Research Bulletin

Agronomical management practices for higher productivity, resource use efficiency and farm income in semi-arid region

A case study in Ayalur Watershed

K. Kannan, O.P.S. Khola, V. Selvi,
D.V. Singh and R. Mohanraj

Central Soil & Water Conservation Research & Training Institute
(Indian Council of Agricultural Research)
Research Centre, Udhagamandalam-643 004, India

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The Head
Central Soil & Water Conservation Research & Training Institute
(Indian Council of Agricultural Research)
Research Centre, Udhagamandalam - 643 004
Tamil Nadu, India
Phone: +91 423 2444038, 2443992
Fax: +91 423 2446757
Email: cscooty@gmail.com

CONTENTS

Executive Summary

Watershed management has emerged as a new paradigm for planning, development and management of land, water and biomass resources with a focus on social and environmental aspects following a participatory approach. Scientific planning and management of the available resources is vital for the maintenance of their production potential, quality and diversity.

Watershed programs in India so far have focused mainly on natural resource conservation and interventions such as soil and rainwater conservation. As for as the production aspect is concerned, no much important has been given. For meaningful interventions in the production aspects, it is important to design the interventions as technical package as per the constraints identified for various production system in a particular area.

Agronomical interventions like integrated nutrient management, intercropping, crop diversification, improved compost production, integrated farming system, fodder improvement and alternate land use system were carried out in Ayalur watershed, Erode district, Tamil Nadu to increase productivity, resource use efficiency and farm income based on the constraints identified in relation to agriculture in the watershed. The watershed comes under semi-arid region which receives about 600 mm of rainfall annually. The soil is gravelly red sandy to sandy loam which is poor in soil depth, water holding capacity and nutrient content which resulted in poor productivity.

An average additional yield of 42%, 34%, and 22% with an additional benefit of Rs 21732, Rs 15450 and Rs 8000 per ha was achieved with the improved cultivation practices respectively for supplemental irrigated groundnut, rainfed groundnut and maize. Intercropping of rainfed groundnut with red gram at 10:1 ratio resulted in 20% increase in groundnut equivalent yield besides increasing rainwater use efficiency. Preparation of compost with locally available coir pith waste was demonstrated and its application increased the yield of rainfed maize by 17% due its moisture absorption capacity. Crop diversification with marigold and cabbage produced an additional farm income of Rs 44225 and Rs 36615 compared to the conventional crops like groundnut and maize.

Integrated farming system model which involves fish culture in the surface pond, poultry unit in cage constructed over the pond, fertigation with cow urine resulted in an additional income of Rs 10800 per unit.

Higher survival rate of fruit trees in dryland horticulture and agri-horticulture was achieved with micro-site improvement. From annual crops, during first three years, an average income of Rs 87890 per ha was realized. After five years of planting, mango is expected to yield 8-10 t ha^{-1} with a net benefit of Rs 160000 per ha. *Melia dubia*, a money spinning tree, was introduced as block plantation for commercializing the agriculture.

These demonstrations on agronomical interventions on production system in a systematic way in the watershed not only helped in conserving the natural resources but also helped in increasing productivity and maximising the farm income.

Background

Soil and water are the most precious natural resources, which sustain our life. In rainfed area watershed management is the approach used for conservation of water and other natural resources as well as for sustainable management of natural resources. A watershed is a hydrologically defined area that is drained by a network of streams, which meet together in such way that the water leaves through a common point. Soil and water conservation including micro-scale water resource development is the foundation of any watershed development programme supported by a number of other protection, production and livelihood support interventions. Therefore, watershed management is the process of guiding and organizing land use and use of other resources in a watershed to provide desired goods and services to people while enhancing he resource base without adversely affecting natural resources and the environment (Wani *et al*., 2001).

In India, though rainfed areas account for about 67 per cent of the cultivated area (Singh *et al.,* 2000), their contribution is only about 45 per cent of total food grain production. A major part of the coarse cereals, pulses and oilseeds are cultivated in the rainfed regions. Crop productivity in these areas is low and highly variable, depending on the vagaries of monsoon. This has led to wide regional disparities in the income and living standards of farmers. Irrigation facilities in these areas are limited due to lack of suitable sites for large storage, high cost involved and environmental considerations. There is a general tendency to exploit groundwater for food crops by few resourceful farmeRs

Watershed programs in India so far have mainly focused on natural resource conservation and interventions such as soil and rainwater conservation and to some extent afforestation in the government forest lands (Sreedevi *et al.*, 2004). As for as the production aspect is concerned, no much important has been given. Mostly it was confined with the distribution of inputs like, fertilizers, seeds and organic manures for agriculture and distribution of fruit seedlings and tree seedlings as horticulture and agro-forestry intervention. However, watershed projects should move from purely soil and moisture conservation and water harvesting interventions to approach which includes production aspects also. For meaningful interventions in the production aspects, it is important to design the interventions as technical package as per the constraints identified for various production system in a particular area. This approach not only increases the productivity but also helps in conserving the natural resources. In the backdrop of this, the research cum development effort was focused here on increasing productivity, resource use efficiency and farm income in the semi-arid area.

Ayalur Watershed

This dryland development project was undertaken at Ayalur watershed during 2008-09 to 2012-13. The Ayalur Watershed is located in Gobichettipalayam taluk, Erode district, Tamil Nadu state at 21 km from Sathyamangalam on Sathyamangalam - Perundurai road. It is about 120 km from Ooty and 8 km from Gobichettipalayam between the longitudes of 77^{o} 22’ 43” to 77^{o} 24’ 10” E and latitudes of 11^{o} 22’ 16” to 11^{o} 25’ 19” N. Five revenue villages namely Mallipalayam (including the hamlet Puthucolony), Kulaimuppanur (including the hamlet Anna colony), Palapalayam (including hamlets Odaimedu, Kattusalai, Papathikadu) Semmandampalaiyam and Pulliyangadu are located in the watershed.

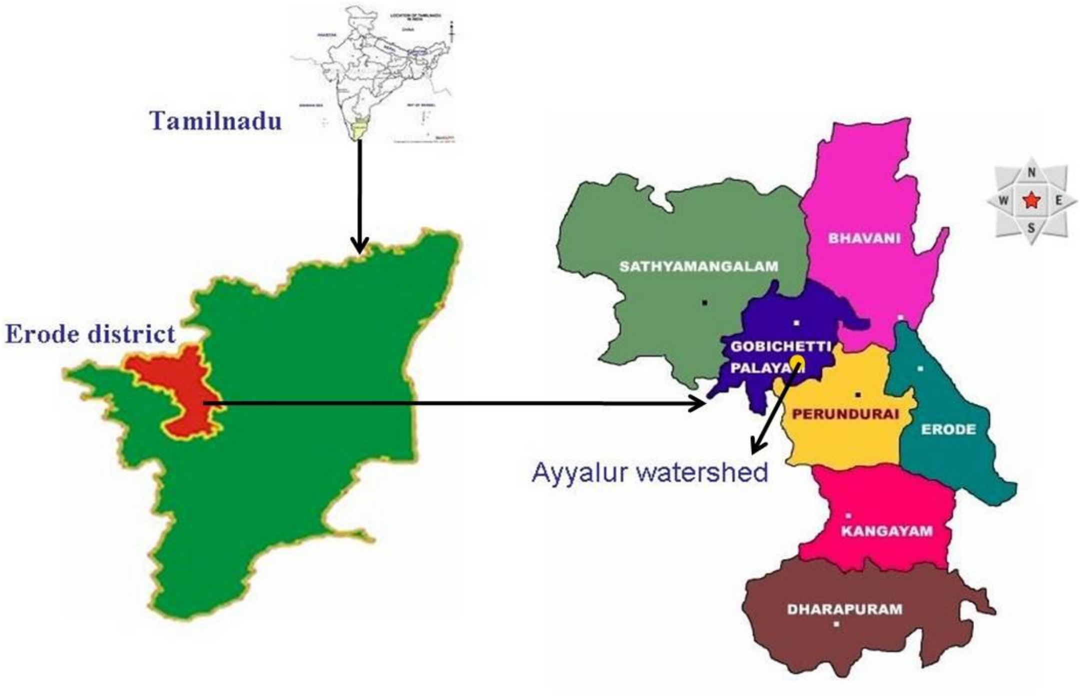

Fig. 1. Location of the Ayalur watershed

The area where we conducted this programme lies in the tropical zone characterized with scanty rainfall and dry climate. The average annual rainfall is about 600 mm. Most of the annual rainfall (about 51%) is received during the North-East monsoon (October to December) accompanied with high intensity storms. The watershed receives good rains (30%) during South-West monsoon also. The uncertainty of North-Eastern monsoon and not too favourable contribution from the South-West monsoon make the plight of local agriculturists miserable. Even though North-East monsoon contributes more than South-West monsoon, farmers take up rainfed sowing during South-West monsoon only as the distribution of rainfall is poor in case of North-East monsoon.

Socio-Economic Conditions in the Watershed

The total population of five villages of the watershed is 3610 with average family size of 6 persons. Majority of the watershed farmers are in the category of small and marginal with average land holding of 1.2 ha. These small land holdings are further scattered in 3-4 different places which makes cultivation very difficult. Small farmers (1-2 ha) contribute 50.2 per cent followed by marginal (<1 ha) farmers (32.5%). Annual net income from agriculture and allied activities in dryland area ranges from Rs 15000 to 65000. Out of which only 56% is contributed by the agricultural crops. Land less labours constitutes 30 per cent of the population who resides mainly in the small hamlets. Their livelihoods are mainly depends on the labour demand on day to day basis.

Rainfed Agriculture

In the watershed, out of the total area (782.0 ha), about 90 per cent area (708.38 ha) is under agriculture, of which 60.1 per cent (430.47 ha) is under rainfed agriculture. Area under this land use is restricted to the upper and middle part of the watershed. Only single cropping is followed in this area. Groundnut - fallow or Fodder sorghum - fallow is the main crop sequence in the watershed.

Photo 1. General view of *rainfed* area

Crop failure is very common in this area. Crops are sown during the second week of July and harvested in the last week of September to first week of October. Even though the watershed receives 51 per cent of rainfall during North-East monsoon during October-November, the number of rainy days is very less. Hence fields are kept fallow during *rabi* season. The productivity of crops depends on amount and distribution of rainfall during South-West monsoon. Quite often late onset of monsoon, early withdrawal of monsoon rainfall and large intervening gaps adversely affect the germination, growth and productivity of *kharif* crops. The low water holding capacity of soils present in this area (gravely red sandy soil) also causes soil moisture stress.

The level of productivity is very low in this area. Average productivity of groundnut crop is around 625 kg ha^{-1}. This watershed area is characterized by low input use and even farm yard manure is applied only in little quantity. Appropriate dry land technologies can considerably increase efficiency of the rainfed *kharif* cropping for achieving higher productivity.

Agriculture with Supplementary Irrigation

Out of 708.38 ha of total agricultural area, 17.27 per cent (122.35 ha) is under partial irrigation. Bore well is the main source of irrigation. Average depth of bore well is about 650 feet. Water yield of bore well largely depends on monsoon. Bore well water is pumped into open well before irrigating the crops. Lot of energy is wasted in this system. Some farmers are pumping water into surface ponds from where irrigation is given to field crops leading to low water use efficiency. In this method also lot of water is wasted as deep percolation and evaporation.

Double crop is followed in this area. Since the water yield is poor in bore wells, crops are not fully irrigated. Only supplementary irrigation is given along with the rainfall. These wells remain in dry condition for most part of the year. Crops often experience moisture stress. Depending on water yield in bore wells, few farmers take up three crops per year. Groundnut – Tobacco, Maize – Tobacco, Groundnut – Fallow are the crop sequences followed in this areas. The yield level is not up to the irrigated crop as only supplementary irrigation is practiced and the input use is also less compared to irrigated agriculture. This type of land use is mostly present in the middle reaches of the watershed. Soil of this area is red sandy to red sandy loam. Crops often express micro nutrient deficiencies (boron in groundnut and zinc in maize). Average yield of groundnut and maize is 1.5 t ha^{-1} and 3.0 t ha^{-1} respectively under supplementary irrigated conditions.

Agro-forestry and Horticulture

The watershed does not have much organized orchards. However, farmers have planted fruit plants (tamarind, citrus, mango, pomegranate etc.) in the homesteads and kitchen gardens. *Palmyra* trees are scattered in few farm lands especially in the rainfed areas as natural / plantation trees. The climate and soil is suitable for growing *sapota, aonla*, tamarind, drumstick, guava and mango. *Neem* and *Erythrina indica* are the main multipurpose agro-forestry trees grown along the field boundaries. Trees like *Leucaena leucocephala* and *Gliricidia spp*. were found in few fields as scattered trees.

Problem Identification

Problems identified and prioritized during the transect walk and PRA exercises in all villages were pooled and a list of eight problems predominant in the watershed was prepared. Lack of water resources for agricultural needs and low water yield in the bore well are the major problems. Less rainfall, increased water demand and more dependence on ground water further leads to faster ground water depletion. Rapid runoff due to poor vegetative cover and lack of water conservation measures are leading to poor ground water recharge.

Most of the red soils in the watershed are gravelly, light and are prone to erosion. Poor ground cover and improper management add more severity to the erosion problem. Soils of the watershed have low water holding capacity and low nutrient status. 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 etc. There was no forest as such in the watershed and the open pasture or vegetation on rocky and degraded wastelands with sparse grassy vegetation are used for grazing. Land-less labourers form a significant part of population and need employment or other income generation activities.

Approach

One of the major short comings/reason of non adoption of technology by rianfed farmers is the incompatibility of technology with their socio economic conditions and risk taking capacity. Thus it is essential to indentify different levels of package of practices to give the farmer an option to choose the level of technology as per the site condition and socio-economic conditions and risk taking capacity (Kannan *et al*., 2004). Demonstrations were carried out successfully by the Central Soil and Water Conservation Research & Training Institute (CSWCRTI), Research Centre, Udhagamandalam, during 2008-09 to 2012-13 on Agronomical Measures to improve productivity, resource use efficiency and farm income in Ayalur Model Watershed, Erode District, Tamil Nadu developed under Macro Management of Agriculture (MMA-NWDPRA) programme of the Ministry of Agriculture, Govt. of India. Watershed management plan for Ayalur watershed was prepared with specific objectives of increasing farm income, productivity, employment generation and water use efficiency. In plan preparation due importance was given to problems, needs, priorities of the villagers, topographic fragility, land suitability, irrigation potentiality and prevailing farming systems.

Organic Manure Production

Since the soil of the watershed has low nutrient content, low water holding capacity and poor soil depth, emphasis has been given on maximum use of farmyard manure (FYM) and suitable modifications are suggested for increasing the quantity and quality of FYM. Enrichment of FYM by suitable technologies would further increase the soil productivity.

In the context of rainfed semi-arid agriculture, organic farming system has been specially recommended for achieving high productivity. This is more important in view of the fact that the soils of the watershed have large proportion of inert gravels, meagre fine soil and generally low nutrient status.

Management of Major Crops

In the rainfed areas, integrated nutrient Management (INM) with the use of drought tolerant high yielding variety approach was adopted to enable good crop growth and get maximum yield in the watershed. Emphasis was given for inter cropping for insurance against the crop failure and increasing rainwater use efficiency in groundnut crop. Emphasis was also given for gypsum and coir pith application for avoiding surface crust. In the partial irrigated area, crop diversification options were explored for higher income. Considering the huge livestock population and absence of sufficient fodder, importance was given for the introduction of high yielding fodder grasses.

Horticulture and Agri-horticulture

About 32 ha area of the watershed constituted cultivable and uncultivable wastelands. Rehabilitation of these areas through alternative, sustainable, economical and perennial system of biomass production was envisaged by putting these areas under horticulture, agri-horti, agro-forestry and forestry plantations covering marginal and degraded lands with shallow gravelly soils of rainfed, partial irrigated area and cultivable waste. Under dryland horticulture, mango and tamarind were planted whereas coconut, *sapota*, mango and lemon were planted under agri-horticulture. Improved micro-site condition for soil working and planting by adopting 1 m^3 pit size, back filling pit with gravel free soil mixed with pond silt and FYM was demonstrated.

Agro-forestry

Under afforestation works, species like *Leucaena leucocephala*, *Albizia lebbeck* and *Acacia leucophloea, Erthrina,* teak were planned in 7 ha of waste land, cultivable waste and field bunds in the private land with the spacing of 3 x 3 m by following a pit size of 0.45 m^3.

Interventions to Enhance Productivity and Income

Integrated Nutreint Managment

Indiscriminate use of chemical fertilizers for the supply of major nutrients and declining use of secondary nutrients and organic sources of inputs over time led to the of secondary and micronutrient deficiencies, particularly boron and zinc are emerging as one of the major constraints for sustainable production in rainfed areas. Micronutrient deficiencies, particularly Zn and Boron are one of the emerging constraints in sustainable crop production even in rainfed areas (Srinivasarao and Vittal, 2007).

Groundnut is the major crop under oilseeds accounting for 8.36% of the total cropped area in Tamil Nadu. But the average yield of groundnut in most of the areas is still extremely low when compared to those prevailing in other areas of the country. The reasons for low groundnut yield are the use of low yield potential varieties, poor soil fertility and nutrient management. Groundnut performs better in terms of yield and quality when good cultivar sown under optimum nutrient management coupled with organic and inorganic nutrient management. Groundnut is capable of fixing atmospheric nitrogen with the help of the bacteria *Rhyzobium.* Biofertilisation, in contrast to the use of chemical fertilisers, is receiving steadily increased attention and recognition from scientists because the microbial inoculants (including *Rhizobium* and mycorrhizal fungal inoculants) introduced into soil or plant culture enhances plant productivity directly or indirectly (Mahdi and Atabani, 1992). Applications of fertilizer including gypsum in adequate quantities become more essential for obtaining higher yields.

Even though use of improved variety is common in case of maize, zinc deficiency reduces the maize yield by 20 per cent. Nutrients such as boron and zinc are important to plant growth and yield of groundnut and maize respectively, which are deficient in the watershed. Traditional cultivation practices, coupled with poor quality seeds and varieties resulted in low crop yields. Average productivity of groundnut crop during good rainfall year is around 800-900 kg ha^{-1} against the potential yield of 1916 kg ha^{-1} in rainfed condition.

Based on the nutritional deficiency identified in the fields in watersheds, fourteen farmers evaluated the response to Integrated Nutrient Management (INM) for groundnut and maize as participatory mode. For groundnut, along with the recommended dose of chemical fertilizer (10:10:45 kg NPK ha^{-1} for rainfed groundnut and 17:34:54 kg for irrigated groundnut), *Rhyzobium* and *Phosphobacteria* (each 2 kg ha^{-1}), gypsum (200 kg ha^{-1}) and boron (5 kg ha^{-1}) were used in the demonstration fields. Farmers used improved VRI-2 and CO 6 variety of groundnut under rainfed condition and VRI-2 under irrigated condition.

Irrigated Groundnut

Crop demonstrations on integrated nutrient management on groundnut were conducted under irrigated condition on six farmer's fields. Each farmer's field, four plots measuring 0.1 ha were used for experimentation.

The average yield and additional benefit obtained from different farmers for different interventions in groundnut under irrigated condition is given in table 1.

Table 1. Response of groundnut to INM under irrigated condition

Interventions	Yield (kg ha^{-1})	Additional yield (kg ha^{-1})	Additional cost (Rs ha^{-1})	Additional income (Rs ha^{-1})
Farmer's practice	1650	-	-	-
Local variety with INM	2400	750	3668	12832
Improved variety (VRI-2)	1950	300	2400	4600
Improved variety with INM	2850	1200	4668	21732

An average additional yield (31%) was obtained when the farmers practiced INM with their local variety. And an additional yield of 15% was realized when they used improved variety even without INM compared to their practice of using local variety without INM. The increase in groundnut was still higher (42%) when they practiced both improved variety and INM. Additional return of Rs 12832, Rs 4600 and Rs 21732 per ha was achieved respectively with the practice of INM, use of improved variety and both improved variety and INM.

Rainfed Groundnut

Eight crop demonstrations on improved seed and integrated nutrient management were conducted in the farmer's field. The average yield and additional benefit obtained from different farmers for different interventions in groundnut under irrigated condition is given in table 2.

For groundnut 24.7% higher yield with additional income of Rs 5875 was obtained due to INM in local varieties. High yielding varieties CO-5 and VRS-2 produced 14.8% and 9% higher yield respectively compared to the farmers practice. When these varieties are introduced with INM practices, produced 34% and 32% higher yield compared to the farmer's practice. Additional return of Rs 15450 to 13105 per ha was achieved with the introduction of high yielding varieties coupled with integrated nutrient management practices.

Photo 2. Good rainfed groundnut under INM

Other researchers have also reported beneficial effect of bio-fertilizer (Parasuraman and Mani, 2003) and micronutrient (Chitdeshwari and Poongathai, 2003) on groundnut productivity.

Table 2. Response of groundnut to INM under rainfed condition

Interventions	Yield (kg ha^{-1})	Additional yield (kg ha^{-1})	Additional cost (Rs ha^{-1})	Additional income (Rs ha^{-1})
Farmer's practice	1078	-	-	-
Local seed with INM	1345	267	3470	5875
Improved seed (CO 5) without INM	1265	187	1100	5445
Improved seed (CO 5) with INM	1650	572	4570	15450
Improved seed (VRI 2) without INM	1184	106	1100	2610
Improved seed (VRI 2) with INM	1583	505	4570	13105

As part of the convergence approach in Ayalur Watershed sponsored by Ministry of Agriculture under MMA-NWDPRA, the groundnut variety ICGV 00351 developed by International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad and promoted by the Tamil Nadu Agricultural University (TNAU), Coimbatore was introduced in the farmer's field along with the integrated Nutrient Management as crop demonstration activities to increase the productivity of groundnut during *rabi* season as irrigated crop. This intervention led to the increased groundnut yield to the tune of 48 per cent over local practice.

Photo 3. Field day: visit by ICRISAT scientists

To promote this intervention, a field day was conducted in the Ayalur Watershed with the help of CSWCRTI, Udhagamandalam and jointly organized by ICRISAT and TNAU on 11th October, 2012. During the programme, Dr. Emmanuel Monyo, Project Co-ordinator, Tropical

Legume II (TL II), ICRISAT and Dr. Upadhyaya, Assistant Research Program Director and Principal Scientist and Head Gene Bank, ICRISAT insisted the farmers to preserve the seed after the harvest for further multiplication and reuse in the watershed. Dr. K. Ganesamurthy, Professor and Head, Department of Oil seed, TNAU thanked the CSWCRTI, Udhagamandalam for the successful introduction of this variety and for the help in organising the field day.

Maize

In case of maize, along with the recommended dose of chemical fertilizer (60:30:30 kg NPK ha^{-1}), bio fertilizer (*Azospirillum* and *Phosphobacteria* each 2 kg ha^{-1}) and $ZnSO_4$ @ 25 kg ha^{-1} were applied. Improved variety COH (M) 4 was introduced. About 22 per cent increase in yield (5500 kg ha^{-1}) was achieved with improved practices. Rain Water Use Efficiency (RWUE) was also 22 per cent higher compared to the farmer's practice. An additional benefit of Rs 8000 ha^{-1} was achieved over farmers' practice when hybrid seeds and INM were adopted (Table 3).

Photo 4. Maize with INM practice

Table 3. Response of maize to INM

Particulars	Farmer's practice	INM
Yield (kg ha^{-1})	4500	5500
Additional yield	-	1000
Additional cost (Rs)	-	2747
Additional benefits(Rs)	-	8000
RWUE (kg ha^{-1} mm)	10	12.2

Intercropping in Groundnut

Adverse weather conditions like delay in the onset of rains and/or failure of rains for few days to weeks some time or other during the crop period is very common in the rain fed groundnut growing areas. Adverse weather conditions result in economic losses to the farmers due to the partial or total failure of groundnut crop. To overcome this situation there is need to adopt or follow groundnut based cropping systems like intercropping or mixed cropping in rainfed groundnut growing areas. Even though the Ayalur watershed receives both southwest and

Photo 5. Intercropping rainfed groundnut with red gram

northeast monsoon, cropping activities in dryland confined to *kharif* only as the number of rainy days during northeast monsoon is very less. In order to utilize both monsoon effectively, long duration (180 days) red gram variety CO-6 was inter cropped with groundnut variety VRI-2 (110 days) duration in 10:1 ratio. Groundnut was harvested during the month of October and red gram was harvested in the month of February. Cow pea was intercropped with groundnut at 6:1 ratio for insurance against crop failure. In this system, 20% and 10% higher groundnut equivalent yield was achieved with groundnut + red gram and groundnut + cowpea intercropping respectively (Table 4). Higher rain water use efficiency (RWUE) and land equivalent ratio (LER) were also achieved due to the intercropping system.

Photo 5b. Groundnut + cowpea intercroping

Table 4. 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

Crop Diversification

At present, our agricultural system is dominated by a certain group of crops as more than 80% of our food comes from about 10 species only (Sharda *et al.*, 2006). Under circumstances, crop diversification will be a boon from ecological as well as nutritional point of view. Concept of diversification is need based as well as economically viable. Crop diversification is intended to give a wider choice in the production of a variety of crops in a given area so as to expand production related activities on various crops and also to lessen risk. Crop diversification in India is generally viewed as a shift from traditionally grown less remunerative crops to more remunerative crops.

Photo 6. Crop diversification with marigold and cabbage

Groundnut - tobacco or maize - groundnut is the cropping pattern followed in the partially irrigated area in the watershed. In order to diversify the crops and increase the net income, cultivation of marigold and cabbage was introduced for groundnut crop. The price of groundnut pod, marigold and cabbage during the intervention is Rs 23, Rs 15 and Rs 4 per kg of produce. Among three crops cultivated, marigold produced the highest net income (Rs 70850 per ha^{-1}) which was followed by cabbage (Rs 63240 per ha^{-1}). Marigold and cabbage produced 62.4% and 57.8% higher net income compared to the conventional crop groundnut (Table 5).

Table 5. 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

Compost Production

With the introduction of the farm machinery and commercial fertilizers, the reliance of the animal power as cultural tool has substantially reduced in the recent past and has thus reduced the availability of farm yard manure availability in the farm. Environmental degradation is a major threat and the rampant use of chemical fertilizers contributes largely to the deterioration of the environment through depletion of fossil fuels.

Coir pith compost is a good source of organic manure for dry land agriculture as it can absorb water five times its weight and thereby when applied to soil increase the water holding capacity of soil. Coir industry in Tamil Nadu generates nearly 4.5 lakh tonnes of organic waste (coir pith) every day which needs safe disposal. Coir pith contains constituents like lignin (30%) and cellulose (26%), which do not degrade quickly but can be decomposed by employing the fungus *Pleurotus sojar-caju* with urea supplementation. At the end of the composting period, the coir pith is changed in to a well-decomposed black mass. The C : N ratio is reduced to nearly 24:1 with the N content enhanced from 0.26 to 1.06%. The advantages of coir pith compost over other compost materials are that it adds micronutrient to the soil, enhances microbial activity and reduces soil erosion. In addition to the higher moisture content, coir pith compost is known to supply micro and secondary nutrients such as magnesium, sulphur, calcium besides nitrogen, phosphorous and potassium.

Preparation of coir pith compost

One tonne of coir pith, 5 kg of urea and 5 bottles of *Pleurotus* spawn is required to prepare one ton of coir pith compost. First 100 kg of coir pith waste should be spread over a shady place. Then one bottle of *Pleurotus* spawn should be applied over this layer uniformly. Now 100 kg of coir pith waste should be applied over this first layer and one kg of urea spread over the second layer of coir pith. This procedure of alternate application of *Pleurotus* and urea should be done for the whole one tonne of coir pith waste. Sufficient moisture should be ensured for speedy decomposition in this composting process. It takes nearly one month for complete decomposition of coir pith indicated when its colour changes to black.

Case studies in Ayalur watershed

Demonstrations were carried out successfully by the Central Soil and Water Conservation Research & Training Institute (CSWCRTI), Research Centre, Udhagamandalam, on preparation of compost from coir pith and its application in rainfed maize, for improving soil quality and increasing the crop productivity, in Ayalur Model Watershed.

Next to groundnut, maize is grown as the important crop with an average yield of 4.5 t ha^{-1}. The maize area under this watershed is increasing as it is being used for industrial purpose. Since the soil physical and chemical properties are not conducive for getting good yield in maize, it is suggested to ameliorate the soil with the application of farm yard manure. But the availability of farm yard manure is the limitation in the watershed. Hence it is important to look for alternate composting using locally available materials.

Photo 7. Coir pith composting

Coconut is the important plantation crop cultivated in substantial area in and around watershed. Coir pith, a by-product of coir industry which is available in plenty can be used for making compost. With the technical guidance from CSWCRTI, RC, Udhagamandlam, Mr. Arun Kumar and Mr. Rajamani in Ayalur watershed have set up two coir pith composting unit in their respective fields to produce 16 tonnes of compost. Coir pith waste was decomposed within two months and this well decomposed coir pith compost was applied to the maize crop (variety COH (M) 4) @ 5 t ha^{-1} for improving soil condition and soil moisture. Plant height, length of the cob and stover yield of maize was higher under coir pith compost applied field compared to control plot. Higher yield of maize grain (17%) was achieved with the application of coir pith compost compared to normal practice due to the higher soil moisture content with the application of coir pith compost in rainfed maize (Table 6).

Photo 8. Maize growth under coir pith compost applied and control field

Table 6. Effect of coir pith compost on maize growth, yield and RWUE

Treatment	Plant height (cm)	Cob length (cm))	Number of grains/ear	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	WUE (kg ha^{-1} mm)
Control	158	17.4	530	4210	5473	4.95
Coir pith	184	21.2	610	4925	6382	5.79

Number of grains per maize cob was 15 per cent higher than the control. Higher (5.79 kg ha^{-1} mm) Rain Water Use Efficiency (RWUE) was also achieved with the application of coir pith compost. There was an average increase of net income to the tune of Rs 5350 due to coir pith compost application in rainfed maize.

Integrated Farming System

The ground water resources were depleting as a result of deficient recharge and increased dependence on groundwater. Infiltration was quite high due to gravelly loamy sandy texture of the soil. As a result, farmers in the watershed are going for the bore wells to a depth greater than 200 meter to get water. These bore wells are mostly fitted with 7.5 HP air compressor pumps in order to fill water in surface ponds.

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 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. Farmers used to keep a minimum depth of 60 cm of water in this surface pond. This gives the opportunities to include *pisciculture* in their farming system. An integrated development model was developed in the partially irrigated area for 2.5 ha of land is developed with the following component.

1. Agriculture (Groundnut 0.4 ha, fodder sorghum 0.4 ha, maize 0.4 ha and sugarcane 1.3 ha)
2. Cow 4 numbers
3. Surface pond with an area of 200 m^2
4. Since the water will always be available in the surface pond (2 feet as dead storage) high density *pisiculture* (common carp - surface feeder) is introduced @ 2 per m^2
5. Girijaj poultry in the cage (64 sq feet) constructed over the pond @ 1 per sq. feet

In this model, the area under sugarcane, fodder sorghum and maize was 1 ha, 0.4 ha and 1.1 ha. Sugarcane top produced (32 tons of fodder) from one hectare land was sufficient to feed 4 animals @ 25 kg per animal in a year along with the dry fodder (fodder sorghum 16 tons) produced from 0.4 hectare land. Cow urine form 4 animals produced 200 litres every ten days were utilize for fertigation of 1.3 ha of sugarcane. Maize grain was used as feed for the poultry. Poultry droppings served as feed materials for fish and increase the nutrient content of irrigation water.

Photo 9. Components of IFS: Improved cattle shed with urine collection tank, fish culture and poultry over the surface pond, fertigation unit for cow urine and fodder sorghum

Results show that the fertilizer requirement for sugarcane can be reduced by 50 per cent by fertigation with cow urine. Sixty four poultry birds grown in the gage constructed over the pond produced 70 kg meat every three months, which produced grass income of Rs 8400 for every three months. Sixty kg of fish (frylings) was harvested from 200 m^2 area after six months. In this model, an additional income of Rs 10800 per ha was achieved resulted from the poultry unit, *pisiculture* and the saving from fertilizer. Besides, this model helped in achieving nutritional security.

Fodder Improvement

Since the watershed has large animal population and area under coconut cultivation, improved and latest fodder Hybrid Napier grass (Variety CO 4) introduced in the watershed in an area of 1 ha involving 10 farmers in the year 2009.

Coconut being a tall palm, with unbranched trunk and compact terminal crown of leaves, allows raising of remunerative intercrops which is virtually impossible with many other perennial tree crops. Planted at a wide spacing of 8m or more between palms the unutilised soil resources and under-storey sunlight in plantations can be used by judicious selection of compatible intercrops. In general plantations with palms of 8-25 years age are not suitable for intercropping of any sort because the canopy of palms is large to completely cover the ground and the height of the palms is not yet sufficient to create under-storey light environment congenial for intercropping. During this period, fodder crops can be successfully grown.

Hybrid Napier produces more tillers and numerous leaves compared to Napier grass. It grows faster and produces more herbage but the stems are hard and the plants less persistent. Pusa Giant Napier has larger leaves, softer and less persistent hairs on leaf blades and sheaths and less sharp leaf edges. The stems are also less fibrous than Napier. The tillers are more numerous and grow faster. The grass grows throughout the year in the tropics. Hybrid Napier is superior in quality than Napier grass and contains about 10.2% crude protein and 30.5% crude fibre. The leaves are larger and greener, the sheaths are softer and the margins less serrated and hence the herbage is more palatable. It is juicier and succulent at all stages of growth. It is less fibrous and more acceptable.

Photo 10. Hybrid Napier as intercrop in coconut

In the watershed recently released CO-4 hybrid Napier grass was introduced as inter crop in the coconut garden. Hybrid Napier slips were planted with the spacing of 60 x 60 cm between the rows of coconut. 50 kg each of phosphorous and potash were applied as basal before planting. Nitrogen @200 kg/ha in three split doses were applied as top dressing. The first cut was taken two months after planting. Subsequent cuts were taken at 40 days interval. These cuttings were again used for planting in other farmer's field to cover 4 ha area in the watershed. The average fodder yield of 250 t ha^{-1} was achieved with this intercrop.

Integrated Pest Management

Integrated pest management (IPM) was adopted to optimize crop productivity along with integrated soil, water, crop and nutrient management in the watershed. Crop surveys carried out revealed that farmers use chemical pesticides to control insect pests. Tobacco caterpillar (*Spodoptera*), pod borer (*Helicoverpa*) and red hairy caterpillar (*Amsacta*) are the main insect pests in groundnut grown under rainfed condition. IPM practices such as deep summer ploughing, intercropping red gram for controlling pod borer, shaking of pigeon pea plants for controlling pod borers, use of pest tolerant varieties and castor as trap crop were adopted for controlling tobacco caterpillar. Good pest control was achieved with this cultural management practices (Photo 11).

Photo 11. Castor trap crop for IPM

Alternate Land Use System

Growing of food crops alone may not be a profitable enterprise because of erratic and uneven rainfall, particularly in arid and semi-arid regions. Inclusion of fruit trees and fuel and fodder trees may be remunerative cropping systems. Alternate land use system not only help in generating much needed off season employment in mono-cropped rainfed areas but also utilize off-season rains which may otherwise be lost as runoff, prevent degradation of soils and restore balance in the eco-system (Sharda *et al*., 2006).

Dryland horticulture: Dryland or rainfed horticulture has assumed greater attention now a day due to better economic returns. In drylands, fruit trees provide a better substitute and offer alternative opportunity in areas where cropping may not be possible due to non-availability of irrigation. Considering frequent crop failure due to erratic monsoon in the region, dry land horticulture was introduced in Ayalur watershed in an area of 7.5 ha involving mango, *sapota*, lime and *amla*.

Micro-site improvement technique was adopted for proper establishment of tree species in the degraded areas. Under this technique, taking pits of proper size (1x1x1 m), removal of gravels from soil in the pits and application of FYM (30 kg/pit), *Neem* cake @ 200 g/pit and bio-fertilizers (VAM, *Phosphobacteria* and *Azospirillium* @ 50 g each/pit) were demonstrated in the watershed.

Photo 12. Micro-site improvement for better establishment of fruit trees

Table 7. Fruit trees planted in Ayalur watershed and their survival rate

Fruit trees	Variety	No. of saplings	Survival % in the first year	Survival % in the third year after gap filling
Mango	Bangalura	840	79.8	98.2
Mango	Neelum	425	69.9	95.6
Mango	Alphonsa	649	95.3	95.3
Mango	Senthura	146	52.0	88.6
Sapota	CO-4	80	100.0	100.0
Lime	Grafted	50	80.0	85.5
Amla	BSR-1	40	72.5	75.6

High density mango plantation was taken up with the spacing of 5 x 5 m. Observation on survival of different fruit saplings shows that almost in all the cases there is more than 70 per cent survival except for the mango variety *Senthura* where the problem of water stagnation in a particular field had caused nearly 50 per cent saplings to perish.

Photo 13. Before and after establishment of high density mango orchard in dryland

However, more than 90 % was achieved in the third year after gap filling and proper management. During the initial growth period of mango, fodder yield of 20 t ha^{-1} from fodder sorghum and 840 kg of groundnut pod was achieved as intercrop during *kharif* season.

Agri-horticulture: Agri-horticulture system was introduced in the partial irrigated area where farmers used to take up two crops with supplemental irrigation. For developing agri-horticulture, coconut in 14.0 ha and *sapota* in 0.5 ha and mango in 3.0 ha have been established using micro-site improvement technique described above, in areas where earlier only annual crops were cultivated in the watershed. A spacing of 6m x 6m, 7m x 7m and 8m x 8m was adopted for the mango, coconut and *sapota,* respectively.

Photo 14. Agri - horti: Coconut+ turmeric

Table 8. Growth of mango varieties under agri-horticulture system

Variety	Survival (%)	Canopy (m)	Plant height (m)	Dbh (cm)	Yield after 3 years of planting (kg/tree)
Bangalura	98.2	E-W: 2.7 m N-S: 27 m	2.1	6.4	8
Alphonsa	95.3	E-W: 2.5 m N-S: 2.4 m	1.8	4.5	10

E-W: East to West; N-S: North to South

Photo 15. Mango with groundnut intercrop during *kharif* and tobacco during *rabi*

From annual crops, during first three years an average income of Rs 87890 per ha was realized. After five years of planting, mango is expected to yield 8-10 t ha^{-1} with a net benefit of Rs 160000 per ha (Table. 9). The other benefits from this system as stated by the farmers are: higher rainwater use efficiency, resource use efficiency, less labour requirement and less soil loss.

Table 9. Intercrop yield (average of three years: 2010-12)

Sl. No.	Yield (kg ha^{-1})	Cost (Rs)	Return (Rs)	Net return (Rs)
Kharif: Ground nut	1450	13000	36250	23250
Rabi: Tobacco	3175	36960	101600	64640

Agro-forestry and Farm-forestry: Agro-forestry is a sustainable land management system which increases the overall yield of the lands; combine the trees and shrubs with agricultural crops and or livestock on the same unit of land, either simultaneously or sequentially. The agro-forestry based production system envisages conserving and improving the land and also optimising the combined productivity of the trees and the agricultural crops.

One of the main problems that farmers face today is decreasing income from an acre per year against sudden increase in the value of agricultural lands. Planting certain tree varieties such *Melia dubia* (*Malai Vembu* in Tamil) which fetch a handsome price in the market, assured buyback, and require low maintenance expenditure may help in this regard. In addition, the trees also aid the planet by preventing temperature rise and checking gas emission into the atmosphere. *Melia dubia* is the fastest growing tree and the wood from this tree is used in Plywood Industry. *Melia* is a money spinning tree of

Photo 16. Soil working before planting *Melia*

short duration. Since there is a total mismatch between demand and supply for wood, block planting of 300 to 400 trees per acre can ensure a minimum profit of rupees one lakh per year.

Melia dubia grows on a variety of soils, however, it grows well in deep, fertile and sandy loam soils. It has the unique feature of growing to 40 feet within two years from planting and can be mechanically pruned and harvested. It is commonly found in the hills at elevations ranging from 600 – 1800m. It does well in moist regions, with a mean annual rainfall exceeding 1000 mm. However, it can be successfully grown in dry region also with supplemental irrigation. The rooted saplings are planted onset of the monsoon or during the monsoon. The suggested pit size is 0.6 x 0.6 x 0.6 m. Spacing of 3 m x 3 m is recommended. This will give better girth in shorter duration. Straight pole fetches good price in the market. Under irrigated condition in fertile soil, the plant produces 3 to 4 branches at the height of 12-14 feet. Pruning of side branch should be done at this stage. When planted in dry lands and in drought prone areas, the tree branches at the height of 6-8 feet. Grazing by cattle is the major problem when taking up any forestry intervention in the watershed. This problem was solved in the Ayalur watershed by planting this *Melia* tree as the leaves are less palatable.

Block plantation of *Melia dubia* was successfully established with micro site improvement technique in the watershed. In this technique, pits of 0.45 x 0.45 x 0.45 m were dug at the spacing of 3 x 3 meter to accommodate 1100 seedlings per hectare in the farmer's field. After removing gravels and stones the pits were filled with top soil and farm yard manure (10 kg pit^{-1}). To induce early and better growth of seedlings, bio-fertilizers (*Azopirillum, phosphobacteria* and VAM @ 50 gm pit^{-1}) was applied during the planting. *Neem* cake @ 200 gm pit^{-1} was applied to control root pests. Seedlings were planted during the onset of south-west monsoon. Initially, irrigation was given through drip @ 8-10 litres once in two days during summer. Branches were pruned periodically to get straight poles.

Photo 17. Well established *Melia* under block plantation

Photo 18. Teak plantations on bunds

Apart from these block plantation 3000 number of *Melia* and 3100 number of *teak* seedlings were planted as boundary plantation along with agricultural crops with 3 m spacing as single row. In this technique, 92 per cent survival was achieved with average girth of 12 cm and height of 6.4 meter within one year (Table 10). The tree attained an average height of 8.5 m with 13.5 cm girth two year after planting with supplementary irrigation. To plant one hectare of land as block plantation, it cost around Rs 27500. 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.)

Table 10. Growth of *Melia* and *teak*

	Melia dubia		***Teak***	
Age	**Height (m)**	**Girth (cm)**	**Height (m)**	**Girth (cm)**
Six months	1.8	7.0	0.95	2.1
One year	6.4	12.0	4.08	3.6
Two years	8.5	13.5	6.2	6.8

Many line department officials, WDT members and farmers visited the site and were convinced that this kind of farm-forestry can be taken up on commercial basis.

Conclusion

Emphasis given on production system in a systematic way in the participatory watershed development planning and implementation process not only helps in conserving the natural resources but also helps in increasing productivity and maximising the farm income. Site-specific integrated nutrient management based on crop requirement and soil nutrient status increases productivity of rainfed crops. Since, farm yard manure is becoming very scarce, it is important to look for alternate composting using locally available materials. Crop diversification, integrated farming system and alternate land use system provides good opportunities for conserving natural resources and maximising the farm income besides achieving nutritional security. Micro-site improvement / soil working is necessary for achieving good survival rate of tree and fruit seedlings.

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