Return (Rs.)
	Yield (kg/ha)	Total production (kg)	Gross return (Rs.)	Yield (kg/ha)	Total production (kg)	Gross return (Rs.)	
Groundnut	1062	849.6	18700	1100	1430	31460	12760
Tobacco	2250	1800	63000	2337	2571	90000	27000
Fodder sorghum	15000	3000	7000	15000	3000	7000	-

Table 3: Impact of drip irrigation on water saving and irrigated area

Sample site	Crop		Volume of water (lit)			Area (ha)		
	Before	After	Before (per flood irrigation)	Drip used for flood irrigation interval	% of water saving	Before	After	% increase
1	Sugarcane	Sugarcane	122400	61568	49.7	0.8	1.1	37.5
2	Tobacco	Sugarcane	216000	166400	23.0	3.2	4.8	50.0
3	Tobacco	Sugarcane	97200	66560	31.5	0.8	1.0	25.0
4	Coconut	Coconut	43200	36000	16.7	1.4	1.4	0.0
5	Coconut	Coconut	86400	45864	46.9	1.6	1.8	12.5

B. INM and intercropping for higher productivity and farm income

Crop demonstrations on new drought resistant varieties and integrated nutrient management with micronutrients (boron in groundnut and zinc sulphate in maize), soil amendments and bio-fertilizer in groundnut and maize resulted in 18-72% and 22% yield increase respectively.

Even though the watershed receives both south-west and north-east monsoon, cropping activities in dryland confined to *kharif* only as the number of rainy days during northeast monsoon is very less. Crop failure is common in *kharif* groundnut due to late onset and early withdrawal or long dry spell. In order to utilize both monsoon effectively, long duration (180 days) red gram variety CO6 was inter cropped with groundnut variety VRI-2(110 days) duration at 10:1 (groundnut: redgram) ratio resulted in 20% higher groundnut equivalent yield and higher rain water use efficiency (RWUE) and land equivalent ratio(Table 4 to 6)

Table 4: Benefits of improved cultivation practices over farmers' practice for different crops in Ayalur watershed

Interventions	Yield (kg/ha)	Additional yield (kg/ha)	Additional cost (Rs/ha)	Additional income (Rs/ha)	Rain water use efficiency (kg/ ha. mm)
Groundnut					
Farmer's practice	1650	-	-	-	3.8
Local seed with INM	2400	750	3668	12832	5.6
Truthful seed without INM	1950	300	2000	4600	4.5
Truthful seed with INM	2850	1200	4668	21732	6.6
Maize					
Farmer's practice	4500	-	-	-	10.0
Hybrid seed with INM	5500	1000	2747	5253	12.2

Table 5: Intercropping in groundnut on productivity and RWUE

Intervention	Groundnut yield (kg/ha)	Red gram yield (kg/ha)	Groundnut Equivalent yield (kg/ha)	RWUE (kg/ha-mm)	LER
Groundnut alone	2840	-	2840	3.32	1.0
Groundnut + red gram intercropping 10:1 ratio	2840	250	3408	3.98	1.2
Groundnut + cow pea intercropping 6:1 ratio	2720	150	3129	3.65	1.1

Table 6: Economics (Rs ha^{-1}) of crop diversification (Average of three farmers)

Particulars	Groundnut	Marigold	Cabbage
Yield (kg ha^{-1})	1875	8120	28560
Cost of cultivation	16500	50950	51000
Gross income	43125	121800	114240
Net income	26625	70850	63240
Additional net income	-	44225	36615

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C. Alternate land use system for higher farm income and livelihood and to avoid crop failure

About 10 ha land had been brought under dryland horticulture. More than 90 % establishment was achieved with micro-site improvement technique (pits size: 1x1x1 m, removal of gravels from soil in the pits and application of FYM (30 kg/pit), bio-agent (Neem cake @ 200 g/pit) and bio-fertilizers (VAM, *Phosphobacteria* and *Azospirillium* @ 50 g each/pit). During the initial growth period of mango, fodder yield of 20 t ha^{-1} from fodder sorghum and 840 kg ha^{-1} of groundnut pod was achieved as intercrop during *kharif* season. Fruiting had started in the third year of planting.). Commercial forestry involving *Melia dubia* was introduced first time in the watershed. Each tree is expected produce 5-7 cu.ft. of timber and the farmers may get 15 lakh from one hectare of land after six years with current price of wood (Rs. 300 per cu.ft.). Site specific Integrated Farming System which involves agriculture, poultry, fishery and livestock resulted in reduction of fertilizer requirement by 50 % by fertigating crops with cowdung and urine mixture and increasing farm income by Rs. 8400/month.

In order to minimize the risk of crop failure and increase the livelihood in *rainfed* area, more land was brought under agri- horticulture, in which, groundnut was intercropped with mango. Inclusion of commercial forestry trees in marginal land increased farm income and supplies timber and fuel wood in the watershed. Considering the large population of livestock in the watershed, improved fodder crops like Hybrid Napier (CO-4), multi-cut fodder sorghum (CO-FS 29) and fodder maize (African tall) were introduced to augment the fodder requirement. Crop diversification involving non traditional vegetable crops and floriculture increased farm income by 33% -77%. To increase the nutritional security 30 units of backyard poultry (Asseel variety) was introduced in the watershed. To increase the resource use efficiency, integrated farming system model suitable for semi-arid region was developed which increased farm income and reduce the fertilizer requirement by 50%.

Considering the presence of large number of land less poor in the watershed, alternative income generating activities were taken up through formation of self help groups (SHGs) for the upliftment of landless poor and resource poor farming families in the watershed. Thirty two SHGs (17 women and 15 men) and 12 user groups have been formed with ten members each from the resource poor community in the watershed to take agricultural based and other livelihood. Half of the executive committee was represented by women and scheduled caste people. More than the 50 per cent of self help group was represented by the women and schedule caste peoples. Women do stripping groundnut pod from plant which is a very difficult process. To reduce the drudgery of women folk who mainly do the groundnut stripping, ground nut stripper was introduced in the watershed which made stripping ground nut easy for women.

5. Lessons learnt from this approach

Active participation of local community at each and every stage is a pre-requisite to any programme on development and management of watersheds, wastelands or resource poor lands. Success rate of activities pertaining to the water resource creation and their efficient use is very high as the farmers show more interest in these activities and these activities should be given more importance and fund allocation. When we introduce any alternate land use system, simple distribution of tree seedlings leads to failure of the activity. Hence associated technologies like micro-site improvement, micro irrigation, live fencing should be given due importance for success of dry land horticulture and agro-forestry system.

The important hiccup we learned from this watershed is after withdrawal of the project, people show little interest in periodical auditing and renewal of watershed association.

6. The Way forward

The interventions of water harvesting, lining of surface storage pond, integrated nutrient management, alternate land use system and integrated farming system can be up scaled in red soil areas of north western and western region (Coimbatore, Erode, Thirupur, Karur, Theni, Dharmapuri, Krishnagiri, Namakkal, Perambalur and Salemand Dindigul districts) of Tamil Nadu

Name of the project: Improving natural resources base, productivity and farm income in the western region of Tamil Nadu

Key partners: Departments of Agricultural Engineering and Agriculture, Govt. of Tamil Nadu and KVKs in this region under the guidance / supervision and monitoring by TAWDEVA, Chennai

Project duration: Five years

Chapter 10

Innovations in Agricultural Extension

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Agriculture extension system bridges the gap between research labs to a farmer's field. However, the reach of the public extension is limited in the country and in addition it is burdened with non-extension responsibilities such as the distribution of subsidies and inputs, with little time left to attend to core extension activities like advising farmers to enhance adoption of new practices and techniques (Reddy 2018). Agricultural extension in India is skewed towards crop production neglecting allied sectors, though the allied sectors such as dairy and fishery significantly contribute towards farmer's household income. However, extension support is weak in the case of animal husbandry and fisheries in India. Agriculture Extension as an empowering system of sharing information, Knowledge, Technology, Skill, Risk and farm management practices across Agricultural sub-sectors, all along the Agricultural value chain, so as to enable the farmers to realise higher net income from their enterprise on a sustainable basis. Agricultural extension plays a crucial role in boosting agricultural productivity, increasing food security, improving rural livelihoods, and promoting agriculture as an engine of pro-poor economic growth. In general, extension includes transferring information, knowledge, and technologies from research systems to farmers; advising farm families in their decision-making; educating farmers; and empowering farmers to be able to clarify and realize their goals. To a large extent, most extension programs are publicly funded, supported by local, state, and national governments. During the past several decades, numerous models of agricultural extension and community outreach services have been implemented.

1. Public Extension

Public extension refers to extension services provided by public departments like Union Ministry of Agriculture and Farmers Welfare, State Department of Agriculture and allied line department, agricultural research institutes under ICAR, State Agricultural Universities, Directorate of Extension and other government agencies falls under public sector agricultural extension**.** The public extension approach disseminate those technologies in which private sector shows less interest due to its non-profitable nature. According to Stefanie Kaegi (2015), some of the major challenges faced by Public Extension in India are it is burdened with non-extension duties, lack of qualified public extension professionals, extension professional's unwillingness to work in remote areas, depending on State priorities, public agricultural extension delivery is neglected. The public sector extension is currently offering a one-size-fits-all to all category farmers and all kind of products. Considering heterogeneity among farmers, crops they produce, agro-climatic zones, soil types farm resources endowments, enabling policy environment, etc., there is a need for continues capacity building of extension professionals as they lack recent advancements in agriculture technologies and development.

a) Krishi Vigyan Kendra (KVKs):

Presently, ICAR runs 732 KVKs across the country. KVKs assess, refine and transfer the agricultural technologies to the farmers in diverse farming systems. Also develop the capacity of farmers to update their knowledge and skills in modern agricultural technologies. Trainings are also imparted for extension personnel to orient them in the frontier areas of technology development. More recently, KVKs are working as resource and knowledge centre of agricultural technology for supporting initiatives of public, private and voluntary sector for imparting the agricultural economy of the district.

b)Agricultural Technology Management Agency (ATMA):

ATMA is a society of key stake holders involved in agricultural activities for sustainable development in the district. In India, the ATMA is conceived to be the major single best-fit institutional extension reform in extension advisory systems. It is act as a platform for integrating research and extension activities and decentralizing day to day management of public agricultural technology system of the district and below levels. It is registered society responsible for technology dissemination at the district level. As a society, it can receive and spend project fund, enter in to contracts and agreements and maintain the revolving accounts which can be used to collect fees and there by recovering the operational cost.

2. Private Sector

Private extension involves personnel in the private sector that delivers advisory services in the area of agriculture and is seen as an alternative to public extension. The private extension is becoming popular day by day because it reduces the economic burden of governments, increases accountability of extension agents, increases competency of extension system, provides relevant and highly effective agro-advisory services on high value crops and enterprises, promotes cooperatives, farmer production and marketing groups and also provides advisory services in post-production technologies. Private organisations such as UPASI, Parry's corner, Dhan foundation, Hatsun Agro products, Sustainable Agro Alliance limited, progressive farmers, input dealers (both DAESI Trained and non trained), AC&ABC Candidates, and mass media are the major sources of information to farmers in India (Ferroni and Zhou, 2012).

3. Public-Private Partnership

Public-Private Partnership (PPP) describes a government service or private business venture which is funded and operated through a partnership of government and one or more private sector companies. It is a contractual agreement between a public agency and a private sector entity. Through this agreement, skills and assets of each sector (public and private) are shared in delivering a service or a facility for the use of the general public. In addition to the sharing of the resources, each party shares risks and rewards potential in the delivery of the service and/or the facility. The PPP approach supplements scarce public resources, creates a more competitive environment and helps to improve efficiencies and reduce costs. It provides an opportunity for private sector participation in financing, designing, construction, operation and maintenance of public sector programme and projects. Risk allocation plays a vital role in PPP management. Preplanned proposals with time

a) Contract Farming

Contract farming involves a forward contract according to which growers are committed to provide an agricultural commodity of a certain type at a certain time and price in a specified quantity to a known buyer, an agribusiness company. A number of agro-processing and trading firms makes contract with the farmers to produce specific commodity and these firms after provide extension services as part of contract farming arrangement providing extension services helps in procuring adequate quantity with specified quality and type of produce or processing or trading in high value market.

4. Market-Led Extension Approach

It is an approach through which extension system reached to the clientele on an end basis, beginning from package of practices for production to selling of produce at the consumer's door so that the farmers can get remunerative prices for their produces. Farmers are sensitized on the production aspects like (i) what to produce (ii) when to produce (iii) how much to produce (iv) when and where to sell. Besides this, farmers are also sensitized on consumer preference, market intelligence, processing and value addition and market information system. The market-led extension deals with all these parameters from production to marketing of agricultural produce.

5. Non-Government Organizations (NGOs)

It is any non-profit, voluntary citizen’s group which is neither a part of a government nor a conventional for-profit business. NGOs may be funded by government, foundations, businesses or private persons. NGOs provide very important support to Indian smallholders even they cannot cover all those seeking advice as governmental organizations do. NGOs range considerably in size with the high social commitment. Many dedicate themselves as per demand driven extension. NGOs, have gradually been adopting new extension methods, education tools, delivery models, innovative extension structures etc. to overcome the ever increasing challenges related to agriculture and to meet the changing needs of the farming community. NGOs, such as Professional Assistance for Development Action (PRADAN), BAIF Development Research Foundation and Action for Food Production (AFPRO) are actively involved in promoting extension activities in more than one state (Gulati et al., 2018). In the case of NGO led extension models are relatively efficient and exhibit sensitivity to local priorities, however, they lack capacity and scale to make to create impact at large. It is evident that non-public extension players offering extension services in a localized region without any coordination among the players and even with the public extension.

6. Farmers Producer Organization

Farmers Producer Organization (FPO) are essential institutions for the empowerment, poverty alleviation and advancement of farmers and the rural poor (FAO, 2006). These organizations not only ensure a bargaining edge to farmers but also reduce cost of cultivation, food processing, supplying inputs at affordable prices, supply of quality planting materials, organizing training, capacity development programmes etc., on the latest agricultural technologies as well as developing model farmers, organizing field visits to progressive farmers fields, etc (Vincent and SaravananRaj). The Producer Organizations of primary producers viz., farmers, milk producers, fishermen, weavers, rural artisans, craftsmen are forming producers companies, providing sharing of profits/benefits among the members. These FPOs may be input and output management organizations at village level.

7. Farmer Field School (FFS)

It is a group-based learning process that has been used by a number of govt., NGOs, and international agencies. The first FFS was designed and managed by the UN Food and Agriculture Organisation in Indonesia in 1989 since then more than two million farmers across Asia have participated in this type of learning. FFS consists of 20-25 farmers who meet one morning every week for an entire crop growing season. A FFS is facilitated by extension workers on skilled farmers. Employing non-formal education method, the field is used as the primary resource for learning. Farmer field schools (FFS) are a participatory method of learning.

8. Nutrition-Sensitive Agriculture

Nutrition-sensitive agriculture is a food-based approach to agricultural development that puts nutritionally rich foods, dietary diversity, and food fortification at the heart of overcoming malnutrition and micronutrient deficiencies. This approach stresses the multiple benefits derived from enjoying a variety of foods, recognizing the nutritional value of food for good nutrition, and the importance and social significance of the food and agricultural sector for supporting rural livelihoods. The overall objective of nutrition-sensitive agriculture is to make the global food system better equipped to produce good nutritional outcomes.

9. Climate Smart Extension

Climate Smart Extension is an approach used for transfer of different forms of climate information to the farmers to make informed farming decisions, climate smart technologies to cope with the climate change and to mitigate the effects of climate change as well as to reduce GHG emission in agricultural practices to achieve the global food security. Extension methods for capacity development are Climate Trainings and Demonstration, Climate-Smart Farmers Field Schools (CFFS), Village Level Custom Hiring Centre (CHCs), Community based Disaster Management (CBDM) approach, Agrometeorological Advisory Service and Climate Smart Villages.

10. Family Farmer:

Similar to the family doctor, the family farmer concept has to be promoted among consumers. It is a win-win situation as the consumers get clean and pesticide-free farm produce and the producers are motivated further to continue the practice of safe production of foods. This will allow the consumers to know about their producer, production methodology, nature of produce etc., thereby trust will be built between producers and consumers. Family Farming (which includes all family-based agricultural activities) is a means of organizing agricultural, forestry, fisheries, pastoral and aquaculture production which is managed and operated by a family and predominantly reliant on family labor, including both women's and men's. The family and the farm are linked, co-evolve and combine economic, environmental, social and cultural functions.

11. Farmer Led Extension:

Many of the past projects failed due to lack of farmer participation. Farmer participation is required for problem diagnosis, process implementation, monitoring and evaluation and provision of feedback. The traditional knowledge and technologies are to be developed keeping in mind the local conditions. For this, a strong partnership between farmer and extension agent is imperative. Proper incentives and recognitions in the form of awards are also being arranged for innovative farmers in various Krishi Melas and other institutional arrangements.

12. Agripreneurship Led Extension:

In view of shrinking land base and rampant unemployment, there is need to commercialise and diversify Indian Agriculture in such a way that one can generate more income per unit of area and time and create agro-based employment opportunities. For this to happen we need to convert agriculture into agri business. Another issue is that with liberalisation, privatisation and globalisation, the whole world has become like a local market where our farmers and their products will have to compete with multinationals in terms of quality and price. In this scenario, a shift in extension approach is demanded. Unlike crop production, developing entrepreneurship is not an activity but a chain of events and require functional linkages with various support systems. Agripreneurship provides value addition to agricultural resources typically engaging rural human resources.

a) Entrepreneurial Opportunities in Agriculture and Allied Sectors:

Agriculture sector provides various employment opportunities like Organic farming, Agro based industries, farm mechanization, post- harvest processing, quality input production and supply chain, synthesis of bio fertilizers like vermi composting, medicinal plant farming, pickle production, flori culture, mushroom cultivation so on. Furthermore, an important subsector of agriculture i.e. Veterinary and Animal Husbandry Sector provides opportunities for milk processing and chilling, meat processing, feed preparation, Vaccine and drug preparations along with other allied sectors like honey bee rearing, fish production, oyster farming etc. are the innovative ways to take agriculture as a means of commercialization and profitable venture.

b) Agri Clinics & Agri Business Centres (ACABC) Extension:

The Ministry of Agriculture and farmers welfare, Government of India, in association with NABARD has launched a unique program to take better methods of farming to each and every farmer across the country. This program aims to tap the expertise available in the large pool of Agriculture Graduates. Irrespective of whether a fresh graduate or not, or whether currently employed or not, Graduate can set up own Agri Clinic or Agri Business Centre and offer professional extension services to innumerable farmers. Committed to this program, the Government is now also providing start-up training to graduates in Agriculture, or any subject allied to Agriculture like Horticulture, Sericulture, Veterinary Sciences, Forestry, Dairy, Poultry Farming, and Fisheries, etc. Those completing the training can apply for special start-up loans for venture.

13. Agriculture Value Chain Extension

The Agriculture Value Chain Extension helps to farmers succeed in increasing their yield and income by building technical agriculture skills and an agro-business mindset. It develops skills and knowledge related to in-season, harvest, and post-harvesting farming practices. It helps to Increase decision-making and investment skills that are necessary for a farming-as-a-business approach. The emerging trend for agricultural sector in the global market creates opportunities for smallholder farmers in the developing countries to benefit from such opportunities by linking their activities to value chains through vertical and horizontal linkages. Value chain is the entire range of activities required to bring a product or service from the initial input-supply stage through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use (Kaplinsky and Morris, 2001).

14. Participatory Technology Development (PTD):

Participatory Technology Development (PTD) is an approach that promotes farmer driven technology innovation through participatory processes and skills building involving experimentation to allow small scale farmers to make better choices about available technologies. Those innovations could be in improving local technologies or through introducing new technologies from elsewhere.

15. Information and Communication Technology in Agriculture:

Agriculture is prime occupation of Indians although it is still substance nature, farmers are work hard entire year in day and night but their socio economic conditions getting worse over the years. With invention of new technologies, software technologies, communication tools, audio visual systems helps to transfer new technologies, improved cultivation practices, weather information, marketing and price information to farmers with timely helps to improved production, productivity and better price for products of the farmers. ICT in agriculture is also known as 'e- agriculture' is developing and applying innovative ways to use use ICTs in rural area, with the primary focus on agriculture. ICT in agriculture offers a wide range of solutions to some agricultural problems. It is seen as an emerging and field focusing on enhancement of agricultural and rural development through improved information and communication processes.

a). Kisan Call Centres (KCC):

In order to harness the potential of Information & Communication Technology (ICT) in Agriculture, Ministry of Agriculture & Farmers Welfare launched the scheme "Kisan Call Centres (KCCs)" on January 21, 2004. The main aim of the project is to answer farmers' queries on a telephone call in their own dialect. These call Centres are working in 14 different locations covering all the States and UTs. A countrywide common eleven digit Toll Free number 1800-180-1551 has been allotted for Kisan Call Centre. This number is accessible through mobile phones and landlines of all telecom networks including private service providers. Replies to the farmers' queries are given in 22 local languages.

Call center services are available from 6.00 am to 10.00 pm on all seven days of the week at each KCC location. Kisan Call Centre agents known as Farm Tele Advisor (FTAs), are graduates or above (i.e. PG or Doctorate) in Agriculture or allied (Horticulture, Animal Husbandry, Fisheries, Poultry, Bee-keeping, Sericulture, Aquaculture, Agricultural Engineering, Agricultural Marketing, Bio-technology, Home Science etc. and possess excellent communication skills in respective local language.

Conclusion:

Several innovations of agricultural extension have been developed and implemented to support farmers. Every model has its strengths and weaknesses, and the success of these innovations have varied from country to country and from region to region depending on sociocultural aspects and institutional support structures. No single innovation fits everywhere. Extension and advisory services will always remain a key pillar of agriculture development programs. Presently, extension service providers such as Public, Private, civil societies are working independently without functional coordination among themselves at field level. As a result, best practices generated by each of the actors not accessible to the wider application.

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