Best-bet Options for Integrated Watershed Management - Proceedings of the Comprehensive Assessment of Watershed Programs in India

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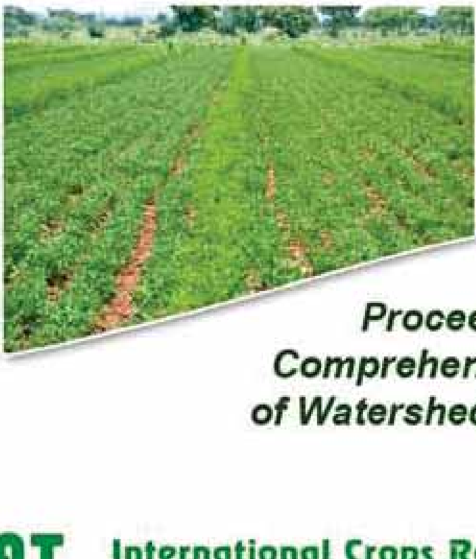

Proceedings of the Comprehensive Assessment of Watershed Programs in India

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International Crops Research Institute for the Semi-Arid Tropics

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1. Watershed Management Concept and Principles

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Abstract

Watershed is not simply the hydrological unit but also socio-political-ecological entity which plays crucial role in determining food, social, and economical security and provides life support services to rural people. The criteria for selecting watershed size also depend on the objectives of the development and terrain slope. A large watershed can be managed in plain valley areas or where forest or pasture development is the main objective. In hilly areas or where intensive agriculture development is planned, the size of watershed relatively preferred is small.

Keywords: Watershed, consortium, community, water, livelihood.

Introduction

The rain-fed agriculture contributes 58 per cent to world's food basket from 80 per cent agriculture lands (Raju et al. 2008). As a consequence of global population increase, water for food production is becoming an increasingly scarce resource, and the situation is further aggravated by climate change (Molden, 2007). The rain-fed areas are the hotspots of poverty, malnutrition, food insecurity, prone to severe land degradation, water security and poor social and institutional infrastructure (Rockstorm et al. 2007; Wani et al. 2007). Watershed development program is, therefore, considered as an effective tool for addressing many of these problems and recognized as potential engine for agriculture growth and development in fragile and marginal rain-fed areas (Joshi et al. 2005; Ahluwalia and Wani et al. 2006). Management of natural resources at watershed scale produces multiple benefits in terms of increasing food production, improving livelihoods, protecting environment, addressing gender and equity issues along with biodiversity concerns (Sharma, 2002; Wani et al. 2003a,b; Joshi et al. 2005; and Rockstorm et al. 2007).

History of Watershed Development Program in India

About 60 per cent of total arable land (142 million ha) in India is rain-fed, characterized by low productivity, low income, low employment with high incidence of poverty and a bulk of fragile and marginal land (Joshi et al. 2008). Rainfall pattern in these areas are highly variable both in terms of total amount and its distribution, which lead to moisture stress during critical stages of crop production and makes agriculture production vulnerable to pre and post production risk. Watershed development projects in the country has been sponsored and implemented by Government of India from early 1970s onwards. The journey through the evolution of watershed approach evolved in India is shown in Figure-1 (Wani et al. 2005 and 2006). Various watershed development programs like Drought Prone Area Program (DPAP), Desert Development Program (DDP), River Valley Project (RVP), National Watershed Development Project for Rain-fed Areas (NWDPRA) and Integrated Wasteland Development Program (IWDP) were launched subsequently in various hydro-ecological regions, those were consistently being affected by water stress and draught like situations. Entire watershed development program was primarily focused on structural-driven compartmental approach of soil conservation and rainwater harvesting during 1980s and before. In spite of putting efforts for maintaining soil conservation practices (example, contour bunding, pits excavations etc.), farmers used to plow out these practices from their fields. It was felt that a straightjacket top-down approach can not make desired impact in watersheds and mix up of individual and community based interventions are essential.

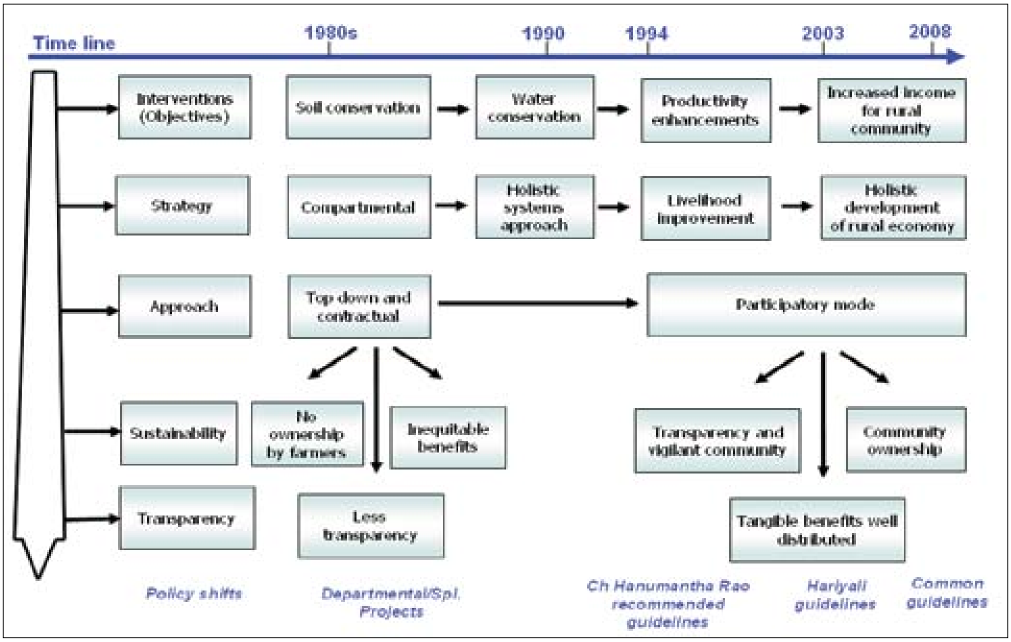

Figure 1. Journey through watershed approach in India (Wani et al. 2005 and 2006).

The integrated watershed development program with participatory approach was emphasized during mid 1980s and in early 1990s. This approach had focused on raising crop productivity and livelihood improvement in watersheds (Wani et al. 2006) along with soil and water conservation measures. The Government of India appointed a committee in 1994 under the chairmanship of Prof. CH Hanumantha Rao. The committee thoroughly reviewed existing strategies of watershed program and strongly felt a need for moving away from the conventional approach of the government department to the bureaucratic planning without involving local communities (Raju et al. 2008). The new guideline was recommended in year 1995, which emphasized on collective action and community participation, including participation of primary stakeholders through community-based orgnizations, non-governmental organizations and *Panchayati Raj* Institutions (PRI) (GoI, 1994, 2008; Hanumantha Rao et al. 2000; DOLR, 2003; and GoI, 2008; Joshi et al. 2008). Watershed development guidelines were again revised in year 2001 (called Hariyali guidelines) to make further simplification and involvement of PRIs more meaningful in planning, implementation and evaluation and community empowerment (Raju et al. 2008) and guidelines were issued in year 2003 (DOLR, 2003). Subsequently, Neeranchal Committee (in year 2005) evaluated the entire government-sponsored, NGO and donor implemented watershed development programs in India and suggested a shift in focus "away from a purely engineering and structural focus to a deeper concern with livelihood issues" (Raju et al. 2008). Major objectives of the watershed management program are: 1) conservation, up-gradation and utilization of natural endowments such as land, water, plant, animal and human resources in a harmonious and integrated manner with low-cost, simple, effective and replicable technology; 2) generation of massive employment; 3) reduction of inequalities between irrigated and rain-fed areas and poverty alleviation.

What is Watershed

Definition of Watershed

A watershed, also called a drainage basin or catchment area, is defined as an area in which all water flowing into it goes to a common outlet. People and livestock are the integral part of watershed and their activities affect the productive status of watersheds and vice versa. From the hydrological point of view, the different phases of hydrological cycle in a watershed are dependent on the various natural features and human activities. Watershed is not simply the hydrological unit but also socio-political-ecological entity which plays crucial role in determining food, social, and economical security and provides life support services to rural people (Wani et al. 2008).

Delineation of Watershed

Hydrologically, watershed is an area from which the runoff flows to a common point on the drainage system. Every stream, tributary, or river has an associated watershed, and small watersheds aggregate together to become larger watersheds. Water travels from headwater to the downward location and meets with similar strength of stream, then it forms one order higher stream as shown in Figure-2.

The stream order is a measure of the degree of stream branching within a watershed. Each length of stream is indicated by its order (for example, first-order, second-order, etc.). The start or headwaters of a stream, with no other streams flowing into it, is called the first-order stream. First-order streams flow together to form a second-order stream. Second-order streams flow into a third-order stream and so on. Stream order describes the relative location of the reach in the watershed. Identifying stream order is useful to understand amount of water availability in reach and its quality; and also used as criteria to divide larger watershed into smaller unit. Moreover, criteria for selecting watershed size also depend on the objectives of the development and terrain slope. A large watershed can be managed in plain valley areas or where forest or pasture development is the main objective (Singh, 2000). In hilly areas or where intensive agriculture development is planned, the size of watershed relatively preferred is small.

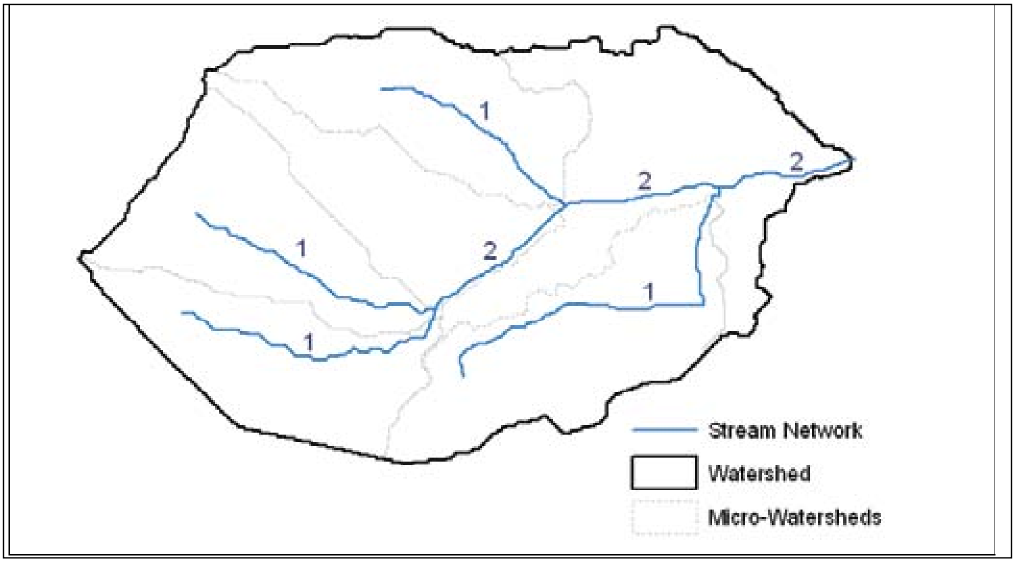

Figure 2. Stream network, micro-watersheds and watershed large watershed has divided into six micro-watershed based on stream order. Numbers on the stream network shows the stream order of respective stream.

Components of Watershed Management

Entry Point Activity (EPA)

Entry Point Activity is the first formal project intervention which is undertaken after the transect walk, selection and finalization of the watershed. It is highly recommended to use knowledge-based entry point activity to build the rapport with the community. Direct cash-based EPA must be avoided as such activities give a wrong signal to the community at the beginning for various interventions. Details of the knowledge-based EPA to build rapport with the community ensuring tangible economic benefits to the community members are described here.

Land and Water Conservation Practices

Soil and water conservation practices are the primary step of watershed management program. Conservation practices can be divided into two main categories: 1) *in-situ* and 2) *ex-situ* management. Land and water conservation practices, those made within agricultural fields like construction of contour bunds, graded bunds, field bunds, terraces building, broad bed and furrow practice and other soil-moisture conservation practices, are known as in-situ management (Figure 3). These practices protect land degradation, improve soil health, and increase soil-moisture availability and groundwater recharge. Moreover, construction of check dam,

Figure 3. Broad band and furrow practices (in-situ management). Photo: (BW7 watershed) at ICRISAT, Patancheru.

farm pond, gully control structures, pits excavation across the stream channel is known as *ex-situ* management (Figure 4). *Ex-situ* watershed management practices reduce peak discharge in order to reclaim gully formation and harvest substantial amount of runoff, which increases groundwater recharge and irrigation potential in watersheds.

Figure 4. Water stored in check dam built across the stream channel (ex-situ management); Photo: Kothapally watershed.

Integrated Pest and Nutrient Management

Water only cannot increase crop productivity to its potential level without other interventions. A balanced nutrient diet along with adequate moisture availability and pest and disease free environment can turn agricultural production several folds higher compared to unmanaged land. Integrated nutrient management (INM) involves the integral use of organic manure, crop straw, and other plant and tree biomass material along with little application of chemical fertilizer (both macro and micro-nutrients). Integrated pest management (IPM) involves use of different crop pest control practices like cultural, biological and chemical methods in a combined and compatible way to suppress pest infestations. Thus, the main goals of INM and IPM are to maintain soil fertility, manage pest and the environment so as to balance costs, benefits, public health, and environmental quality.

Crop Diversification and Intensification

The crop diversification refers to bringing about a desirable change in the existing cropping patterns towards a more balanced cropping system to reduce the risk of crop failure; and crop intensification is the increasing cropping intensity and production to meet the ever increasing demand for food in a given landscape. Watershed management puts emphasis on crop diversification and intensification through the use of advanced technologies, especially good variety of seeds, balanced fertilizer application and by providing supplemental irrigation.

Use of Multiple Resources

Farmers those solely dependent on agriculture, hold high uncertainty and risk of failure due to various extreme events, pest and disease attack, and market shocks. Therefore, integration of agriculture (on-farm) and non-agriculture (off-farm) activities is required at various scales for generating consistent source of income and support for their livelihood. For example, agriculture, livestock production and dairy farming, together can make more resilient and sustainable system compared to adopting agriculture practice alone. Product or by-product of one system could be utilized for other and vice-versa. In this example, biomass production (crop straw) after crop harvesting could be utilized for livestock feeding and manure obtained from livestock could be applied in field to maintain soil fertility. It includes horticulture plantation, aquaculture, and animal husbandry at indivisible farm, household or community scale.

Capacity Building

Watershed development requires multiple interventions that jointly enhance the resource base and livelihoods of the rural people. This requires capacity building of all the stakeholders from farmer to policy makers. Capacity building is a process to strengthen the abilities of people to make effective and efficient use of resources in order to achieve their own goals on a sustained basis (Wani et al. 2008). Unawareness and ignorance of the stakeholders about the objectives, approaches, and activities are the reasons that affect the performance of the watersheds (Joshi et al. 2008). Capacity building program focuses on construction of low cost soil and water conservation methods, production and use of bio-fertilizers and bio-pesticides, income generating activities, livestock based activities, waste land development, market linkage for primary stakeholders. Clear understanding of strategic planning, monitoring and evaluation mechanism and other expertise in field of science and management is essential for government officials and policy makers. The stakeholders should be aware about the importance of various activities, their benefits in terms of economics, social and environmental factors. Therefore, organizing various training at different scales are important for watershed development.

Watershed Management Approaches

Integrated Approach

This approach suggest the integration of technologies within the natural boundaries of a drainage area for optimum development of land, water, and plant resources to meet the basic needs of people and animals in a sustainable manner. This approach aims to improve the standard of living of common people by increasing his earning capacity by offering all facilities required for optimum production (Singh, 2000). In order to achieve its objective, integrated watershed management suggests to adopt land and water conservation practices, water harvesting in ponds and recharging of groundwater for increasing water resources potential and stress on crop diversification, use of improved variety of seeds, integrated nutrient management and integrated pest management practices, etc.

Consortium Approach

Consortium approach emphasizes on collective action and community participation including of primary stakeholders, government and non-government organizations, and other institutions. Watershed management requires multidisciplinary skills and competencies. Easy access and timely advice to farmers are important drivers for the observed impressive impacts in the watershed. These lead to enhance awareness of the farmers and their ability to consult with the right people when problems arise. It requires multidisciplinary proficiency in field of engineering, agronomy, forestry, horticulture, animal husbandry, entomology, social science, economics and marketing. It is not always possible to get all the required support and skills-set in one organization. Thus, consortium approach brings together the expertise of different areas to expand the effectiveness of the various watershed initiatives and interventions.

Recommendations for Practioners

- Select watershed sites where dire need exists in terms of improving soil and water conservation, enhancing productivity and improving livelihoods.
- Adopt holistic and participatory consortium approach from the beginning ie, from selection of watershed.

- Ensure that ground rules for operation are made clear to the community as well as consortium partners.
- Adopt knowledge-based entry point approach to build rapport with the community and ensure tangible economic benefits for the community.

Kothapally Watershed in Andhra Pradesh, Southern India

Kothapally watershed is located at 17^0 22' N latitude, 78^0 07' E longitude and about 550 meters AMSL altitude in Ranga Reddy district, Andhra Pradesh, India. This watershed is part of the Musi sub-basin of the Krishna river basin, and situated approximately at 25 km upstream of Osman Sagar reservoir. Soil has been classified as Vertisols with shallow soil depth (10 to 90 cm ranges) and has medium to low water holding capacity. The average landholding per household is about 1.4 ha. Average crop yield was less than 1 ton/ha therefore Kothapally was characterized by low productivity, low income, and low employment with high incidence of poverty in year 1999 and before. ICRISAT, consortium with local partners (government agencies and NGOs) started watershed development program in Kothapally village from year 1999 onwards. Integrated watershed management approach was used. Soil and water conservation, both *in-situ* and *ex-situ* practices were made in watershed. Integrated nutrient and pest management approach adopted. Efforts were put in direction of increasing crop productivity. Good variety of seeds and fertilizer were made available in village and helped farmers in selecting right cropping pattern according to their soils. Water balance of Kothapally watershed shows that after doing such interventions, groundwater recharge has increased from 7 to 32 %, outflow reduced from 37 to 9 % of total rainfall. Crop yields increased by 2 to 5 times in monsoon season and irrigation potential increased from 13 % to 31 % compared to pre-development stage. Survey suggest that average household income in Kothapally watershed is greater than 50 % compare to adjoining locations where watershed interventions were not been made. This program has significantly increased crop productivity, reduced poverty and increased employment opportunity and has become the site for learning to the farmers, researchers and policy makers.

Box 1: A Case Study of Kothapally Watershed.

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2. Selection of Watersheds

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Abstract

Watershed selection criteria evolved over a period of time keeping in view the changing expectations of the program. It has evolved from serving the soil and water conservation program to meeting the all round developmental needs encompassing various sectors of the developmental program activities. Though various guidelines exist at centre as well as state level, practicing guidelines including bio-physical, socio economic and mandatory participatory involvement of communities etc., have proved to be the factors for the success of watershed programs. Several developments on bio physical charactisration over a period of time helps in revising the present set of parameters, which are primarily chosen for river valley programs in reducing the soil erosion, which may not be a significant problem in low to medium rainfall areas. Parameters such as runoff potential index, which has more relevance for watershed program in semi arid areas can be assessed through a set of surrogate parameters using GIS techniques with DEM information. Efforts need to be made to utilize these techniques at district level which are primary administrative boundaries for watershed implementation. Further, there is need to develop a common set of socio-economic parameters, which could be applied across India for watershed program.

Keywords: Watershed, selection criteria, silt yield, poverty.

Introduction

Before the discussion on watershed selection, it is necessary to define the watershed. It is a hydrologic unit that has been described and used both as a physical-biological unit and as socio-economic and socio-political units for planning and implementing resource management activities. Thus, watershed is a topographically delineated area that is drained by a stream system. 'Watershed-plus' was used to cover activities that would not normally be included in the watershed program but, in the interests of equity, would be included in the new livelihoods projects. These activities might include better water management, minor irrigation, drinking water, sanitation, forestry and interventions to address the specific needs of the poorest – including credit, collection and processing of non-timber forest products (NTFPs), aquaculture, vegetable/fruit garden activities and local crafts. Watershed selection guidelines can be broadly categorized into pre 1994 and post 1994 scenarios.

Watershed Selection Criteria Prior to 1994

In this early model of selecting watersheds, the following variables were considered:

- inputs through evapo-transpiration potential and data;
- amount of rainfall;
- sediment yield index (SYI);
- level of management of natural resources.

On the basis of these criteria watersheds were selected in five categories from the very high to the low priority. All India Soil and Landuse Survey (AISLUS) in 1990 has brought out a National Watershed Atlas on 1:1 M. scale at national level, in which delineation of watershed has been done in five stages namely region, basin, catchment, sub-catchment, and finally a watershed of size ranging between 500 and 800 sq.km. Alpha numeric sympotic codes consisting of a combination of alternating Arabic numbers and English capital alphabet letters have been used to designate different stages of delineation as indicated below.

- Water resources regions are assigned Arabic numbers –1,2,3,4.
- Basins are assigned letters as –A,B,C.
- Catchment are assigned Arabic numbers –1,2,3.
- Subcatchment are asigned letters as –A,B,C.
- Watersheds are assigned Arabic numbers –1,2,3.
- Thus watershed will have code like 2B, 2A3, 3A5,C4, 4C4.

Similar efforts were also made by state remote sensing agencies to create watershed atlas at higher resolution. One such approach followed by MSRAC is illustrated below.

MRSAC in the early nineties, realizing the need for natural resources database at the state level generated resources database for all the districts of Maharashtra covering 30.7 million ha on 1:250,000 scale. The district wise thematic information on the themes on geomorphology map, soil erodibility map (derived from soil map), land use/land cover map, watershed maps of district prepared by GSDA. The approach involves identification of watershed with high run-off using the qualitative run-off assessment method. The methodology is based on the assumption that the run-off characters are influenced largely by resources such as soil, geomorphology and land use/land cover which can be depicted in the spatial format in form of theme maps. Each theme is broadly divided into 5 to 6 classes as per the run-off characteristics. The highest weightage index is given to unit indicative of high run-off, while the lowest weightage index is given to the unit indicative of low run-off as shown below.

Table 1. Unit wise assigned weightage index			
Assigned weightage index	Theme		
	Soil erodibility	Geomorphology	Land use/land cover
1.	Area of negligible erosion	Valley fill, lower plateau plain	Double cropped area
2.	Area of low erosion	Pediplains, plateau with thick soil cover	Single cropped area
3.	Areas of moderate to low erosion	Slightly dissected plateau, weathered pediment	Open and closed forest
4.	Area of moderate erosion	Moderately dissected plateau, pediments	Scrub forest and grassland
5	Area of high erosion	Highly dissected plateau, denudational slope	Scrubland
6.	Area of severe erosion	Denudational hills, residual hills, structural hills	Stony waste

The weighted average index of entire watershed was then worked out to derive the rating of watersheds as per the runoff characteristics. Weighted index more than 9 has been classified as priority watersheds, while watersheds with weighted index lower than 9 were classified as least priority watersheds. Adopting the above approach, watersheds of all the districts were prioritized in GIS environment.

It will be observed that this set of criteria had a mono-focus on the natural and physical factors, especially of land, water and vegetation, which were crucial for watershed development.

Watershed Selection Process After 1994

The thinking reflected in the Dharia Committee report 'High Level Committee on Wastelands Development', paved the way for the change in existing a soil and water conservation strategy to a 'rural development program'. This was effected through the transfer of governmental mandate for watersheds from the MoA to the Ministry of Rural Development (MoRD). The Dharia Committee recommended that SWC efforts should be extended to all lands, whether already degraded or not, whether very productive or not, in order to prevent further deterioration and depletion. Secondly, an integrated approach to biophysical resource conservation was required, based on the physical (rather than administrative) area of a micro-watershed. The promulgation of the 73rd Amendment to the Constitution of India

In 1992 empowering PRIs to act as the medium of local self governance and the realization of people's participation in the governance and management of their livelihood resources as the key to poverty alleviation also helped in changing the existing guidelines of watershed program to serve larger developmental goals.

The watershed guidelines (Hanumantha Rao Commission, 1995) have provided a definite design for a participatory watershed development approach and have been adopted by many state governments in India since 1995. These guidelines brought in significant changes in the implementation of DPAP, DDP and IWDP programs. The broad classification of DPAP, DDP and IWDP was done through an index called aridity index. GoI categorised these districts by environmental, social and developmental indicators. High priority is accorded to low-rainfall regions with concentration of scheduled castes (SC) and scheduled tribes (ST) and low literacy rates. These guidelines further refined in Hariyali guidelines. The suggested criteria includes the following.

Hariyali Guidelines

- People's participation is assured through contribution of labour, cash, material, etc., for its development as well as for the operation and maintenance of the assets created.
- Areas having acute shortage of drinking water.
- Presence of large population of scheduled castes/scheduled tribes dependent on it.
- Preponderance of non-forest wastelands/degraded lands.
- Preponderance of common lands.
- Watersheds where actual wages are significantly lower than the minimum wages.
- Contiguous to another watershed that has already been developed/treated.

Watershed area may be of an average size of 500 hectares, preferably covering an entire village. However, if on actual survey, a watershed is found to have less or more area, the total area may be taken up for development of a project. In case a watershed covers two or more villages, it should be divided into village-wise sub-watersheds confined to the designated villages. Care should be taken to treat all the sub-watersheds simultaneously.

The Ministry of Agriculture followed the revised criteria given below for the selection of watersheds under NWDPRA program (WARASA guidelines) from the year 2000. The change in watershed selection process basically includes parameters associated with socio-economic conditions along with bio-physical requirements.

Block Selection Criteria: Blocks having less than 30 per cent assured means of irrigation in the arable land would continue. Exception may, however, be made in the case of A&N islands where micro-watersheds on island basis instead of block basis be allowed.

Demarcation and Prioritization of Watersheds: Prioritization of sub-watersheds (5000-6000 ha) be carried out on the basis of sediment yield, runoff potential index, degree of land degradation, underground water status, etc., which are derived from macro watersheds of 25000-30,000 ha available from regional survey maps. Information available from All India Soil and Land Use Survey, state and national level remote sensing agencies, etc., may be utilized to derive information on the above mentioned parameters. Each of the prioritized sub-watershed may then be sub-divided into micro-watersheds, each having an area of about 500 ha. Each micro-watershed shall become a unit for the watershed association. Prioritization of these micro-watersheds may also be done on the basis of similar parameters indicated above.

The above criteria depend mostly on sediment yield, which was factor for consideration in RVP. The present watershed atlas by AISLUS also provides the same information and watersheds were categorized based on this parameter. On the other hand, runoff potential index is more apt parameter for inclusion in watershed program as it provides the information on available water for use in improving the agriculture/livelihoods. Though various procedures are available, a commonly adopted method was not devised at national level so that an atlas similar to that available with SYI could be prepared for use by developmental agencies. Further, the improvements in information technology and geographic information systems, researches devised surrogate parameters for estimation of runoff potential by use of available topographic/contour data. Availability of DEM information in public domain also hastened this process. A mechanism to use these developments at district level could be promoted for identification of watersheds on scientific parameters.

Identification of villages having prioritized watersheds would be carried out by superimposing the topography map (having the prioritized micro-watersheds) on the cadastral map of the village. Usually each micro-watershed would be co-terminus with an average size of the village. However, in situations where the area of the identified village is very large, more than one micro-watershed may be considered in the given village. On the other hand if the identified village is small more than one village may be considered under each micro-watershed.

Criteria for Eligibility of Watershed Villages: Final selection of villages may be conducted in an objective manner by using a combination of the above scientific parameters for the micro-watersheds and also the following additional parameters, which represent the socio-economic parameters for the watershed village.

- Severity of land degradation.
- Location in upper reaches of watershed.
- Lack of earlier investment through any other watershed development project, in the village.
- Significant proportion of arable land under private cultivation (preferably 50% or more).
- Pre-ponderance of resource poor, SC/ST.
- Willingness of community to participate and contribute in the program and take up responsibility of post project maintenance of the created assets.

In addition, the guidelines suggest the following points also to be considered for finalization of villages before taking up the watershed program.

- Willingness to manage watershed program through a separate WA/WC after its registration under the Society Registration Act.
- Willingness to implement the project by people themselves without any contractor.
- Willingness to maintain all records properly and own the audit responsibility for the developmental funds to be released under the project to the proposed registered society.
- Willingness to pay contribution for individual as well as community works as per the guidelines.
- Willingness to operate revolving fund for improving farm production system (of landowning families) and livelihood support system (of landless families) through organized UG/SHG.
- Willingness to maintain community structures to be created under the project by *panchayat* in the event of the WA/WC fail to maintain it.
- Willingness to operrationalize social fencing (ban on free grazing, ban on un-authorized cutting of trees) for development of common land/forest land where exists; and also allocation of usufruct over the perennial vegetation from these land in favor of resource-poor families and women SHG to promote equity.
- Willingness to contribute as *shramdaan* for implementation of entry point activity as well as development of common land resource.
- Willingness to cooperate with PIA/WDT for organizing the community into SHG, UG, WA, WC and for carrying out PRA exercises for preparation of watershed plan.
- Identification of appropriate office bearers of WA/WC who are local residents, capable, respected and non political, which primarily indicate the participation of the village in the program since the beginning of the program.

The Government of India created a Watershed Development Fund and mandated NABARD (National BanK for Agriculture and Rural Development) to implement the same in selected districts. NABARD, based on their experience in Indo German Watershed Development Program, have drawn the following guidelines for selection process of watershed is under WDF.

Criteria for Selection of Districts

The districts will be selected in consultation with the concerned state government. For selecting districts, preference is given where the per centage of irrigation is less than 30%, where there is a concentration of SC/ST population and where the extent of rain-fed farming and potential for watershed development is large. Priority will be given to the districts having the lowest proportion of irrigated area in the state, subject to the availability of basic ingredients needed for successful implementation of watershed development projects.

Watershed selection criteria for inclusion in the program is based on physical and socio economic characteristics.

- *Physical Characteristics*
    - Dry and drought-prone villages, in any case the proportion of irrigated area may not exceed the average for the state or 30% whichever is lower.
    - Villages with noticeable soil erosion, land degradation, resource depletion of water scarcity problems.
    - Villages in the upper part of drainage systems
    - The size of a watershed project should be around 1000 ha (but not less than 500 ha).
    - Well defined watersheds with the village boundaries coinciding to the greatest extent possible with the watershed boundary.
    - Villages where the general cropping sequence does not include high water demanding and long duration crops like sugarcane, banana, etc., and if such crops are grown in small pockets in the watershed, the villagers should agree that the area under such crops will not be extended during implementation or after completion of the watershed development project.

- *Socio-Economic Characteristics*
    - Predominantly poor villages.
    - High proportion of SC/ST in the total population.
    - There should not be much difference in the size of the land holdings.

- Villages with a known history of coming together for common causes.
- Villages that have shown concern for resource conservation.
- Villages with alternative sources of employment must not be selected.
- Villages that are willing to commit themselves to the following conditional ties.

  - To ban clear felling of trees.
  - To ban free grazing and in treated areas for protecting vegetation.
  - To reduce the livestock population if in excess, and maintain the same at the carrying capacity of the watershed (number which can be supported by the watershed).
  - To ban cultivation of water intensive crops like sugarcane and banana or at least not to increase the area under such crops from the present position.
  - To contribute initially four days of *shramdaan* on watershed treatment works by the entire village community and later, once selected for the program to contribute by way of *shramdaan*.
  - To collect contribution equitably (impartially and in a just manner) from the village community. The landless and poor single parent households are excluded.
  - Promote equity for women and poor through preferential allocation of usufruct right in common lands.
  - To start and contribute a watershed maintenance fund, from the second or third year onwards to maintain and upgrade the treatments and assets created under the project at a rate of Rs.100 per land owning families.
  - To take all such steps as are necessary for achieving and maintaining a sustainable production system.
  - To constitute, at the village level, a body called the village watershed committee (VWC), which would have to be registered during the implementation phase within 6months of the commencement of the work, so that it can under take responsibility for maintenance of all the valuable assets created and generated by the project.

In addition, watersheds selection includes the preference for ridge to valley implementation, less dependence on mechanical structures, and willing to improve the farming in watershed areas.

APRLP Watershed Selection Process

Andhra Pradesh Rural Livelihoods Program (APRLP) started with a goal to poverty eradication ie, of ensuring sustainable livelihoods and equity sought to institutionalize sustainable livelihoods approaches. Towards this, APRLP has succeeded in designing — namely, the new selection criteria. The success of the APRLP approach to watershed-based livelihood habitations hinges on the proper selection of livelihood habitations and program implementation agencies (PIAs). Hence, the criteria that have been refined by APRLP, for this purpose, reflect its larger objectives. A special focus on gender and usufruct rights over common pool of resources (CPR) is also reflected in APRLP's revised selection criteria. With this the concept of watershed development has moved from being a land-and-water program to a people-centred one. Following these guidelines, AP devised what came to be popularly known as the 100 marks criteria covering nine point for the selection of watershed habitations. APRLP successfully identified following the integration natural resource degradation and multiple deprivation criteria for habitats identification under the present initiative.

The nine significant factors that it took into account are:

- percentage of small and marginal farmers;
- percentage of SC/ST holdings;
- percentage of women organised in SHG's and participating in the program;
- status of ground water;
- APSRAC (AP state remote sensing organization) prioritisation;
- Live stock population;
- Number of families affected/involved immigration;
- Contiguity with treated/proposed watershed;
- Availability of fallow/waste land and CPR for the poor and landless to utilise insufruct.

Clearly, there have been important changes in the selection criteria after the Ministry of Rural Development put forward the Common Guidelines for Watershed Development. Since 1995, the focus has expanded to include not only geo-hydrological details like sedimentation, evapo-transpiration and rainfall but also socio-economic indices like poverty, illiteracy, migration for wage labour, availability of drinking water, etc. There is also a new stress on the willingness of the community to involve themselves in all stages of watershed development.

Nine point selection criteria, devised by Dept. of Rural Development

Parameters	Range	Mark	Weightage
1. % of small and marginial farmers	<25%	5	
	>25 & 50%	10	
	>50%	15	15
2. % of SC/ST holdings	<10%	3	
	>10 & 25%	10	10
3. % of women organised in SHGs and participating in program	<20%	3	
	>20% & 50%	5	
	>50%	10	10
4. Status of groundwater	<10 mts	2	
	>10 & 15 mts	3	
	>15 mts	5	5
5. APSRAC prioritisation	VL	6	
	L	12	
	M	18	
	H	24	
	VH	30	30
6. Livestock population	<1000 (Nos)	2	
	>1000 & <2000	3	
	>2000	5	5
7. No. of families affected/involved in migration	<50	3	
	>50 & <100	5	10
	>100	10	
8. Contiguity with trusted proposed	Yes	5	
	No	0	5
9. Availability of fallow/waste/land & CPR for the poor to utilise usufruct	<10%	3	
	>10% & <20%	5	
	>20%	10	10
Total			100

Natural Resource Degradation Criteria

Andhra Pradesh State Remote Sensing Application Centre (APSRAC) identified micro and macro watersheds and these watersheds have been prioritised by using the following basic criteria.

SYI is expressed in percentage terms. This index indicates land degradation due to erosion and has been combined with dependability of precipitation and evapo-transpiration.

For this, two criteria have been used:

a) the variability of rainfall, ie, timeliness and number of rainy days, and

b) deviation of rainfall, which is perhaps a more sophisticated index dealing with the volume of rainfall at appropriate times.

Where the sediment yield is high, ie, erosion is high and rainfall dependability is low, there is a high level of natural resource degradation vis-à-vis agriculture and water supply. The habitations have been ranked according to the levels of degradation and the worst areas have been given the first or the highest priority for treatment. All the habitations have been ranked on a scale ranging from very high, high, medium, low to very low and non-DPAP, to indicate the watershed priorities. These categories have been renamed as natural resource deprivation typologies. The last three categories on this scale, ie, low, very low and non-DPAP have been combined to form category IV (low). The other three have been renamed as I (high), II (medium) and III (moderate).

Multiple Deprivation Criteria

Since APRLP is concerned with rural poverty, it has designed a poverty profile by taking into account multiple dimensions of poverty as reflected in deprivations of

- i) income;
- ii) accessibility to services; and
- iii) social status of the people defined according to the concentration of the most disadvantaged sections of society, namely *dalits and adivasis*.

All the three habitation typologies were prepared separately and the multiple deprivation typologies were derived subsequently. These typologies are useful for prioritising investment decisions according to the intensity of deprivations. A *mandal*-wise analysis was presented, since it was considered the most viable unit of decentralised governance in AP. The following is a brief description of how the above-enumerated deprivations can be analysed.

Income Deprivation

To estimate the levels of poverty using the secondary data available, two sets of calculations were carried out.

1. The estimate of incomes of various occupational groups.

2. The estimate of expenditure required for the standard minimum calorie intake based on consumption expenditure data.

The calorific values of commodities consumed were assessed on the basis of consumption expenditure pattern, and this was used as the basis for assessing the poverty levels related to the nutrition of various income groups. The nutritional poverty levels can be compared to the levels of income to arrive at the levels of poverty of the occupational groups in question.

Accessibility Deprivation

The Human Development Report, 1997, focuses not merely on the poverty of income but also on deprivation from a human development perspective. In other words, poverty is understood as a denial of choice and opportunities for living a tolerable life. The term "facilities and services" in this context has come to signify the basic infrastructure provided by the government to every citizen of the country. These facilities and services comprise drinking water, irrigation, health, education, post and telegraph, transport and communication, and electricity. The lack of basic facilities and services, their inaccessibility and inadequacy is, therefore, what resulted in accessibility deprivation. Accessibility deprivation is an aspect of human poverty, which leads to a feeling of insecurity. Any effort to promote human development and to eradicate poverty must necessarily focus on improving the physical conditions of the people. Similarly, livelihoods outcome include improved access to natural resources, food security and incomes, better self esteem and coping mechanism to deal with stress due to calamities, etc. Existing norms as per GoI were taken into consideration for estimation of adequacy and accessibility deprivation.

Social Deprivation

The third important criterion selected for evaluating the level of deprivation is the social status of the people. Poverty has a social dimension and in India it is often the case that the class system corresponds with the caste system. Overwhelmingly, the oppressed castes and the *adivasis* continue to be powerless and poor. Social deprivation refers to the poverty, powerlessness and alienation, which the *dalits* and *adivasis* experience in their everyday life. For arriving at social deprivation typologies, it was assumed that the greater the concentration of *dalit* and *adivasi* populations in a settlement, the greater would be the marginalization and social deprivation. Therefore, the population profiles of the *dalits* and *adivasis* are collected. This is almost in line with recommendation of MoA/MoRD on consideration of preponderance of SC/ST communities.

Depending on the above-described factors of poverty deprivation, also called multiple deprivation, the habitations that are the most deprived in all the three categories were selected. These multiple-deprivation habitations are then integrated with the indices of natural resources degradation.

Since APRLP seeks to consider people's livelihood situations and opportunities in their entirety, it has sought to integrate the above-delineated indices of multiple deprivations and natural resources degradation. The watershed analysis carried out by APSRAC, giving the four modified categories of natural resources degradation, and the multiple deprivation (also called social and material deprivation) categories are given equal importance. When integrated, they generated sixteen typologies.

Typologies 1 to 4 comprise habitations with the highest levels of natural resource degradation and decreasing levels of social and material deprivation. Thus, typology 1 denotes the habitations which are the worst off, ie, having the highest levels of natural degradation as well as poverty. Typology 4 is constituted by habitations, which present a paradox. They are badly deprived as far as natural resources are concerned and yet showed low levels of socio-economic deprivation. It will be interesting to take up further investigation to know such peculiar situations.

Typologies 5 to 8 bring together the habitations with medium levels of natural resource degradation and decreasing levels of social and material deprivation. Type 5 was constituted by habitations with high levels of poverty and type 8 with habitations having low levels of poverty.

Typologies 9 to 12 cover the habitations with moderate levels of natural resource degradation and decreasing levels of poverty. Typology 9 settlements have high levels of multiple deprivations and typology 12 habitations have low levels of the same.

Typologies 13 to 16 include the habitations with low levels of natural resource degradation and differing levels of poverty. Type 13 habitations have high poverty and typology 16 have low poverty.

These criteria were used for the selection of new/future watersheds in the five APRLP districts.

The types 1, 2, 5, 9 and 13 are centralized for prioritizing the habitations.

Type 1 – habitations with very high natural resource degradation and high socio-material deprivation

Type 2 – habitations with very high natural resource degradation and medium socio-material deprivation

Type 5 – habitations with high natural resource degradation and high socio-material deprivation

Type 9 – habitations with moderate natural resource degradation and high socio-material deprivation

Type 13 – habitations with low natural resource degradation and high socio-material Deprivation

Conclusions

In order to ensure the success of the watershed program in optimally achieving the project objectives, it has become important to include the social factors also besides bio-physical factors for selection of watersheds. The extent of socio-economic parameters followed by different agencies ranges from simple to very complex. Availability of data at habitation level, and analysis time requirement are crucial for implementation of complex systems though they tend to prioritise the investment in a very objective manner for poverty eradication. On the other hand, experiences from field suggest that the willingness of the community to participate in the entire process of development from the beginning is the key to success of the program. Participation of the community along with community strictures on high water consuming crops such as banana, sugarcane, etc., helped in achieving the better use of available resources with in watersheds along with other developmental goals. Bio-physical parameter characterization is mostly dependent on sediment yield index which was primarily used in river valley programs for reducing the inflow into reservoirs. Though emphasis was given for runoff potential index as a parameter to be included, availability of information and the use of same by all agencies concerned is not same. There is a need to identify a common method which could be applicable by all agencies at district level. Since the process of estimation runoff potential involves large number of variables, to the extent possible, it may be estimated for various micro watersheds based on parameters like slope, drainage density, etc., which could be derived through GIS by using the publicly available DEM information. As a first step this process also could be institutionalized at district level.

Reference

Guidelines of MoA (WARASA), MoRD (Hariyali), APRLP on watershed programs and related documents.

3. Baseline Socio-economic Characterization of Watersheds

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Abstract

Baseline characterization is important to measure project performance before making any changes to project processes. The paper provide insights into the baseline characterization of watersheds with special reference to socio-economic aspects to propose appropriate policy directions for enhancing productivity and sustainability in the semi-arid zone.

Keywords: Watersheds, characterization, socio-economic, stratified sampling, baseline.

Introduction

The arid and semi-arid tropics are generally characterized by rainfall variability, low productivity, natural resource degradation, climate variability and low development of infrastructure. Large investment made on irrigated agriculture and technological development had little impact on dry areas. Therefore, it is imperative to manage and conserve water and soil resources in order to enhance productivity and improve the well being of people (Wani et al. 2003a,). In this context, watershed development programs have become engines of development especially to reduce poverty, maintain food, fodder and fuel security with sustainable manner for huge population and seen as the lynchpin of rural development in dry regions (Wani et al. 2003b). Several noteworthy watershed programs have been carried out since inception that have yielded sterling results (see Wani et al. 2003b) while reviews and studies show that overall the performance have not kept pace with the expectations (Joshi et al. 2005; Joy et al. 2006). According to meta analysis of watershed development, only 35 per cent of watersheds have yielded favourable benefit-cost ratio while others have performed little by way of unbalanced development (Joshi et al. 2005). One of the major reasons for poor performance is that improper characterization of watersheds and poor project planning and implementation.

Baseline characterization is important to measure project performance before making any changes to project processes. If we do not have baseline data then there is no way to evaluate whether a change is making a difference. It is used during the project to indicate progress towards the goal and objectives and after the project to measure the amount of change. It allows those involved in the project to understand the initial livelihood conditions of the people, and what needs to be done to reach the goal of improving the livelihoods of the poor. Thus, baseline characterization builds necessary foundation for the plan and obtains proper information for effective planning, implementation and monitoring.

Therefore, proper characterization of watersheds is a prerequisite for appropriate policy directions for enhancing productivity and sustainable development. Tools of geomatics (eg, satellite data, GIS and GPS) besides conventional ones (eg, field survey, topographical and cadastral maps) along with traditional multi-disciplinary methods (eg, PRA, soil and water analysis, socio-economic survey etc.,) provide insight into characterization of watersheds, project formulation and proper implementation of such development programs.

Strategy and Approaches

Broad Areas of Enquiry for the Socio-economic Characterization

The main purpose to characterize socio-economic systems in the watersheds is to identify existing and potential production constraints, and propose potential areas for targeting technology transfer for sustainable development. It requires huge information from a number of sources, published, unpublished and micro level field investigation. The following broad areas (indicators) may be essential to characterize socio-economic systems in the watershed (Appendix 1). Thus, careful identification of these indicators may provide an opportunity for better implementation and monitoring of watershed development programs.

Demographic Information

Demographic information has many purposes; it is used for research in the social sciences, creation of policy, and identification of potential socio-economic networks. The demographic information is a guide to and starting point for research about basic information on the areas of investigation. Demographic information consists of numeric data or statistics involving groups of people.

Demographic information includes household profile, village profile, livelihood options available to the people in the village, primary and secondary occupation and literacy level among male and female etc. In addition, age, sex, education and marital status of the family members form a base for understanding demographic condition of the household.

Agriculture

Land Ownership

Land ownership builds a strong base for the utilization of resources for production purposes. It is a habitual conception that ownership of land is acceptable. Most societies are characterized by the convention of ownership. In the context of watershed, land ownership determines the participation of the community in watershed development activities to conserve, manage and use of natural resources that are crucial for overall development of the society.

Land Use Pattern

The land use pattern includes geographical area, forest area, non-agricultural use, barren and uncultivable land, permanent pasture and other grazing lands, land under miscellaneous trees and groves, culturable wasteland, permanent (other) fallow, current fallow, net area sown, area sown more than once, and gross cropped area (GCA). This information gives broad picture about the production structure of the society and thereby facilitates for better policy directions.

Area, Production and Yield of Crops

Information on area, production, and yield of all major and minor crops grown in the production system will be required to examine spatial and temporal changes in area under different crops and possible crop substitution. This information is useful to compare the baseline situation with improved technology due to project intervention. Important crops in the production system include cereals: rice, wheat, sorghum, pearl millet, maize, finger millet, and other millets. pulses**:** chickpea, pigeonpea, and other pulses. Other crops include oilseeds: groundnut, rapeseed and mustard, sesame, linseed, and other oilseeds; cash crops: sugarcane, cotton, jute, and tobacco; fruits and vegetables: onion, other vegetables, and fruits. The cropping system changes according to seasonal variability. Thus, care need to be taken to capture seasonal variability on the productivity and yield.

Crop Utilization and Commercialization

The information pertaining to crop utilization and commercialization need to be collected. The information required may include, crop utilization for different domestic purposes and quantity sold in the market, which is a marketable surplus, provides value addition to household economy.

Input Use

The baseline information on input use across crops is a prerequisite for identifying potential strengths and weaknesses of the production system. The information needed for input use characterization includes: crop-wise labor use, crop-wise fertilizer use, crop-wise area under high-yielding varieties (HYVs), crop-wise pesticide use, crop-wise irrigated area, number of tractors, number of bullocks, and crop-wise cost of cultivation. Input change in watershed development areas may indicate the progress made in terms of effective cultivation practices and training and capacity building for farmers. Input change, for example, reduction in fertilizer utilization can also improve water quality and soil health.

Output and Input Prices

The aim of the watershed development program is to strengthen natural resource base to achieve sustainable development. The efficient management of available resources facilitates for improved cultivation and higher productivity. This can be linked with suitable pricing system. Farm harvest and retail prices of important crops and the prevailing input prices during the project implementation period is required to examine the cost, profitability, and competitiveness of different crops in the region so that performance of watershed development program can be assessed effectively. The farm harvest prices for all the important crops and input prices such as seed, fertilizers, pesticides, farm operations, labor wages, and electricity charges for irrigation would be required to assess the performance of the watershed development.

Irrigation

Irrigation is a major input for agriculture development. One of the major objectives of watershed development strategy is to conserve water resources. Thus, to characterize production system in the watershed, information regarding gross irrigated area, net irrigated area, irrigated area under different sources, crop-wise irrigated area, number of private tube wells, number of public tube wells, number of pumpsets, and irrigation potential are required. Irrigation enhances the productivity and production of crops and baseline production capacity helps to assess the performance levels of the project in a more effective manner. This suggests whether the watershed development strategy is making any changes in terms of its effectiveness.

Livestock

Livestock is an integral component of the conventional farming systems and plays a major role in the rural economy with high contribution to the gross domestic product (GDP). Since watershed development is expected to improve the feed and fodder situation and facilitate dairy development, special attention needs to be given on the livestock sector. Small ruminants like, sheep or goats are the best source of regular cash income for rural poor with less investment. The year round income can be assured from these sources. The selection of appropriate livestock species matters much in improving the productivity of livestock, which is an important consideration in the development of an integrated farming system. The crop-livestock system in semi-arid region enhances income flows of rural households by increasing outputs such as milk, meat, wool, etc., Therefore, a clear account of large and small ruminants will be essential. It is therefore, necessary to take note of changes in the composition of livestock breed and outputs, using pre and post watershed data, to be quantified from landed and landless people.

Economic Variables

One of the crucial aspects of watershed development is to improve rural livelihoods through increase in income. There are different avenues and sources of income-generating activities due to watershed development. The growth of income and expenditure and changing poverty status can be examined through information pertaining to work force, agricultural labourers, poverty indicators such as income and consumption pattern (disposable income on various activities and consumption expenditure). The important economic variables include: income across different social groups as well as landholding classes; household income and consumption pattern; and poverty status across social groups. The information regarding economic variables during pre and post watershed development facilitates to measure the impact of watershed development program on household economic condition.

Rural Infrastructure Facilities

Availability and access to infrastructure facilities is a backbone for rural development. Apart from availability, quality of infrastructure makes difference in people's standard of living. Therefore, characterizing socio-economic system involves gathering information about available infrastructure for better monitoring and evaluation of the project. The information includes: intensity of roads in rural areas, regulated markets, number of rural banks (nationalized, cooperative, regional rural banks), number of electrified villages, number of small-scale and medium industries, number of other processing mills, number of technology transfer agencies, number of staff engaged in technology transfer and other infrastructure facilities.

Infrastructure development is a major criterion to assess the development of the economy. Watershed development program provides opportunity to create number of infrastructure facilities to enhance the growth process. Thus, baseline data in the watershed area is essential to compare the infrastructure development and the feasibility of these structures for development process. For instance, availability of transport and markets are essential to boost the confidence of landed and landless households to undertake income generating activities to strengthen their economic condition. Thus, pre and post watershed data might be useful for quantifying the changes across watershed villages.

Economic Feasibility of Improved Technologies

Watersheds are learning and experimental sites. Hence, watersheds provide opportunity for the application of improved technology for better outcomes. However, understanding the economic feasibility of all improved management strategies and technologies are essential to know their costs and benefits under different scenarios. The information regarding capital cost, input cost and output cost are essential to understand the feasibility of improved technologies. For instance, capital cost includes component-wise cost of any soil and water management technology which has a long life; input cost include item-wise cost of all inputs required for crop production with existing (local) technology; item-wise cost of all inputs required for crop production with improved technology; and output cost consists of output produced and prices with existing (local) technology; output produced and prices with improved technology.

Procedure and Practices

Sampling Procedure

There are number of methods available to collect data for an enquiry. However, care should be taken to avoid error caused by multiple methods. Stratified Random Sampling procedure would be allowed to collect information. Stratified random sampling is the purest form of probability sampling. Each member of the population has an equal and known chance of being selected. When there are very large populations, it is often difficult or impossible to identify every member of the population, so the pool of available subjects becomes biased. The commonly used probability method is superior to random sampling because it reduces sampling error. A stratum is a subset of the population that shares at least one common characteristic. Random sampling is then used to select a sufficient number of subjects from each stratum. Stratified sampling is often used when one or more of the stratums in the population have a low incidence relative to the other stratums. Reliable information needs to be collected by applying below steps.

- Divide the whole study area (watershed) into two strata. Stratification is done on the basis of the intensity of the specific activity, which one intends to study. For example, if one plans to study agricultural intensification in a watershed, the two strata are: (i) upstream; and (ii) down stream. The upstream and downstream needs to be classified based on toposequence.
- Select appropriate number of villages (as per the convenient) from each of the strata and one additional village may also be selected as a control village. Equal number or percentage with minimum number of farmers (large, medium, small, and one control) from each village may be selected. The criteria of categorizing, farmers are: small farmer – less than 2 ha; medium farmer – 2.01 and 5 ha; and large farmer – more than 5.00 ha. Selection of farmers is made randomly from each size class.
- Survey timing is very important to obtain reliable information. Sufficient timing should be allotted to collect data. It should be done when farmers are relatively free to give sufficient time to enumerators for discussion. Data collection immediately after the harvest of the crop will give more reliable information about production and input use.

Selection of Households

In most cases, the number of households within the watershed will be too large to feasibly survey every household. In this case, one must pick a representative sample of households. Sampling means that only some of the households in the watershed area are picked for survey. The concept of 'representative' is important and means that the sample of households interviewed must reasonably represent the entire group. To accomplish this, a random sample needs to be chosen. In situations where there is a census of the entire targeted population, households can be randomly chosen by various means such as picking every fifth household or using a random numbers table. The ideal sample should cover 20-25 per cent of the households, depending on the sample size, without double counting of their landholding in the village. The minimum number of households per village should be fifty.

Method of Data Collection

Data collection means gathering information to address those critical evaluation areas that we have identified earlier. There are many methods available to gather information, and a wide variety of information sources. The most important issue related to data collection is selecting the most appropriate information or evidence to answer our questions. Several approaches are adopted to generate desired information from the respondents. These include:

a) community group interviews;
b) household survey (interview, questionnaire survey);
c) frequent visits to the study area and regular discussions with the respondents;
d) direct observations;
e) participatory rural appraisal methods;
f) rapid rural appraisal; and
g) case studies.

To plan data collection, one must think about the questions to be answered and the information sources available. Also, we must begin to think ahead about how the information could be organized, analyzed, interpreted and then reported to various audiences. The selection of a method for collecting information must balance several concerns including: resources available, credibility, analysis and reporting resources, and the skill of the evaluator. Thus, either of the approaches may be selected depending upon the objectives of the study. However, questionnaire is an appropriate and widely used instrument to collect data in social science research in addition to many participatory approaches. Therefore, care needs be taken while preparing the questionnaire (Box 1 for checklist). In addition, following points needs to be considered when planning a baseline survey:

- The baseline survey should be strongly linked with the critical aspects of the project's M&E plan.
- There is need to understand the current condition in which the baseline survey will be conducted. Eg, what season of the year is it? What political condition prevails? What is the current state of the economy? Will the baseline survey occur during, or follow on from, extraordinary events such as natural disasters, political upheavals or economic shocks?

Analyzing the Data

The first step in analyzing data (after collection of data) is to determine what method of data analysis we would be using. If most of the information collected contains numbers, then the data is quantitative data. If the information collected consists of words, then the data is qualitative data. With quantitative data the analysis does not begin until all data are collected. In contrast, most qualitative data analysis begins as data are collected. For example, when conducting group interviews, group discussions, the transcripts are analyzed as soon as possible in order to generate additional questions for follow-up interviews.

If most of the information collected contains numerical (quantitative) data, then descriptive statistics (mean, median, mode, standard deviation, etc) can be used to characterize the data. If most of data collection was done using focus group interviews, open-ended questions, or case studies, then data will be in the form of qualitative data. Unlike being able to use a hand calculator or computer program to analyze numerical data, the qualitative data of words need to be analyzed initially by reading and sorting through the data. With qualitative data, how the data is ordered, categorized, and arranged is important because most qualitative data are words that must be interpreted for content. This process will include carefully reading the information, and then identifying, coding, and categorizing the main themes, topics, and or patterns in the information. Coding is simply attaching some alpha-numeric symbol to phrases, sentences, or strings of words that follow a similar theme or pattern. This process allows us to then place these phrases of similar themes into a category for further analysis.

Box 1: Checklist for Forming Questionnaire

- Is this question necessary? How will it be useful? What will it tell us?
- Will you need to ask several related questions on a subject to be able to answer your critical question?
- Do respondents have the necessary information to answer the question?
- Will the words in each question be universally understood by the target audience?
- Are abbreviations used? Will everyone in the sample understand what they mean?
- Is the question too vague? Does it get directly to the subject matter?
- Can the question be misunderstood? Does it contain unclear phrases?
- Have you assumed that the target audience has adequate knowledge to answer the question?
- Is the question too demanding? For example, does it ask too much on the part of the respondent in terms of calculations/estimation?
- Is the question biased in a particular direction, without accompanying questions to balance the emphasis?
- Are you asking two questions at one time?
- Is the question wording likely to be objectionable to the target audience in any way?
- Are the answer choices mutually exclusive?
- Is the question technically accurate?
- Is an appropriate referent provided? For example: per year, per acre, etc.

Recommendations for Practitioners

Following points are necessary for practitioners to undertake baseline survey in characterizing watersheds.

- Plan and conduct participatory rural appraisal (PRA) and focused group discussions (FGDs) with the watershed villagers including women, landless and marginal farmers.
- Team of multi-disciplinary experts should be involved in PRA & FGDs facilitated by a good facilitator.
- The results of PRAs and FGDs should be used to fine-tune the questionnaire to be used for detailed stratified household survey.
- Explain the importance and purpose of the household survey, which will help to plan watershed interventions needed for them to improve their livelihoods and assess the impact of watershed interventions.
- Pretest the questionnaire in the village and train all the enumerators by the expert and tell them the importance and expectation of high quality baseline data.
- Baseline survey should be launched in the first three months of project initiation and completed within first six months.
- Good baseline report of a watershed lays a strong foundation for the project and provides insights in various aspects of the watershed.
- It is often best to create a graph of the data that summarizes the frequency or percentage of what is being measured over time.

Conclusion

Socio-economic characterization of watershed involves several steps to follow. However, the baseline characterization provides great deal of ideas to better monitoring and evaluation of projects. The socio-economic characterization of watersheds generate results and helps to identify trends, commonalties and testimony that will help answer the critical questions that were part of an evaluation. If the evaluation is to be useful, the evaluator must interpret the information so that the stakeholders will understand the results and know how to use them for further action. The very purpose of characterization of watersheds is to study the potential change on economic, ecological and social system in a watershed. Information generated through baseline survey provides knowledge. Knowledge is achieved when people examine information, think about it, discuss it, compare it, and relate it to other sources of information. This is to increase our level of understanding so that we may take appropriate actions.

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Appendix 1: Information Needed for Socio-economic Characterization of Watersheds.

Characteristics	Purpose	Method
1. Demographic condition		
Household profile (age, sex, education, marital status, etc)	For understanding demographic condition	Data collection and analysis
Primary & secondary occupation	-do-	Data collection and analysis
Literacy (male and female)	-do-	Data collection and analysis
Livelihood options (farm and non-farm activities)	For watershed development plans	Data collection and analysis
2. Agriculture		
Cropping systems- *kharif, rabi,* summer	To introduce new cropping interventions and management to bridge yield gaps	Sampling/survey
Crop-wise Input use- seeds, fertilizers, organics, pesticides etc	- do -	Sampling/survey
Yields obtained	- do -	Sampling/survey
Trends in area	- do -	Historical records
Trends in crop production	- do -	Historical records
Trends in crop yield	- do -	Historical records
Land ownership	Land & water mgmt and crop planning	Sampling/survey
Land use pattern	- do -	Sampling/survey
Area, production & yield	- do -	Sampling/survey
Crop utilization and commercialization	- do -	Sampling/survey
Input use	- do -	Sampling/survey
Input and output prices	- do -	Sampling/survey
Irrigation	- do -	Sampling/survey
Characteristics	Purpose	Method

Contd...

Contd...

3. Livestock		Sampling/survey
Availability of feed and fodder	For land use and livestock planning	Data collection and analysis
Livestock breed	- do -	Sampling/survey
Milk production	For economic feasibility	Sampling/survey
Meat production	- do -	Sampling/survey
Wool production	- do -	Sampling/survey
4. Economic variables		Sampling/survey
Employment (work force, and agricultural laborers)	For sources of income and availability of work	Data collection and analysis
Migration	-do-	Sampling/survey
Income across different landholdings	For land productivity and capacity	Data collection and analysis
Income and consumption	For poverty status	Data collection and analysis
Consumption expenditure	- do -	Sampling/survey
Expenditure on health, sanitation and drinking water	- do -	Sampling/survey
Disposable income on various activities (eg, cloths, food, shelter etc)	- do -	Sampling/survey
Poverty related indicators	- do -	Sampling/survey
Financial institutions (formal/informal)	For understanding the livelihood opportunities	Sampling/survey
5. Rural infrastructure facilities (roads, market, transport, etc)	For watershed development plans	Sampling/survey
6. Economic feasibility of improved technologies	- do -	Sampling/survey

4. Biophysical Resource Characterization of Watersheds

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Abstract

In India drylands are generally characterized by highly variable rainfall, poor soils, low yields and poor development of infrastructure. The fragile eco-systems in rain-fed areas suffer from land degradation. The economic conditions of the farmers are miserable and deplorable. Biological resources of watersheds vary with time and space. There is a need to undertake a comprehensive study to quantify, map and appraise the resources through various techniques for successful implementation of watershed development programs.

Baseline survey therefore is essential to strike a balance and evaluate tangible and intangible benefits. The chapter elaborated various parameters that need consideration including active involvement of R&D institutions for evolving an action plan acceptable to both primary and secondary stakeholders. With the advancements made in space, dryland and information technologies, it is now possible to demystify watershed science in a more people-centric manner. The pre-requisite is collection of baseline information to appreciate the change over space and time due to watershed programs and justify the investments made.

Keywords: Characterization, baseline, watershed, water resources, soils.

Introduction

Watersheds have multiple uses and therefore, the nature and extent of characterization of these resources will depend upon the very purpose of watershed management. As human and animal pressure on these resources is increasing, their proper management and use without deterioration is essential to provide sustainable livelihoods to the rural people who are dependant on these resources. Watersheds are dynamic and keep changing over time. Initial surveys and resources characterization serve as a baseline for monitoring potential change in economic, ecological and social criteria. A baseline survey is therefore, an essential tool to assess project impacts and to justify investments.

Need for Baseline Characterization

- To evaluate opportunities for natural resource development, control of soil erosion and land degradation, assess vulnerability of watershed resources to management and other changes in watersheds.
- To understand farmers' reasons for current soil, water, crop and nutrient management practices and constraints for adoption of new practices.
- To assess the potential, constraints, and risks in natural resource management and production of crops, animal husbandry and forests or other natural vegetation.
- To carry out most appropriate watershed development plans and interventions to improve living standards and conditions of people.
- To develop homogeneous management zones for precision farming.
- To serve as baseline information to assess the progress as well as the impacts of various interventions.
- For scaling up methods and models.
- Establishment of ecological balance between man and environment, and many more needs for human welfare.
- To serve as an input to various biophysical models aimed at developing short- and long-term scenarios for improved management.
- To develop environment-friendly resource management practices that conserve soil and water resources.
- To promote sustainability practices of watershed management in the long-run after cessation of the project.
- To monitor and evaluate the program in terms of tangible and intangible benefits.

Physiographic Features of Watersheds

Drainage basin or a watershed is the area of land where all of its water drains off into the same place. Watersheds come in all shapes and sizes. The size of a watershed is dependent on the size of the stream, river, the point of interception of a stream or river, the drainage density and its distribution. Watersheds cross taluks, districts and even state boundaries. Physiography refers to the natural features of the earth's surface. These are divided into general groups and subgroups containing features such as uplands, hills, ridges, plains, valleys, etc. Delineation of watersheds at various levels of hierarchy based on drainage network is necessary. Water quality is affected through water runoff due to physiography.

Survey of India toposheets (1:50,000 scale) provides location, drainage network, contour and presence of surface water bodies. Satellite imagery is useful in updating information on water bodies and drainage, slope, aspect and altitude are important terrain parameters from land utilization point of view. Among the three parameters, slope is important for assessing land capability, erodibility, stability and irrigability. Aspects and slope have direct bearing on vegetation type and conditions. All India Soil and Land Use Survey has prepared guidelines for preparation of slope categories which can be safely adopted for deriving slope classes on 1:50,000 scale, which are given below:

Slope categories	Slope (%)
Nearly level	0 - 1
Very gently sloping	1 - 3
Gently sloping	3 - 5
Moderate sloping	5 - 10
Strong sloping	10 - 15
Moderate steep to steep sloping	15 - 35
Very steep sloping	> 35

Modern tools like geographic information system (GIS) and remote sensing can help make better assessments of the watersheds at varying scales and over time periods economically. The use of GIS in watershed management becomes more relevant where multidisciplinary efforts are the key to the development of the community and the ecosystem as a whole. GIS can facilitate baseline survey for prior assessment and characterization of the natural resources of the watershed by providing more detailed information to aid in proper decision-making.

The first and foremost task is the creation of a spatial database of the watershed through primary and secondary survey. A primary survey may involve using a Global Positioning System (GPS) (for precise altitude) used to record features /phenomena or events at specific points in the watershed. Also remote sensing data can serve as another source of primary data since it records the data.

Elevation data is of prime importance for hydrological modelling. This data can be obtained either from available large-scale topographic sheets (1:25,000) or stereographic data from remote sensing or aerial photography. First hand data can be generated from topographic survey using total station survey equipment or differential GPS.

Soil Resources of Watersheds

Spatial Distribution

Mapping spatial distribution of soils and their properties is a basic requirement for proper utilization of soils and for implementing soil and water conservation practices in a watershed. It is achieved through various types of soil surveys coupled with remote sensing to classify soils into units using uniform system of classification and uniform nomenclature. This helps in making comparisons with soils in other areas; envisage their suitability for crops, grasses and trees; define input requirements and expected yields under different systems of land use and management.

Characterization of Typical Soil Profiles

Typical soil profiles to provide information are studied. Soil characteristics measured or observed during the field work in a standard soil survey include: i) texture; ii) depth to bed rock, hard pan, sand, gravel, *kankar* or other root limiting influences; iii) structure; iv) consistency; v) colour and mottling; vi) kind and amount of coarse fragments; vii) kind, sequence and thickness of horizons; viii) pores, cracks, slicken sides, concretions, soil reaction and other special features and ix) slope.

Laboratory measurements may be required for several or all of the chemical and physical characteristics like i) particle size distribution; ii) specific gravity; iii) porosity; iv) clay mineralogy; v) CEC; vi) exchangeable cations; vii) pH; viii) alkaline earth carbonates; ix) organic carbon; x) toxic ions and salinity xi) moisture content at field capacity and permanent wilting point.

Soil survey provides information on grouping of soils on the basis of their genesis into order, suborder, great groups, sub groups, families and series. Survey data also helps in the diagnosis of inherent soil problems and identifying potential solutions. Study of internal soil drainage characteristics, erosion and salinity will assist in proper planning of watershed development projects. Most of the information can be obtained from publications and by contacting National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Nagpur, India. NBSS&LUP has come up with soil resources inventory for most parts of the country at 1:50,000 scale.

Land Capability Classification

The basic principle of watershed management is to utilize the land according to its capability. Land capability classification refers to a systematic arrangement of various types of land according to those properties that determine the ability of land to produce common cultivated crops, grasses or other plants on a sustainable basis. The important soil profile characteristics, which are interpreted for classification of land under different capabilities, are:

- soil texture;
- effective depth and location of hardpan;
- permeability and internal drainage;
- availability of nutrients;
- soil salinity, alkalinity and toxicity;
- coarse soil fragments.

Other external features such as waterlogging, slope and erosion also determine land capability for a particular use. Climatic factors can create waterlogging or drought conditions and affect productivity of land. The lands under various capabilities are classified into groups, classes, subclasses and units from higher to lower level of generalizations. There are two broad groups namely: (a) lands suitable for cultivation which include class I to class IV lands; and (b) lands not suitable for cultivation but very well suited for forestry, grassland and wildlife. This includes class V to class VIII lands. The land use and conservation measures are adopted as per different conservation classes in a watershed.

Soil Fertility Status

Productivity enhancement, in addition to resource conservation, is one of the main objectives of watershed management. This requires an assessment of the soil fertility status ie, the amount and availability of essential plant nutrients in the soil to support crop production. Based on the soil fertility analysis, application of nutrients from various sources is recommended to achieve balanced nutrition of crops to increase and sustain crop production in a watershed. Our experience has shown that most soils in rain-fed areas are deficient in secondary (S) and micronutrients (B and Zn) in addition to the already prevailing deficiencies of N, P and K, which need to be corrected. It is advisable to issue soil health card to individual farmers indicating limiting nutrients for enabling site specific nutrient management (SSNM) based on crops and cropping system.

Climatic Resources of the Watersheds

Knowledge on agroclimatology is a valuable tool in assessing the suitability of a watershed for rainwater harvesting and crop planning. Importance of climate assumes greater importance in the semi-arid rain-fed regions where moisture regime during the cropping season is strongly dependent on the quantum and distribution of rainfall vis-à-vis soil water holding capacity and water release characteristics. A thorough understanding of the climatic conditions helps in devising suitable management practices for taking advantage of the favourable weather conditions and avoiding or minimizing risks due to adverse weather conditions.

Data

Most important input for agroclimatic characterization of a watershed is the daily rainfall data. Other weather parameters like temperature, relative humidity, solar radiation, wind speed and direction are also required for a complete characterization process. Particularly, temperature and solar radiation can be limiting factors for the *rabi* crops in the central and northern parts of India. Moreover, data on all these parameters are required for computing the water balance of watersheds. Long-period daily data of a location near the watershed representing the general climatic conditions are to be collected, checked for quality and compiled to create database. Data at various intervals like daily, weekly, monthly, seasonal and yearly can be retrieved from the database. Either a manual or an automatic weather station is established in the watershed for continuous monitoring of weather conditions. The India Meteorological Department (IMD), state Department of Statistics, state agricultural universities and ICAR institutes are some of the major sources of weather data. Readily usable data on monthly basis for several locations in India is available in the publications of IMD (1985, 1995).

Rainfall Analysis

Receipt of certain amount of rainfall determines agricultural operations at different crop stages. There are specific amounts of rainfall required for the activities like land preparation, sowing, transplanting, fertilizer application, etc., Thus, estimation of probabilities with respect to a given amount of rainfall is useful for planning rain-fed agriculture. Incomplete gamma (Biswas and Khambete 1979) and Markov-chain methods are used for studying rainfall probabilities. Initial Probability is the probability of receiving a certain amount of rainfall (say more than 20 mm) in a given week. Estimating the probability of next week being a wet week, given the condition that the current week is a wet week is also important. Virmani et al. (1982) have computed these rainfall probabilities for 77 selected Indian locations.

Water Balance

Potential evapotranspiration or PE, which is the amount of water that is lost in to the atmosphere through evaporation and transpiration from a short green crop, completely shading the ground, of uniform height and with adequate water status in the soil profile, can be estimated using the modified FAO-Penman-Monteith method (Allen et al. 1998). Water balance of a watershed can be computed following the modified method of Thornthwaite and Mather (1955). Length of growing period (LGP), dry and wet spells during the crop growth period are calculated based on the index of moisture adequacy (IMA), which is defined as the ratio of actual evapotranspiration to the potential evapotranspiration.

Length of Growing Period for Rain-fed Crops

Knowledge on the date of onset of rains will help plan better the agricultural operations, particularly, land preparation and sowing. The length of the rainy season is the duration between the onset and end of agriculturally significant rains. The length of growing period (LGP) is defined as the length of the rainy season, plus the period for which the soil moisture storage at the end of rainy season and the post-rainy season and winter rainfall can meet crop water needs. Therefore, the LGP depends not only on the rainfall distribution but also on the type of soil, soil depth, water retention and release characteristics of the soil. This assumes greater importance from a watershed perspective where soil depth in a toposequence can also alter the LGP across the watershed with it being the highest in the low-lying regions and lowest in the upper reaches of the watersheds.

Several methods are available for estimating LGP. The National Bureau of Soil Survey and Land Use Planning (Velayudham, 1999) has estimated LGP over India using the method adopted by FAO, where the growing period starts when Rainfall (P) >0.5 PE (potential evapotranspiration) and ends with utilization of an assumed quantum of stored soil moisture (100 mm) after P falls below PE. LGP varies from 90 days in NW India to 300 days in NE region. While in semi-arid region, LGP varies between 120-150 days, in dry sub-humid climates it varies from 150-180 days. Kesava Rao et al. (2006) have used water balance method for determining the LGP of nine watershed locations in Nalgonda, Mahabubnagar and Kurnool districts of Andhra Pradesh. Growing season begins when the IMA is above 50% consecutively for at least two weeks, starting from the middle of May. The end of the season was identified when the IMA fell below 25% for two consecutive weeks, when worked backwards starting from the end of December. It was observed that assured rain-fed crop-growing season is about 165 to 175 days in Vertisols and about 130 to 150 days in Alfisols. Beginning and ending of the crop-growing season varies across years; however, the end was more variable compared to the onset. There was no definite relationship between the onset and length of growing season.

Choice of Crops and Cropping System-based on Moisture Availability

The choice of crops grown under rain-fed conditions should be made based on LGP. In semi-arid regions, rainy season crops are grown in soils that have a capacity to hold less than 150 mm of water. Additional post-rainy season crops can be grown on conserved soil moisture in soils that can hold more than 200 mm. In soils with 150-200 mm capacity, intercropping is possible (Ramakrishna et al. 2000). Choice of base and intercrops can be decided based on the distribution of rainfall. In regions with uni-modal rainfall pattern and shallow soils, the base crop should be of shorter duration and the companion could be of longer duration. In case of medium to deep soils, the base crop should be of longer duration while the companion crop can be of shorter duration. In bi-modal distribution, the choice of crops should be such that the peak growth period of the base and companion crop coincides with prominent rainfall peaks.

Dry and Wet Spells

High variability in the distribution of rainfall during the crop-growing period results in dry and wet spells of varying durations. Dry and wet spells during the crop-growing season can be defined based on the IMA.

Type of spell	IMA (%)
Very Dry	0 to 25
Dry	26 to 50
Semi-moist	51 to 75
Moist	76 to 99
Wet	100

When the rainfall and the soil moisture contribution put together cannot satisfy even 25% of the crop requirement, the period is termed as "Very Dry". If the IMA is between 76 and 99%, crops do not suffer from water stress. Some of the "Wet" weeks may have heavy rainfall leading to accumulation of runoff for water harvesting and also soil erosion. In the semi-arid climates, matching crop phenology with dry-spell duration is the key to sustain crop productivity. Dry-spell analysis helps to identify possible mismatch in phenology of the new crop/cultivar before the crop is actually recommended for large-scale introduction.

Water Resources Appraisal

Surface and Groundwater Resources

The four waters namely rainwater, soil water, surface and ground water are interlinked and interdependent. In watersheds, budgeting of water resources and planning for harvesting and recharge play a major role in the success of the program. Water acts as a triggering mechanism for motivating different interventions.

At the very outset, all open dug/bore wells need to be geo-referenced and a few need to be monitored continuously for water levels at least at monthly interval. These wells should represent the ridge, middle and lower portion of watershed. Well hydrographs can be prepared for comparison of watersheds from the available data with respect to rainfall and water use. Water levels in open wells during pre- and post-watershed development will serve as an indicator of water resources development. Remote sensing and GIS can be employed as tools for geo-referencing the water bodies and the area under irrigated crops, particularly during *rabi* and summer periods. Any increase in the number of water bodies and area under irrigation need to be monitored for evaluation at later stages. Further, by employing remote sensing and GIS tools, it is possible to demarcate low, medium and high groundwater potential aquifers/areas for exploitation by integrating thematic information like topography, soil type, parent material, etc.

Potential for Rainwater Harvesting and Recharging

The concept of 'Water Balance' analysis needs to be adopted for detecting the potential for water harvesting and recharge of groundwater. Water balance analysis needs to be carried out for the whole year as well as the cropping season. It helps in assessing the water surplus or deficit during the year to estimate the changes in available water in the wells due to rainfall and atmospheric requirements through evaporation and changes in temporal availability of rainwater and plant water requirement, respectively. Actual rainfall, normal rainfall and normal potential evapotranspiration can be used from available database.

The FAO water balance analysis for the cropping season for individual crops provides the information on the surplus and deficit periods during crop growth season (Thornthwaite and Mather, 1955). This analysis helps in building alternative arrangements for alleviating the moisture deficits during the crop season especially when moisture deficit occurs during the critical stages of plant growth. With the provision of supplemental irrigation at these stages, it is possible to mitigate drought and enhance productivity.

Characterization of Production Systems

Annuals

Crops and Cropping Systems

Land use statistics comprising existing farming systems ie, traditional crops and cropping systems (before and after watershed development) need to be recorded at regular intervals. There is a need to properly document the drivers influencing changes in cropping pattern and cropping systems, improved farming systems such as viz., agronomic and market interventions, water availability, access to inputs/technology, rise in level of income after the implementation of watershed development program.

Spatial Distribution of Crops in Rainy and Post-Rainy Season

With the availability of high-resolution data (IRS Cartosat, LISS IV & PAN) and groundtruthing using GPS, it is now possible in a watershed to have baseline information on land use, acreage under different crops/plantations/CPRs, etc., and its status on a cloud free day for both *kharif* and rabi. This information can be integrated with other thematic layers in a GIS environment and possibility exists for identification of land use for each farmer based on survey numbers. The maps thus generated will help in participatory technology development (PTD) and refinement of existing practices. Also scope exists for linking with site-specific nutrient management and preparation of integrated soil health card and land use plan. Area under cultivation of crops/plantations/pasture prior to and after treatment for arable and non-arable land will be useful for estimating change in land use/land cover and cropping intensity.

Crop Productivity vs Resource Use Efficiency

Crop productivity is the real indicator to judge the economic viability of a crop or cropping system. Production and productivity of major crops grown in the watershed villages in different years (including drought years) need to be studied to understand the impact of watershed interventions in mitigating drought.

Variations in productivity of crops over years may be due to misallocation ie, underutilization or over-utilization of resources. Productivity determines the extent of resource use pattern and efficiency in production of a crop. There is direct relationship between productivity and resource-use efficiency. That is, higher the productivity, higher the resource-use efficiency and vice-versa. Lower or stagnant productivity entails a warning signal to the planners and policy-makers either to reallocate the resources for improving the productivity or profitability or both or to adopt a new strategy like crop diversification.

Perennials/Vegetative Cover

The land use and land cover can be studied using the state of-the-art remote sensing technology (through satellite images) to assess the impact of various interventions made on these parameters. The change in green cover due to mounting of perennial systems like agroforestry, farm forestry, horticulture, pasture, biofuel plantations, etc., can be estimated using Normalized Difference Vegetation Index (NDVI) during pre- and post- project implementation period.

Livestock

Large and Small Ruminants

Livestock is an integral component of both conventional and integrated farming systems. Small ruminants like sheep or goats are the best source of regular cash income throughout the year for rural poor without significant investment. They form a major component in a tree-crop-livestock diversification/integration paradigm. Optimum use of the manure produced by small ruminants is an essential part of sustainability. The selection of appropriate livestock breed is important to improve the productivity of livestock, which is an important consideration in the development of an integrated farming system.

An integrated crop-dairy farming system is a viable and profitable proposition to farmers. Therefore, data on large ruminants like crossbred cows and graded buffaloes is essential. However, data on change in composition of livestock breed (pre and post-watershed) and outputs (milk, meat and wool) is essential for quantifying the impact of watershed on livelihoods of landed and landless people. Social fencing and stall-feeding are interlinked and the success of program lies in effective implementation of both.

Summary and Conclusion

Various Central Ministries (Ministry of Agriculture, Ministry of Rural Development and Ministry of Environment and Forestry), and departments/NGOs are implementing watershed programs for the development of rain-fed areas to convert them from grey to green. The objective of watershed program is conservation, augmentation and sustainable utilization of natural resources for enhancing productivity, profitability and economic viability of rain-fed agro-ecosystems. Over a period of time watershed programs have evolved from purely technical to community-owned. Baseline characterization is essential to strike a balance and evaluate tangible and intangible benefits.

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5. Knowledge-based Entry Point for Enhancing Community Participation in Integrated Watershed Management

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Abstract

Introducing watershed development program to the community has always been recognized as an important activity. This is done through what are called 'entry point activities' (EPA) in the parlance of watershed literature. It involves building the rapport with the community, strengthening and sustaining it through out the program and beyond. Knowledge-based EPAs are found more effective to build rapport with the community by ensuring tangible economic benefits for the community.

Keywords: Community participation, watersheds, entry point activity, knowledge sharing.

Introduction

In rain-fed areas to conserve soil and harvest rainwater community watershed management approach is adopted. Community's participation in program activities from planning, execution, and monitoring is critical for the success and sustainability of the interventions. However, mobilizing community participation is a challenging task and lack of community participation is identified as a major factor for less impact of watershed programs (Farrington et al. 1999, Kerr et al. 2000, Joshi et al. 2005 and Wani et al. 2003). Introducing watershed development program to the community has always been recognized as an important activity. This is done through what are called 'entry point activities' (EPA) in the parlance of watershed literature. It involves building the rapport with the community, strengthening and sustaining it through out the program and beyond.

To build a rapport between the project implementing agency (PIA) and the villagers before initiating the watershed programs, an EPA is envisaged. The entry point intervention/activity is identified through participatory rural appraisal (PRA). The

Common watershed guidelines released by the Government of India (GOI, 2008) mention a specific budgetary allocation of 4 percent which works out to Rs. 4 lakhs (US$ 8510) for 1000 ha micro-watershed to undertake the entry point activity.

An entry point activity, such as providing drinking water and sanitation to the community, conducting health awareness camps, construction of community halls, class rooms, repairing or construction of culverts, approach roads, promotion of kitchen gardens, etc., are carried out. Support to group income activities such as fish farming in village tanks and providing power threshers with the community contribution are some other rapport building measures that are practiced (Fernandes, 2000).

Over the years a lot of time and resources have been spent in trying out various types of EPA. Based on critical analysis of various watershed projects in India, it was observed that major reasons for low impacts of projects were the lack of equity, sustainability and participation by the stakeholders (Kerr et al. 2000, Wani et al. 2002, 2003 and Joshi et al. 2005). Further, low community participation was because of top down approach adopted in the projects and lack of tangible economic benefits due to project interventions for large number of small and marginal farmers. Adoption of top down target driven approach by the implementing agencies followed subsidy approach to enlist stakeholder involvement. Such involvement promoted contractual arrangement and stakeholders never took active interest, which sacrificed the sustainability (Wani et al. 2005). In an innovative farmer participatory consortium model for watershed management by ICRISAT-led consortium, one of the important components is no subsidy for interventions on private farmlands and need-based interventions as demanded by farmers instead of supply-driven interventions padded with free inputs (Wani et al. 2003). An important lesson learned during this time was that undertaking community level EPA such as drinking water schemes, building roads and community halls, identified as priorities during PRAs, do not provide enough incentive to motivate people to participate in the long term conservation activities that provide no immediate benefit (World Bank and FAO, 2001). On the contrary, such direct money-based (subsidy-based) EPA undertaken by the projects to build rapport, are misinterpreted by the community that project will invest financial resources for all the interventions and that the project has financial resources to work with the community. Following the principle of no free inputs for the individual farmers it was decided not to have money-based EPA in the watersheds to build the rapport with the community, in the Asian Development Bank (ADB) supported project started in 1999 for evaluating a new consortium approach (Wani et al. 2003).

Constraints

Earlier, watershed research and development work in the SAT emphasized on augmenting availability of water through constructing soil and water conservation structures within the watersheds. This structure-driven watershed development approach neither provided a positive impact on the productivity nor encouraged the farmers to participate in development and management of watersheds and maintain these structures when the implementing agency withdrew the support mainly because only a few resourceful farmers benefitted from the program (Wani et al. 2003).

Lack of community participation was one of the major factors affecting sustainability and impact of watershed interventions. Major constraints for community watershed are:

- lack of involvement of different stakeholders in watershed development;
- lack of tangible economic benefit to large number of small and marginal farmers;
- showed benefits favouring well to do farmers with well endowed resource base;
- top down approach to identify and execute watershed interventions.

Strategy and Approaches

Constraint Identification through Participatory Rural Appraisal (PRA)

For selection of micro watersheds consortium team members conducted a *gram sabha* (village meeting) and discussed current status of crop productivity, incomes, difficulties faced, possible reasons for low crop yields, current soil, water, crop and nutrient management options followed by the farmers.

During PRA, farmers described the declining status of their natural resources, such as soil, water and vegetation in the watershed. Declining groundwater table, water scarcity, decreased number of trees and need to apply more fertilizer year after year for maintaining crop yields were described by the farmers. Land degradation was described in terms of more run off, less soil moisture, low production capacity, low vegetation as well as continuing need to add increased amounts of plant nutrients to maintain crop yields. Farmers also described good status of NRs in terms of price of land, higher price of land having high production capacity and good groundwater availability (Joshi et al. 1997).During the PRA, rules for implementing project activities were discussed and agreed upon (Fig 1).

The principle of 'beneficiary pays the costs' for individual farm-based productivity enhancement activities was followed. Further, it was optional for the farmers to participate in the participatory evaluations. It was made clear that except knowledge nothing will be provided free.

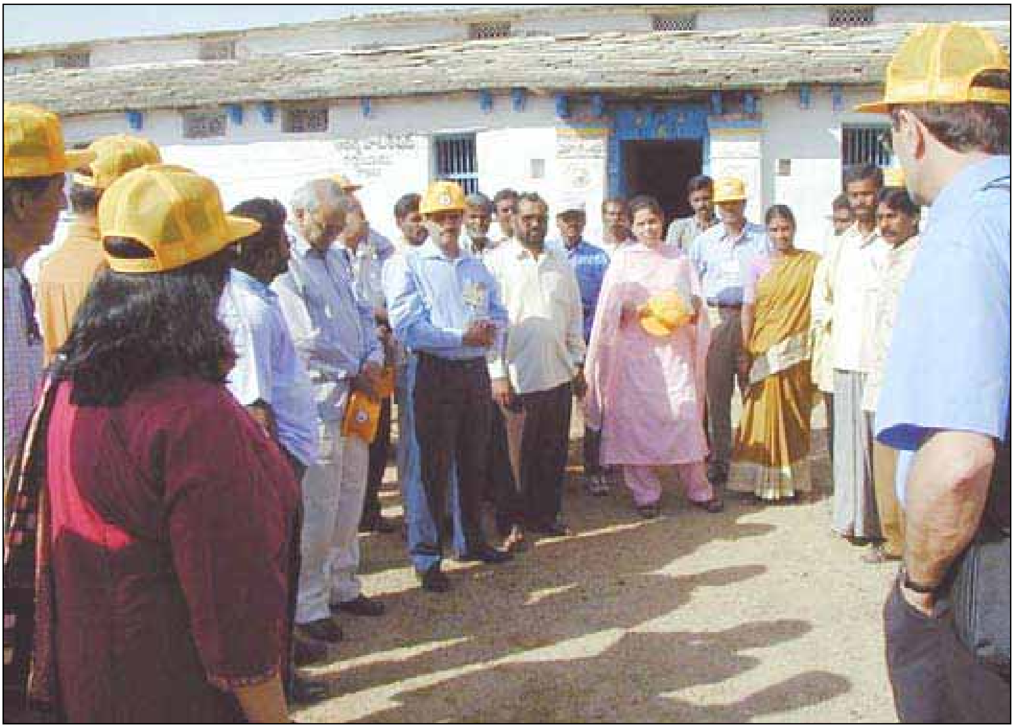

Figure 1. Meeting with farmers.

Identification of Appropriate Entry Point Activity (EPA)

Selection of the appropriate knowledge-based EPA for building rapport with the community is very critical. While selecting appropriate EPA, consider the following points.

- It should be knowledge-based and should not involve direct cash payment through the project in the village.
- Activity should have high success probability (>80-90%) and be based on strategic research results.
- It should involve participatory research and development (PR&D) approach.

- Community members to be involved in undertaking the activity.
- It should result in measurable tangible economic benefits for the farmers with a high Benefit: Cost (B:C) ratio
- It should be simple for farmers to undertake participatory evaluation
- Most importantly, it should be applicable for majority of the farmers
- Should have a reliable and cost-effective approach/method to assess the constraint.

Considering all the above-stated points and based on the PRA, wilt tolerant and high-yielding pigeonpea cultivar was introduced in Adarsha watershed, Kothapally, India. Poor soil health was identified as the EPA for the Andhra Pradesh Rural Livelihoods Program (APRLP) nucleus watersheds.

Representative Soil Sampling of a Micro-Watershed Involving Farmers

Once soil health was identified as knowledge-based EPA, representative, simple and cost-effective method had to be identified for sampling the micro-watershed of 500 - 1000 ha. For identifying representative sampling locations in a micro-watershed farmers meeting was conducted in a village. During discussions, farmers were asked to identify different fertility/soil quality locations which are uniform. Through discussions, it emerged that naturally soil quality varied on a toposequence with good quality soils at lower toposequence position. Another important factor causing variation in soil quality was differential amounts of inputs by individual farmers.

Both these points were factored in while deciding sampling procedure. The micro-watershed was divided on a map in three toposequences. Farm size was taken as a surrogate for socio-economic status of the farmer, which could affect quantity of inputs in the field. For each toposequence, number of farms as per farm size were identified and grouped in to small (< 2 ha), medium (>2 to <5 ha) and large (>5 ha) farm holders. Based on the proportion of small, medium and large farm holders on each toposequence location, stratified random sampling approach was adopted to identify five sampling locations on each toposequence location. Number of samples to be collected depended on proportion of small, medium and large farm holders. Once the numbers of samples for a particular category were decided, farmers were asked to identify the fields which should be sampled.

Farmers were trained in collecting representative soil samples from the selected fields. During discussions it was highlighted to all the farmers that these samples are representative for all the farmers from that category on a topo sequence and these results are not only for the field which is sampled. From each sampling location five samples up to 15 cm depth were collected and pooled together by mixing to form a single sample. Samples were divided into four quarters. Each quarter of soil sample was mixed well and one composite sample of one kg was prepared by collecting mixed soil sample from each quarter. Total number of soil samples collected was 15-20% farmers' fields in a watershed depending on its size.

Figure 2. Participatory farmers with the soil sampling.

Enhanced Awareness through Knowledge Sharing for EPA

Soil samples from all nucleus watersheds were analyzed for biological, physical and chemical parameters by following standard analytical procedures as described (Rego et al. 2005 and Wani et al. 2003).

The results were compiled and along with nutrient uptake data for one or two major cropping systems were used for explaining to the farmers. Simple approach of nutrient budgeting was followed, which included additions to and withdrawals from a farm. For each toposequence field samples charts were prepared highlighting soil nutrient content and used for explanation.

The critical limits for each nutrient along with the results of soil analyses were shared with the farmer groups concerned. The lead farmers selected to sample their fields explained the process of soil sampling to the farmers. In the meeting it was reiterated that the samples collected from randomly selected fields, were representative of the fields in that particular category (topo sequence position and farm holding). During *gram sabha* (village meeting) discussion on soil analysis EPA results, the lead farmers got hands on experience and responded to queries from their peers.

Researchers shared and discussed the soil analysis results with the farmers and during discussions planned PR&D trials for evaluating crop responses to deficient micro-nutrients with simple plus and minus approach along with the existing farmers practice as a control. Voluntary farmers were identified in the *gram sabha* to evaluate the responses in their fields. Necessary guidance, technical support and availability of inputs on payment basis were arranged by the project staff. For PR&D along with responses to deficient micro-nutrients some farmers also volunteered to evaluate improved cultivars of important crops based on yield potential, and available information about pests and disease resistance of the new cultivars.

Participatory Research & Development Trials

Based on the discussions in the gram sabha lead farmers started preparing for experimentation. The lead farmers were told to maintain records for all the operations, inputs as well as crop observations regularly. Farmers who needed help for recording observations took help of other farmers in the village or project staff or their school going children. Internalization of these experiments in *gram sabha* and subsequent discussions in the family served the purpose of creating awareness and interest in the work. The + and - (farmers' practice) trials with specific micronutrients or all deficient nutrients separately and in combinations were laid out depending on the farmers' choice. For each treatment plot size was minimum 1000 m^2. For statistical analysis of results individual farmers served as replications.

During early grain-filling stage, field days were conducted in villages wherein all villagers were invited. In a group farmers moved through all the PR&D trial fields. In each field lead farmers explained what they did from the beginning, what they observed and what they expect. Farmers visiting the fields also collectively evaluated different treatments, discussed different crop growth parameters and compared not only treatments but also provided good suggestions. Cross learning across the lead farmers was also quite effective.

At maturity researchers harvested 6 m^2 from three different spots in the plot for each treatment. Farmers also harvested crops treatment wise and threshed separately and recorded grain and straw yields.

Up-scaling Strategy from Nucleus to Satellite Watersheds.

ICRISAT-led consortium has adopted up-scaling strategy from nucleus to satellite watershed in the APRLP-ICRISAT project. For each nucleus watershed four satellite watersheds were selected during the second year. Farmers from the satellite watersheds were sensitized by using the knowledge-based EPA for which *gram sabha* was conducted in one of the selected satellite watershed villages. For *gram sabha* villagers from all the four satellite watersheds were invited as well as farmers from the nucleus watersheds. Lead farmers were trained to serve as trainers for satellite watersheds and all the necessary information and material were provided. Project staff did hand holding for the lead farmers to serve as trainers. Four to five lead farmers from the nucleus watershed narrated their experiences from the beginning ie, *gram sabha* in their village till the time they are standing as trainers. The complete progress of PR&D starting with problem diagnosis, designing of trials, evaluation of trial results and learning/results and further improvement in planning such trials were discussed by the lead farmers.

Results and Discussions

Improved crop cultivar as an entry point in Adarsha watershed, Kothapally, during the village meetings, farmers while describing the reasons for low crop productivity, indicated that during flowering large number of pigeonpea plants died due to drying and wilting (Fig. 3) Diagnosis of the problem suggested that the pigeonpea cultivars used by the farmers were susceptible to wilt disease. Following the diagnosis of the problem, the introduction of improved, wilt- tolerant pigeonpea cultivars was identified as an appropriate candidate for EPA (Fig. 4). The pigeonpea yields harvested by farmers from the intercropping system were around 200 kg per ha^{-1}. Following discussion with the villagers, the local pigeonpea variety was replaced by wilt-tolerant cultivar, Asha (ICPL-87119). The seeds of improved cultivars ICPL-

Figure 3. Wilted pigeonpea plants.

Figure 4. Good pigeonpea crop.

87119 were made available to the farmers on cost basis or on the condition that after harvest, they will return the seed at the ratio of 1:1.25. During the first season in 1999, farmers harvested 600 kg ha^{-1} of pigeonpea, which were 3-4 folds higher than the yield harvested by growing local cultivar (Table 1). Pigeonpea being a legume and high-value crop, net benefit for the farmers was almost Rs. 6000 ha^{-1} (US$ 146) which acted as a trigger for the community to participate actively in the program. During the subsequent years also, pigeonpea yields improved further with improved nutrient and water management practices during both low and high rainfall years. This knowledge-based EPA proved the power of suitable EPA for building the rapport with the community.

Table 1. Improved crop variety as an EPA-grain yield improved and traditional cultivar of pigeonpea in Adarsha watershed, Kothapally.

Crop	1998 baseline yield	Yield (Kg ha^{-1})									
		1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	Average yields	SE +
Improved Intercropped pigeonpea	190	640	940	800	720	949	680	925	970	861	120.3
Traditional Intercropped pigeonpea	-	200	180	-	-	-	-	-	-	190	-

Soil Sampling, Analysis of Results and Discussions in a Village Meeting.

It was observed during the PRA discussions in all the APRLP nucleus watersheds that farmers were aware of degradation of land. They expressed in simple terms such as need to add increased quantities of fertilizers for maintaining crop yields over the years. Land unit price was used as a composite surrogate indicator for land and water quality/availability in the villages (Joshi et al. 1997). Secondly farmers easily understood the nutrient budget concept and expressed lack of information about their soil quality. Listening to the responses from the farmers, it was clear that traditional extension service model was not working. By adopting PR&D approach in all the nucleus watersheds farmers appeared enthusiastic and willingly came forward to participate in the soil sampling of their fields. Good number of farmers were involved in collecting soil samples along with the NGO/PIA supervision. Farmers collected representative soil samples on a toposequence and sub-sampled, and properly marked soil samples were handed over to the project staff (Rego et al. 2007).

The results showed that in all the nucleus watersheds 81 to 99% soil samples were found deficient in zinc, boron and sulphur, in addition to 100% deficiency in total nitrogen content. These results showed that carefully conducted PRA along with local practices knowledge could help diagnose constraint for identifying knowledge and constraint-based EPA (Fig.5).

Figure 5. Village meeting to share the knowledge and identifiy constraints.

In nucleus watersheds farmers were very happy to learn about their soil health as well as the remedies to address the constraints. In the first year (2002) 15 volunteer farmers from each nucleus watershed were identified for conducting on-farm participatory trials using crop of their choice. In 2002, there were two treatments, ie, control (farmer's nutrient input practice) and application of micronutrients (30 kg S ha^{-1} 0.5 kg B ha^{-1} and 10 kg Zn ha^{-1}) in addition to farmers' nutrient inputs. In all 150 trials in three districts using different crops like mungbean (9), maize (22), groundnut (19), pigeonpea (43) and castor (8) were conducted. Due to drought few trials were abandoned. Impressive responses of grain yield to applied B+Zn+S in all crops (maize 65%, groundnut 33%, mungbean 43%, pigeonpea 63% and castor 50%) (Table 2) were recorded.

Farmers not only harvested increased grain yields but benefited economically (Fig. 6) by additionally investing Rs. 1750/- (US$ 39) per ha for these nutrients.

These results clearly demonstrated that appropriate EPA could ensure tangible economic benefit to individual farmers. As indicated earlier identification of major constraint limiting crop production and its alleviation ensured tangible economic benefits to individuals triggering their interest to participate in project activities (Olson, 1971 and Wani et al. 2003, Sreedevi et al. 2004). These lead farmers not only

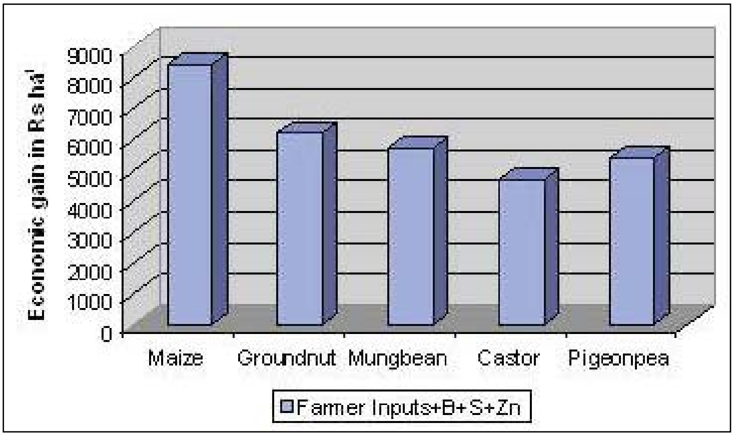

Figure 6. Economic gains due to micronutrient application to various crops in the APRLP watersheds in three districts in Andhra Pradesh, India ,during 2002 rainy season.

continued application of micronutrients and participated actively in community watershed program but also spent their time as resource farmers/trainers for satellite watersheds.

Table 2. Crop response to micronutrients in watersheds in Andhra Pradesh, India, 2002/03

		Grain yield (t ha^{-1})		
Watershed	Crop	Control	Treated	Yield increase over control (%)
Mahabubnagar				
Sripuram	Maize	2.38	4.37	84
	Pigeonpea1	0.24	0.42	75
Malleboinpally	Maize	2.98	4.57	53
Mentepally	Maize	1.20	1.74	45
Nalgonda				
Tirumalapuram	Castor	0.43	0.64	49
	Pigeonpea1	0.41	0.46	12
Nemikal	Mungbean	0.84	1.10	31
	Pigeonpea1	0.35	0.66	89
Kurnool				
Karivemula	Groundnut	1.44	1.96	36
	Pigeonpea1	0.13	0.33	154
Devanakonda	Groundnut	0.94	1.24	32
	Pigeonpea1	0.23	0.50	117
Nandavaram	Castor	0.86	1.29	50
	Pigeonpea1	1.63	2.64	62

1. Represents intercrop

Lead Farmers as Trainers for Up-scaling Strategy

During 2003, in all watersheds (10 nucleus + 40 satellite) operationalized for up-scaling strategy where principle of internal learning was introduced within the PIA as each PIA implemented at least 10 other micro watersheds as well as nucleus watersheds as sites of learning.

The nucleus PIA and lead farmers served as trainers for PIAs and farmers from the satellite watersheds. Lead farmers were equipped with all the details for explanation such as soil analysis data, total yield, nutrient uptake data and economic returns.

In 2003, farmers preferred to evaluate responses to individual micronutrients particularly in nucleus watersheds. Three volunteer farmers in each watershed evaluated B, Zn and S individually and B+Zn+S with and without optimum N and P. For simplicity these treatments were over and above farmers' nutrient inputs. With increased number of treatments plot size was reduced for each treatment to accommodate within 2000 m2. Combined application of micronutrients at optimum N+P resulted in the highest response and the additive response to each deficient element, was observed. Inadequate supply of N & P at farmer's input level, full potential of B, Zn and S could not be harnessed. Increased crop yield at farmers' input level for different crops varied from 37 to 88% and with optimum N and P levels response varied from 55 to 122% for different crops (Table 4).

Table 4. Crop response to micronutrients in watersheds in Andhra Pradesh, India, 2003/04.

District	Crop	No. of farmers	Grain yield1 ($t\ ha^{-1}$)				
			Control	Control+ MN		Control + MN + NP	
Mahabubnagar	Maize	14	3.34	4.58	(37)	5.17	(55)
	Sorghum	6	0.90	1.46	(62)	1.97	(119)
	Castor	8	0.94	1.38	(48)	1.65	(77)
	Pigeonpea	3	0.86	1.48	(71)	1.88	(118)
Nalgonda	Maize	10	2.01	3.60	(80)	4.46	(122)
	Mungbean	6	0.91	1.39	(54)	1.54	(70)
	Castor	9	0.48	0.76	(59)	0.78	(64)
	Groundnut (pod)	7	0.62	0.93	(49)	1.14	(84)
	Pigeonpea	5	0.65	1.21	(88)	1.22	(90)
Kurnool	Groundnut (pod)	23	0.90	1.32	(47)	1.59	(77)
	pigeonpea	4	0.70	1.06	(50)	1.20	(70)

1. MN = micronutrients; NP = optimum nitrogen and phosphorus.

Figures in parentheses indicate percentage increase over control.

Source: Rego et al. 2005.

During the cropping season, the cycle of field days and data collection was repeated. During field days media reporters also participated and helped in dissemination of results to large number of stakeholders. Based on the successful evaluation of up-scaling strategy of one nucleus and four satellite watersheds this approach was used in other community watershed projects in Thailand, Vietnam, China and India supported by the ADB and in different states of India supported by Sir Dorabji Tata Trust in Madhya Pradesh and Rajasthan and World Bank supported Sujala watershed program in Karnataka. Some of the other knowledge-based EPA we have tested in programs are improved stress-tolerant cultivars, village seed banks. However, while selecting EPA main criteria the benefit large number of individuals in a given watershed must be followed.

Recommendation for Practitioners

- Invest good time and resources to conduct initial PRA by a qualified expert along with a multidisciplinary team of scientists.
- Carefully identify most suitable EPA considering the criteria mentioned earlier.
- Ensure active participation of as many farmers through facilitation and engagement.
- Use simple and jargon-free language to communicate with farmers .
- Identify local examples to get realistically farmers engaged in PRA.
- Build and describe scenarios using example of EPA and show potential and realistic benefits.
- Clearly highlight Do's and Don'ts for the EPA.

Conclusion

- For building rapport with the community, good PRA and knowledge about local natural resources can be used to identify knowledge-based EPA.
- Knowledge-based EPA was found far superior than traditional subsidy or cash-based EPA for enabling community participation of higher order ie, cooperative and collegiate rather than contractual mode.
- Lead farmers and PIAs served as good trainers and contributed significantly in up-scaling strategy.
- Field days during the season where lead farmers explained the results to their peers, media personnel and policy makers proved very effective tool for up-scaling community watersheds in the SAT and benefited large number of families.
- This new approach of extension based on enhanced awareness of primary stakeholders by sharing knowledge proved more effective than cash-based EPA.

- There is much need to innovate new methods to share knowledge with primary stakeholders as traditional methods of extension are failing miserably in most of the developing countries in Asia and Africa.

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6. Participatory Net Planning in Watershed Management

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Abstract

WOTR in developing the capacity building tools in the Indo-German Watershed Development Program (IGWDP), Maharashtra, introduced the Participatory Net Planning method in 1995. Today the experience stretches across over 200 micro-watershed projects in Maharashtra. This paper details how PNP serves as tool, designed not just to collect data for the purpose of sanction, but more importantly, to serve as a guide for effective and smooth implementation of planned measures, and to obtain a demand based cost for project measures.

Keywords: Capacity building, watershed development, user groups, common property resource.

Introduction

History has taught us that unless people are actively involved and own the project, any intervention will not sustain, no matter the cost or time invested. Hence, obtaining people's active participation at all stages (from acceptance of the project, through the planning, implementation, monitoring, evaluation and its ongoing maintenance) and their ownership of the project, will give the expected outcomes. This challenge is especially so while implementing a land-based intervention such as watershed development, where the treatment on each piece of land contributes towards obtaining the result/outcome of the whole.

WOTR in its experience of developing the capacity building tools in the Indo-German Watershed Development Program (IGWDP), Maharashtra, through trial and error, introduced the Participatory Net Planning method way back in 1995. Today the experience stretches across over 200 micro-watershed projects in Maharashtra.

Participatory Net Planning – Concept

PNP is a tool, designed not merely to collect data for the purpose of sanction, but more importantly, to serve as a guide for effective and smooth implementation of planned measures, and to obtain a demand based cost for project measures. It is meant to ensure active inclusion of the farmer household (all adult men and women) in the planning and the treatment of their land–the micro-unit–both spatial and social, of watershed development. The respective plot is studied in detail and discussed with the members of the owner household. Then relevant soil and water conservation treatments and land use are proposed. Costs are calculated based on the actual agreed upon requirements. Once consensus has been obtained regarding the proposed measures, confrontation usually does not arise during the implementation. PNP thus fosters ownership and hence the sustainability of the treatments undertaken. It fosters mutual learning, incorporation of indigenous technologies and the suggestions of the farmer household. It is effective for the smooth implementation of the planned measures.

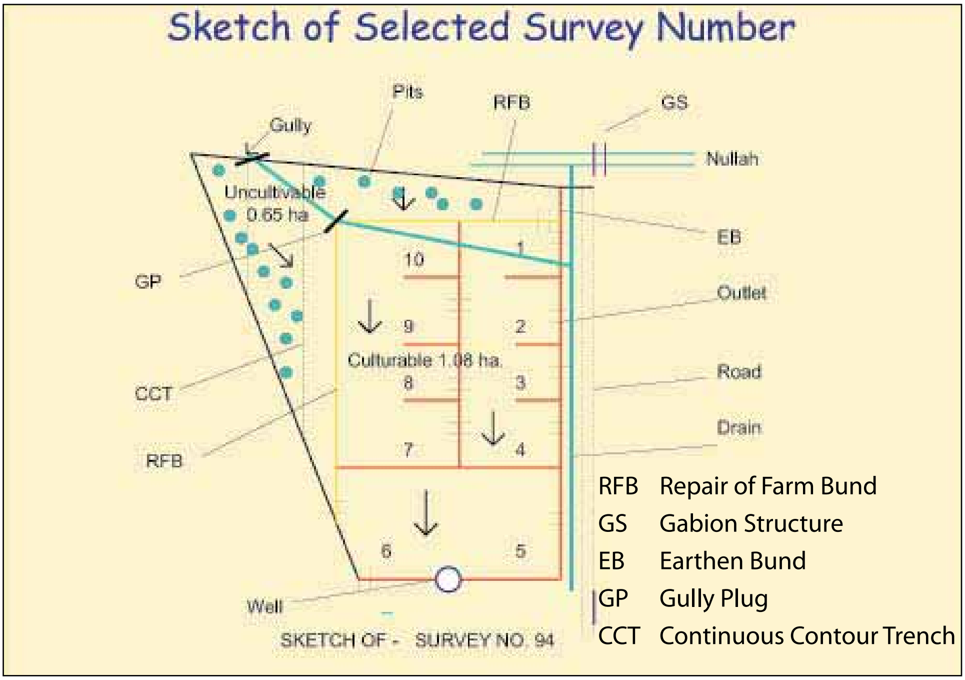
The twin objectives of the PNP are to:

i. promote ownership and hence the sustainability of the work. This is achieved by involving the farmer household (all adult men and women of the household) in the decision making process. The views of the owners are obtained, regarding land use and treatments proposed. They are engaged in a dialogue wherein various issues and interventions pertaining to land husbandry and the potential are discussed, defined, and agreed upon;
ii. site specific/tailor made plans for the specific field situations. Plans are made and treatments are proposed for the actual requirement of the area. Hence appropriate treatments are provided for and more-or-less, the expected results are achieved. Besides, for follow-up, site specific plans not only reduce the differences between planned treatments and those subsequently implemented, but also facilitate a more realistic allocation of finances.

The PNP process:

1. the team that undertakes the PNP consists of a technical person experienced in the field of watershed development and a minimum of 2-3 members of the Village watershed committee (VWC). This team guides and motivates the farmer for the land treatments proposed;
2. the farmer household (men and women) whose land is to be surveyed and planned for is present on site & are put at ease by including them actively in the discussions on their land;
3. the slope of the land is then measured, soil depth taken using an auger, soil texture and erosion status of the field is observed. Depending on these the land is then classified and the most suitable land use and treatments are proposed to the owners whose point of view is also considered. If the reasons are genuine, then the next best options are sought while taking note of their opinions and preferences;

4. during this process the team helps the farmer household visualize how the treatments would help solve the existing problems on their land, the transformation that will take place once treatments are implemented and the benefits that can be obtained. This visualization is effective when the household is present on site;
5. once a consensus has been arrived at regarding the proposed treatments and land use, all the information is noted in the net planning format;
6. at the end of the exercise, the head of the farmer household is given a sheet of paper that contains the diagram of his land, on which details (present and proposed) are indicated. Together with the owners an agreement is signed which formalizes the consent of both husband and wife to undertake and maintain the proposed treatments.



User Group Planning/PNP for Common Property Resources

While PNP is done on the individual farmers' lands, a similar exercise is also advocated for the common property resources. Here the groups who are the nearest to, or who most commonly avail of the produce of these resources should be involved in the exercise, besides the members of the watershed committee, the *gram panchayat* and the joint forest management committee. PNP for common property resources is an opportunity for the village to consider the poor landless, small and marginal land-holders and shepherd communities who are often dependent on these. These groups are usually left out of the process and discussions, while at the same time they are very important stakeholders. The sustainability of the CPR depends of them. The PNP can thus be an exercise for addressing equity issues within the watershed community.

Conclusion

To date, WOTR and NABARD together with our partner NGOs in the IGWDP have extensively used the PNP across 200 watershed projects in Maharashtra, covering approximately 230,000 hectares and involving approximately 200,000 households. Our experiences encourage us, as positive outcomes are observed in the field. We in WOTR have realized that the demystification of technology and putting it in the hands of even illiterate farmers will give tangible outcomes as in improved land productivity and increased economic returns. A sure reason for sustainability!

Reference

WOTR. 2004. Planning for Watershed Development.

Annexure 1

FORMAT 1: NET PLANNING FORMAT

Name of the Watershed:

GAT (SURVEY) No.: Names of Owners:

Village

AREA : ha.

a) Irrigated: ha

b) Rain-fed: ha.

c) Wasteland: ha.

d) Forest: ha.

1. Present Land Use

A. Cultivable Land

Season	Irri/Rainfed	Crop	Area (ha)	Production	
				Grain (Q)	Fodder (ton)
Monsoon					
Winter					
Summer					

B. Waste Lands (ha.)

Open________Rocky______________Pasture____________Thorny Bushes________

C. Forest Lands (ha.)

Thin____________________Thick____________________Open____________________

D. Information Regarding Land Capability Classification

Land Character	Irrigated Area	Rain-fed Area	Waste Land	Forest Land
Area (ha)				
Slope (%)				
Soil Depth (cm)				
Soil Texture				
Erosion Status				
Land Class				

2. PROPOSED LAND TREATMENT ACCORDING TO LAND USE

A. Waste Land

i. Afforestation____

ii. Pasture Development____

iii. Agro Forestry ____

iv. HortiPasture ____

v. ____

vi. ____

Sr.No.	Treatment	Area (ha)/ No.	Length (m)	Cross Section (sq.m)	No of Plants	Plant Species
1.						
2.						
3.						
4.						
5.						

B. Cultivable Land

Single Rain-fed Crop (C1R)_____________Double Rain-fed Crops (C2R)___________
Irrigated Crop (C1I, C2I, C3I) ____

Type of Bund	Area (ha)	Bund Number	Measurements of bunds					
			Length (m)	Existing C/Section (sq.m)	Proposed C/Section (sq.m)	Total Earthwork (cum)	No. of Spillway	Plants

C. Drainage Line

Treatments	Number	Length (m)	Width (m)	Average Height (m)

3. MAP OF GAT (SURVEY) NUMBER

Signature of Farmers (Land Owners)   Signature of Technical Expert

Signature of Site Supervisor   Signature of Community Organizer

7. Best-bet Options on Soil and Water Conservation

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Abstract

The soil and water conservation is one of the most important components of integrated watershed program. Earlier in soil and water conservation programs, efforts were concentrated on construction of various types of bunds across the slope. This helped in controlling erosion and reducing soil loss rather than increasing crop yields through additional moisture conservation. Current emphasis is more on improving moisture through various field- and community-based moisture conservation practices. This paper discusses the key findings from the various watershed programs and research stations on field- and community-based soil and water conservation interventions that were found promising for improving productivity and reducing land degradation in different regions of India.

Keywords: Soil conservation, rainwater, runoff, watershed, *in-situ.*

Introduction

Soil and water are vital natural resources for human survival. Growing world population and increasing standard of living are placing tremendous pressure on these resources. Because the soil and water resources are finite, their optimal management without adverse environmental consequences is necessary, if human survival is to be assured and development is to be sustained. There is growing realization throughout the world that no longer can we afford to misuse these resources. Furthermore, these resources have to be managed using an integrated approach. Fundamental to this approach is the invocation of the watershed-based management.

In India, the problem of soil and water resource degradation has been in existence in the past, however, the pace of degradation has greatly increased in recent times due to burgeoning population and the enhanced means of exploitation of natural resources. An insight into the various regions show a grim picture of water scarcity, fragile ecosystems, drought and land degradation due to soil erosion by wind and water, low rainwater-use efficiency, high population pressure, poverty, low investments in water use efficiency measures and inappropriate policies.

Soil and Water Conservation Problems in Various Rainfall Regions of India

Based on experiences from the various watershed programs and research station works in India, the soil and water conservation practices for the different agroclimatic zones of India were identified and are given in table 1. It clearly shows that for different regions the problems of soil and water conservations are quite different. This information is useful in determining the appropriate soil and water conservation practices for various regions. This classification and related information also assists in utilizing the research and field experience of one place to other places of identical soil, climatic and topographic conditions.

Table 1. Soil and water conservation problems in various soil conservation regions of India.

Sl.No	Soil conservation region	Rainfall (mm)	Important areas	Problems
1	North Himalayan (excluding cold desert areas)	500-2000	Mountains, temperate, arid, semiarid and sub humid areas of J&K, hill areas and Himachal Pradesh	Soil erosion along hill slopes, land slides, torrent, management of ravine lands, siltation of reservoirs, over grazing and deforestation
2	North eastern Himalayan	1500-2500	North eastern hills of Sikkim, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Assam, Nagaland, Tripura and West Bengal	Shifting cultivation, land slides, torrents and gullies problems of riverine lands, siltation of reservoirs and stream beds
3	Indo-Gangetic Alluvium soils	700-1000	Punjab, Haryana, north eastern Rajasthan, UP and Bihar plains Chambal command in Rajasthan, command area in Gujarat	Sheet erosion, ravine lands, floods, stream bank erosion, saline, alkaline lands, water-logging, prolonged dry spells and failure of rains
4	Assam Valley and Gangetic delta	1500-2500	Plains of Assam, Tripura, North Bengal and Gangetic delta, areas of West Bengal	Gully erosion, stream bank erosion, waterlogging, coastal salinity

Contd...

Contd...

Sl.No	Soil conservation region	Rainfall (mm)	Important areas	Problems
5	Desertic area	150-500	Western central Rajasthan, contiguous areas of Haryana and Gujarat, Runn of Kutch	Shifting sand dunes, wind erosion, extreme moisture stress and drought, over grazing, improper land management
6	Mixed red, black and yellow soils	600-700	District of Pali, Bhilwara, Ajmer, Chittorgarh, Udaipur, Rajasamand, Jhalawar in Rajasthan and southern UP (including Bundelkhand area) and northern MP	Ravine, shortage of moisture, recurring drought, problem of drainage, overgrazing, siltation of reservoirs and tanks
7	Black soils	500-700	South eastern Rajasthan, part of Madhya Pradesh, tracts of Maharashtra, Andhra Pradesh, Karnataka and small parts of Tamil Nadu	Sheet erosion, acute water shortage, recurring droughts, ill drained soils, siltation of reservoirs, lack of groundwater recharge
8	Black soils (deep and medium deep)	800-1300	Parts of Madhya Pradesh, Andhra Pradesh and Maharashtra	High soil erosion, gully formation, waterlogging, poor workability of soil, shortage of water during post-rainy season
9	Eastern red soils	1000-1500	Bulk of West Bengal, Bihar, Orissa and Eastern Madhya Pradesh including Chotanagapur and Chattisgarh area, part of Andhra Pradesh	Problems of sheet erosion, gullies, acute water shortage, recurring drought, heavy grazing and improper land management, siltation of reservoir and tanks
10	Southern red soils	Around 750 in Kerala upto 2500	Bulk of Kerala, Tamil Nadu hills and plains, Karnataka, Andhra Pradesh and part of Maharashtra	Sheet erosion, gullies, acute water shortage, recurring drought, siltation of reservoir and tanks, lack of groundwater recharge
11	East-west coasts	East coast about 1000 and rest heavy rainfall	East and West coast from Orissa to Saurashtra	Problems of coastal salinity, soil erosion, coastal sand dunes, wind erosion and flooding of cultivated lands by the sea water or rainwater

(Source: Modified table from Raj Vir Singh, 2000).

Field-based Soil and Water Conservation

Field based soil and water conservation measures are essential for *in-situ* conservation of soil and water. The main aim of these practices is to reduce or prevent either water erosion or wind erosion, while achieving the desired moisture for sustainable production. The suitability of any *in-situ* soil and water management practices depend greatly upon soil, topography, climate, cropping system and farmers' resources. Based on past experiences several field-based soil and water conservation measures have been found promising for the various rainfall zones in India (Table 2).

Table 2. Prioritized field based soil and water conservation measures for various rainfall zones in India.

Seasonal rainfall (mm)			
<500	500-700	750-1000	>1000
• Contour cultivation with conservation furrows • Ridging sowing across slopes • Mulching • Scoops • Tied ridges • Off-season tillage • Inter row water harvesting system • Small basins • Contour bunds • Field bunds • Khadin	• Contour cultivation with conservation furrows • Ridging • Sowing across slopes • Scoops • Tide ridges • Mulching • Zingg terrace • Off-season tillage • BBF • Inter row water harvesting system • Small basins • Modified contour bunds • Field bunds • Khadin	• BBF (Vertisols) • Conservation furrows • Sowing across slopes • Tillage • Lock and spill drains • Small basins • Field bunds • Vegetative bunds • Graded bunds • Nadi • Zingg terrace	• BBF (Vertisols) • Field bunds • Vegetative bunds • Graded bunds • Chos • Level terraces

Some of the most promising practices found from the various watershed programs are discussed in detail.

Broad-bed and Furrow System

On black soils the problem of water logging and water scarcity occurring during the same cropping season are quite common. There is a need for an *in-situ* soil and water conservation and proper drainage technology on deep black soils that can protect the soil from erosion through out the season and provide control at the place where the rain falls. A raised land configuration "Broad-bed and furrow" (BBF) system has been found to satisfactorily attain these goals (Fig. 1).

BBF formation with tropicultor.

Groundnut crop on BBF.

Figure 1. Broad-bed and furrow system at ICRISAT center Patancheru, Andhra Pradesh.

***Recommended agro-ecology**:* Soil : medium to deep black soils (*Vertisols*)
Rainfall : 700 – 1300 mm
Slope : maximum upto 5%

Description: 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 (Fig.2). The BBF system is laid out on a grade of 0.4 – 0.8 % for optimum performance. It is important to attain a uniform shape without sudden and sharp edges because of the need in many crops and cropping systems to plant rows on the shoulder of the broad-bed. This BBF system is most effectively implemented in several operations or passes. After the direction of cultivation has been set out, based on the topographic survey (Fig.2), furrow making is done by an implement attached with two ridgers with a chain tied to ridgers or a multipurpose tool carrier called "Tropicultor" to which two ridgers are attached, and used for this operation (Fig 1). It is important to have the ridgers operate at shallow depth to attain straight lines; sharp curves must be avoided. A bed former is used to further shape up the broad-beds. If opportunity arises (after showers) before the beginning of the rainy season, another cultivation is done to control weeds and improve the shape of the BBF. Thus, at the beginning of the growing season this seedbed is receptive to rainfall and, importantly, moisture from early rains is stored in the surface layers without disappearing in deep cracks in black soils. The BBF formed during the first year can be maintained for the long term (25-30 years). This will save considerable cost as well as improve the soil health (Kampen, 1982).

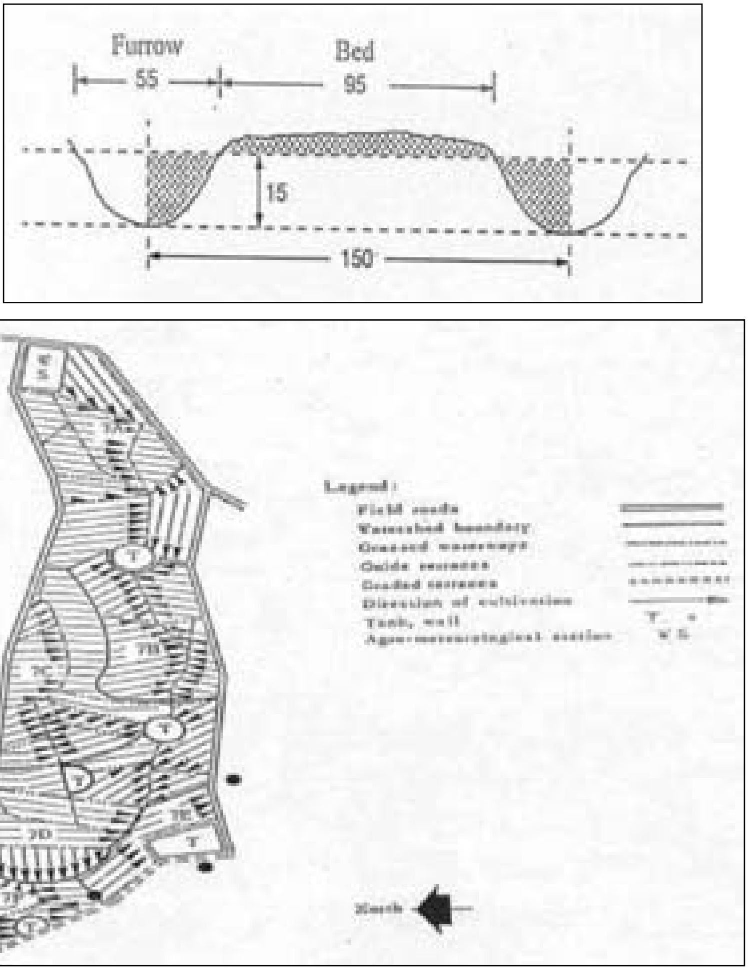

Figure 2. Broad-bed and furrow system dimension (in centimeters) and field layout based on topographic map.

Benefits:

- The raised bed portion acts as an *in-situ* 'bund' to conserve more moisture and ensures soil stability; the shallow furrows provides good surface drainage to promote aeration in the seedbed and root zone; prevents water logging of crops on the bed.
- The BBF design is quite flexible for accommodating crops and cropping systems with widely differing row spacing requirements.
- Precision operations such as seed and fertilizer placement and mechanical weeding are facilitated by the defined traffic zone (furrows), which saves energy, time, cost of operation and inputs.

- Can be maintained on the long term (25-30 years).
- Reduces runoff and soil loss and improves soil properties over the years.
- Facilitates double cropping and increases crop yields.
- Can be adopted for groundnut crop in red soils with a reduced gradient along the bed (0.2–0.4%).

Conservation Furrow System

The conservation furrow is a simple and low cost *in-situ* soil and water conservation practice for rain-fed areas with moderate slope.

Recommended agro-ecology: Soil : Alfisols and associated soils
Rainfall: 400 – 900 mm
Slope : 1 - 4%

Description: This practice is highly suitable for soils with severe problems of crusting, sealing and hard setting. Due to these problems the early runoff is quite common on these soils. In this system series of furrows are opened on contour or across the slope at 3-5 m apart (Fig.3). The spacing between the furrows and its size can be

Groundnut crop with conservation furrow.

Formation of conservation furrows using local implements.

Figure 3. Conservation furrow system at Hedigonda watershed, Haveri, Karnataka.

chosen based on the rainfall, soils, crops and topography. The furrows can be made either during planting time or during interculture operation using country plough. Two to three passes in the same furrow may be needed to obtain the required furrow size. 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% and it costs around Rs 250-350 ha^{-1}. To improve its further effectiveness it is recommended to use this system along with contour cultivation or cultivation across the slope (Ram Mohan Rao et al. 1981).

Benefits:

- Furrows harvest the local runoff and increase the soil moisture for adjoining crop rows.
- Reduced runoff and soil loss.
- Simple and low cost system.
- Easy to adopt and can be implemented using traditional farm implements.
- Increased crop yields (10-25%).

Modified Contour Bunds

Well-designed and maintained conventional contour bunds on Alfisols and other light soils undoubtedly conserve soil and for this purpose contour bunds are perhaps efficient. However, the associated disadvantages – mainly water stagnation (particularly during the rainy season) (Fig. 4) causing reduction in crop yields – outweigh any advantage from the viewpoint of soil conservation. The modified contour bunds with gated-outlets have shown good promise because of the better control on ponded runoff water (Fig. 5).

Recommended agro-ecology: Soil : Alfisols and associated soils
Rainfall: 500 – 900 mm
Slope : 1 - 8%

Description: Modified contour bunding involves constructing embankments on contours with gated-outlet at the lower end of the field (Fig. 5). This gated-outlet allows the runoff to be stored in the field for a desired period, and then released at a predetermined rate through the spillway, thus reducing the time of water stagnation behind the bund, which will have no adverse effect on crop growth and yield and also facilitates the water infiltration into soil to its optimum capacity (Pathak et al. 1989).

Figure 4. Conventional contour bund system.

Figure 5. Gated-outlet contour bund with water stagnation (gated-outlets are shown in inset).

Benefits:

- The problem of prolonged water stagnation around the contour bund is reduced in the gated outlet contour bund system. This results in the better crop growth and higher crop yield.
- The chances of bund breaching are less in this system, while in conventional contour bunds the occasional breaching of bunds is common mainly because of prolonged water ponding.
- Low peak runoff rate compared to conventional contour bunds.
- More timely tillage and other cultural operations are possible in the gated-outlet contour bund system because of better control on ponded runoff water.
- Gated-outlet contour bund system involves low cost for modification and is simple to adopt.

Contour Cultivation or Cultivation Across Slope

The common method of cultivation on sloping lands is up and down the slope. This is one of the causes of poor rainfall infiltration and accelerated soil erosion. Contour cultivation or cultivation across the slope are simple methods of cultivations, which can effectively reduce the runoff and soil loss on gentle sloping lands.

Recommended agro-ecology: Soil : All most all soil types
Rainfall: Upto 1000 mm
Slope : 1.5 – 4.0%

Description: In contour cultivation all the field operations such as ploughing, planting and intercultivation are performed on the contour (Fig. 6). It helps in reduction of runoff by impounding water in small depressions and reduces the developments 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. In order to establish row directions adjusted contours are laid out at one or more elevations in the field. In some situations it is desirable to provide a small slope along the row (cultivation a cross the slope), to prevent runoff from a large storm breaking over the small ridges formed during the contour cultivations. 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 grades 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 (Ram Mohan Rao et al. 1981).

Figure 6. Contour cultivation at Kurnool watershed in Andhra Pradesh.

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 down stream row. Moreover, break over causes cumulative damage as the volume of runoff water increases with each succeeding down stream row.

Benefits:

- Reduces runoff and soil losses.
- Increase in crop yields.
- Simple, low cost and technically feasible even for small farmers.

Vegetative Barriers

Vegetative barriers or vegetative hedges or live bunds are effective in reducing soil erosion and conserving moisture. In several situations the vegetative barriers are more effective and economical than the mechanical measures viz. bunding.

Recommended agro-ecology:

Soil :	Alfisols, Vertisols, Vertic-Inceptisols and associated soils
Rainfall:	400-2500 mm
Slope :	More than 2.5%

Description: Vegetative barriers can be established either on contour or on moderate slope of 0.4 to 0.8%. In this system, the vegetative hedges act as barriers to runoff flow, which slow down the runoff velocity resulting in the deposition of eroded sediments and increased rainwater infiltration. It is advisable to establish the vegetative hedges on small bund. This increases its effectiveness particularly during the first few years when the vegetative hedges are not so well established. The key aspect of design of vegetative hedge is the horizontal distance between the hedge rows which mainly depends on rainfall, soil type and land slope. Species of vegetative barrier to be grown, number of hedge rows, plant to plant spacing and method of planting are very important and should be decided based on the main purpose of the vegetative barrier. If the main purpose of the vegetative barrier is to act as a filter to trap the eroded sediments and reduce the velocity of runoff then the grass species such as vetiver, sewan (*Lasiurus sindicus*), sania (*Crotolaria burhia*) and kair (*Capparis aphylla*) could be used. But if the purpose of vegetative hedges is to stabilize the bund then plants such as *Glyricidia* or others could be effectively used (Fig. 7). The *Glyricidia* plants grown on bunds not only strengthen the bunds while preventing soil erosion, but also provide N-rich green biomass, fodder and fuel. The cross section of earthen bund can also be reduced. Study conducted at

Figure 7. Glyricidia plants on bunds and over view of a watershed with Glyricidia on graded bunds, ICRISAT center, patancheru, Andhra Pradesh.

ICRISAT research center indicated that by adding the N-rich green biomass from the *Glyricidia* plants planted on bund at a spacing of 0.5 m apart for a length of 700 m could provide about 30-45 kg N ha^{-1} yr^{-1} (Wani and Kumar, 2002).

In areas with long dry periods, vegetative hedges may have difficulties in surviving. In very low rainfall areas, the establishment and in high rainfall area, the maintenance could be the main problem. Proper care is required to control pests, rodents and diseases for optimum growth and survival of both vegetative hedges and main crops.

Benefits:

- Once properly established the system is self sustaining and almost maintenance free.
- Land under the hedge is used for multipurpose viz. N-rich biomass, fodder and fuel.
- Can be successfully used under wide range of rainfall (400-2500 mm) and topography.
- Economical and often more effective than other erosion control measures.

Community-based Water Harvesting and Soil Conservation Structures

Currently in most of the watershed programs in India, the community-based soil and water conservation are playing the key role in improving surface and groundwater availability and controlling soil erosion. Large percentage of total watershed fund is currently used in implementing these measures. Studies conducted by ICRISAT have shown that the cost of water harvesting and groundwater recharging structures varies considerably with type of structures and selection of appropriate location. Large variation is found in the cost of water harvesting in different structures (Fig. 8). Selection of appropriate location for structures also can play very important role in reducing the cost of structures (Fig. 9).

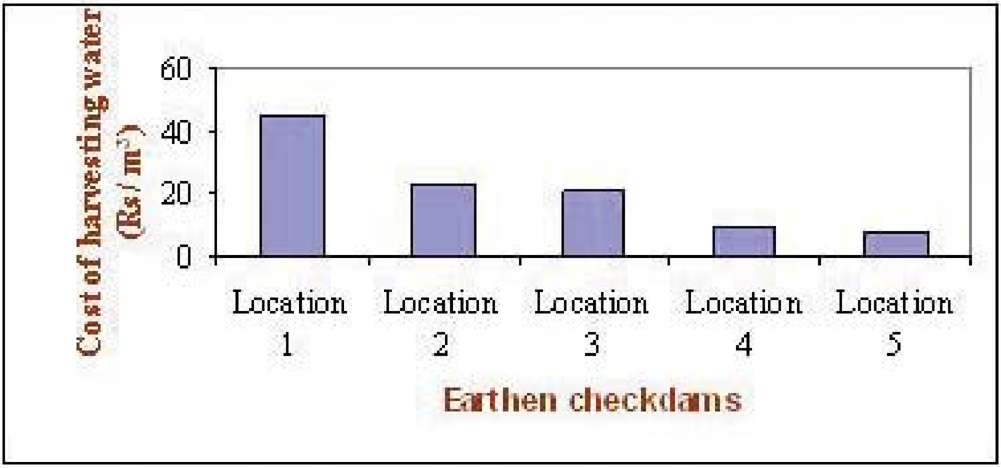

Figure 8. Cost of water harvesting at different locations in Lalatora watershed, Madhya Pradesh.

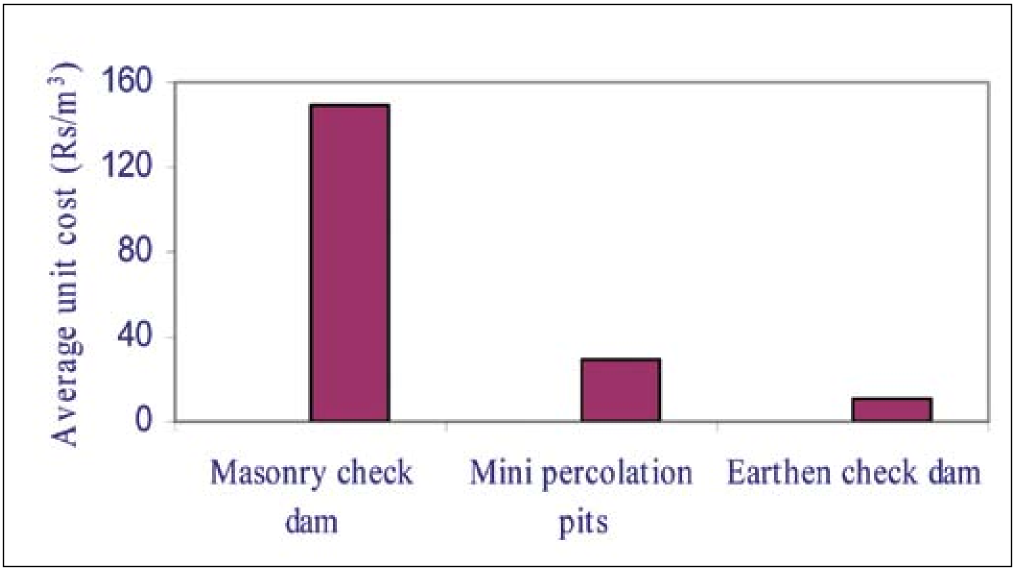

Figure 9. Cost of harvesting water in different structures at Kothapally watershed.

Some of the most promising community based soil and water conservation measures are discussed in detail.

Masonry Check Dam

Masonry check dams are permanent structures effectively used for controlling gully erosion, water harvesting and groundwater recharging (Fig. 10). These structures are popular in watershed programs in India. The cost of construction is generally quite high.

Figure 10. A masonry check dam at Kothapally watershed, Ranga Reddy, Andhra Pradesh.

Description: These structures are preferred at sites where velocity of runoff water flow in gullies/streams is very high and stable structure is needed to withstand the difficult condition. Proper investigations, planning and design are needed before construction of masonry check dams. Masonry check dams are designed on the basis of engineering principles. The basic requirements for designing the masonry check dams are: hydrologic data, information on soils and geology, the nature and properties of the soils in the command area and profile survey and cross-sectional details of the stream or gully. A narrow gorge should be selected for erecting the dam to keep the ratio of earthwork to storage at minimum. Runoff availability for the reservoir should be computed on the basis of rainfall runoff relationship. Depending upon the assumed depth of structure and the corresponding area to be submerged, suitable height of the dam may be selected to provide adequate storage in a given topographic situation (Katyal et al. 1995).

The cross-section of dam and other specifications are finalized considering the following criteria: there should be no possibility of the dam being over-topped by flood-water, the seepage line should be well within the toe at the downstream face;

the upstream and downstream faces should be stable under the worst conditions, the foundation shear stress should be within safe limit; proper spillway should be constructed to handle the excess runoff and the dam and foundation should be safe against piping and undermining.

Benefits:

- Long lasting structures with little regular maintenance.
- Effective in controlling gully and harvesting water under high runoff flow condition.

Low-cost Earthen Check Dam

Earthen check dams are very popular in the watershed programs in India for controlling gully erosion and for harvesting runoff water. These are constructed using locally available materials. The cost of construction is generally quite low.

Recommended agro-ecology: Soil : All soil types
Rainfall: 350-1300 mm

Description: Earthen check dams are those water harvesting structures that have an embankment constructed across the waterway (Fig. 11). The size of the dam depends on the site conditions. In some cases, the stone pitching may be required to protect the bund from scouring. The earthen check dams are used for multiple purposes. They are used as surface water storage structures as well as for recharging groundwater. Economic analysis study of structures in ICRISAT's benchmark watersheds in India revealed that the unit cost of harvesting/recharging of water of these small and medium earthen check dams were Rs 10-45 per m^3, which was less than 1/3rd cost of masonry structures.

Fig. 11. Earthen check dam at Lalatora watershed, Vidisha, Madhya Pradesh.

***Benefits**:*

- These structures serve as water storage and recharging groundwater.
- These structures can be constructed using locally available materials.
- Simple in design and can be easily constructed by local community.
- These structures are low-cost as well as cost-effective (cost of recharging per unit volume of water).

Khadin System

Khadin is a land-use system developed centuries ago in the Jaisalmer district of western Rajasthan. This system is practiced by single larger farmer or by group of small farmers. It is highly suitable for areas with very low and erratic rainfall conditions.

***Recommended agro-ecology**:*

Soil : Sandy and other light soils
Rainfall : 250-700 mm

Description: In *khadin* system, preferably an earthen or masonry embankment is made across the major slope to harvest the runoff water and prevent soil erosion for improving crop production. *Khadin* is practiced where rocky catchments and valley plains occur in proximity. The runoff from the catchment is stored in the lower valley floor enclosed by an earthen/stone '*bund*' (Fig. 12). Any surplus water passes out through a spillway. The water arrested stands in the *khadin* throughout the monsoon period. It may be fully absorbed by the soil during October to November, leaving the surface moist. If standing water persists longer, it is discharged through

Figure 12. Crop cultivation in Khadin system at Goverdhanpura watershed, Bundi, Rajasthan.

the sluice before sowing. Wheat, chickpea or other crops are then planted. These crops mature without irrigation. The soils in the *khadins* are extremely fertile because of the frequent deposition of fine sediment, while the water that seeps away removes salts. The *khadin* is, therefore, a land-use system, which prevents soil deterioration (Kolarkar et al. 1983). This practice has a distinct advantage under saline groundwater condition, as rainwater is the only source of good quality water in such area.

Benefits:

- It improves surface and groundwater availability in the area.
- The *khadin* bed is used for growing post-rainy season crops.
- This requires minimum maintenance (once in 5 years).
- This system results in assured rainy and post rainy season crops, there by improving soci-economic condition of farmer.
- This system provides source of drinking water for livestock.
- It reduces flood or peak rate of runoff.
- It conserves soil and improves rainwater use efficiently.

Farm Ponds

Farm ponds are very age old practice of harvesting runoff water in India. These are bodies of water, either constructed by excavating a pit or by constructing an embankment across a water-course or the combination of both (Fig.13).

Figure 13. A dugout farm pond at Guntimadugu watershed, Kadapa, Andhra Pradesh.

Description: Farm pond size is decided on the total requirement of water for irrigation, livestock and domestic use. If the expected runoff is low, the capacity of the pond will only include the requirement for livestock and domestic use. Once the capacity of the pond is determined, the next step is to determine the dimensions of the pond. To achieve the overall higher efficiency, the following guidelines should be adopted in the design and construction of farm ponds.

- **High-storage efficiency (ratio of volume of water storage to excavation):** This can be achieved by locating the pond in a gully, depression, or on land having steep slopes. Whenever possible, use the raised inlet system to capture runoff water from the upstream. This design will considerably improve the storage efficiency of the structure.
- **Reduce the seepage losses:** This can be achieved by selecting the pond site having subsoils with low saturated hydraulic conductivity. As a rough guide, the silt and clay content of the least conducting soil layer is inversely linked with seepage losses. Therefore, it is best to select the site having subsoil with higher clay and silt and less coarse sand. Also, reduce the pond wetted surface area in relation to water storage volume. This can be achieved by making the pond of a circular shape or close to circular shape.
- **Minimize the evaporation losses:** As far as possible, the ponds should be made deeper but with acceptable storage efficiency to reduce water surface exposure and to use smaller land area under the pond.

Benefits:

- Multiple use of stored water.
- Simple to construct using locally available material.
- Useful for the upstream parts of watershed particularly where groundwater availability is low.

Gully Checks with Loose Boulder Wall

Loose boulder gully checks are quite popular in the watershed program for controlling gully erosion and for increasing groundwater recharge (Fig.14). These are very low cost structures and quite simple in construction.

Description: These gully checks are built with loose boulder only, and may be reinforced by wire mesh, steel posts, if required for stability. Often it is found on the land and thus eliminates expenditure for long hauls. The quality, shape, size and distribution of the boulders used in the construction of gully checks affect the life span of the structures. Obviously, boulders that disintegrate rapidly when exposed to water and atmosphere will have a short structural life. Further, if only small boulders are used in a dam, they may be moved by the impact of the first large water flow. In contrast, a gully checks constructed of large boulders that leave large voids in the structure will offer resistance to the flow, but may create water jets through the voids. These jets can be highly destructive if directed toward openings in the bank protection work or other unprotected parts of the channel. Large voids in gully checks also prevent the accumulation of sediment above the structures. In general, this accumulation is desirable because it increases the stability of structures and enhances stabilization of the gully.

Benefits:

- Low-cost and simple in construction with the locally available materials
- These are effective in controlling gully and improving groundwater

Figure 14. Series of loose boulder wall gully checks at Bundi watershed, Rajasthan.

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8. Cropping Systems for Watersheds/Index Catchments/Farm Lands of Arid and Semi-Arid Ecosystems of India

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Abstract

Sustainable crop production for drylands is difficult but achievable proportion. The crop productivity of farm lands of fragile arid and semi-arid ecosystems can be enhanced manifold (2-4 times) through adoption of resource efficient crops and cropping systems raised with package of improved dryland farming technology. This paper analyses the specific needs of arid and semi-arid regions and the concerted efforts made to design for suitable cropping systems. The strategies to be adopted for the watersheds/index catchment/farmlands of arid agro-ecosystem have been detailed.

Keywords: Watershed, catchment, intercropping, crop intensification, crop diversification.

Introduction

Vagaries of nature have made crop production in drylands a risky and unstable proposition. In these areas water being the most precious, needs to be managed most efficiently for sustained agricultural production and economic stability. For that integrated approaches like watershed based land management in the area where they exist and index catchment/farming systems development in the areas of absence are the most scientific and practical as their main motto is efficient conservation and use of rain water with halt on degradation of natural resource base of fragile arid and semi arid agro-ecosystems. These developmental approaches inherit the components of distress management like drought, famine and flood, ground water recharge, diversified agriculture and biodiversity conservation and sustainability.

Water productivity on farm lands can be increased manifold (2-4 times) by adoption of suitable cropping systems integrated appropriately with other components of improved dry farming technology viz. crop varieties, INM, IPM, weed management, *in situ* and inter-plot-water-harvesting, etc.

In this paper an attempt has been made to focus on the most suitable and remunerative cropping systems of arid and semi-arid zones of India.

Constraints and Opportunities of Cropping Systems

Constraints

- Unavailability of proper seeding device on large scale.
- Lack of skill and knowledge of the farmers.
- Land fragmentation and small land holding.
- Difficulties in harvesting and fear of mixing of seed.
- No concrete recommendations on quantum and method of nutrient application.
- Short sowing season associated with high weather aberration.
- Limited scope of herbicidal weed control and difficulties in mechanical weeding.
- Market fluctuations and lack of policy support.

Opportunities

- Traditional wisdom on cropping systems viz. crop rotations, mixed cropping, multiple cropping, etc., is available.
- To save on the cost of chemical fertilizers and pesticides.
- To conserve the natural resource base at farm level.
- High rain water use efficiency and multiple water productivity.
- Drought mitigation and more effective management of weather aberrations.
- To sustain the market fluctuations.
- Food, fodder, fuel and nutritional security.
- Sustained productivity is expected to result in socio-economic stability and balanced development of the regions.

Strategies and Approaches

Strategies for adoption of cropping systems will vary with the agro-ecosystem. The strategies to be adopted for the watersheds/index catchment/farmlands of arid agro-ecosystem can broadly be narrated in two groups.

- For area receiving rainfall below 350 mm, management of *khadins*, sand dunes and underlying cultivated fields, index catchments with suffocate drainage system need to be adopted, stabilization of sand dunes/sandy, semi-rocky rugged wastelands be integrated with crops and cropping system diversification, wind break and shelterbelts, agripasture, top feed and fodder production systems. The cropping should be integrated with trees, shrubs and grasses to sustain the livestock husbandry which is the mainstay of the farmers in these areas. Development of value chain for animal products and byproducts is also very important for sustainability and economic stability of the area.

- The strategies to be adopted for the area between 350 and 550 mm of rainfall are adoption of crop diversification, inter/mixed cropping in replacement series coupled with *in-situ* rainwater harvesting and recycling systems, crop rotations/cropping sequences and cropping patterns for SLM, in watershed/ IAD approaches. In this region there are some areas of deep and medium soils and double cropping of pearl millet-chickpea, mungbean-chickpea/mustard on conserved moisture in combination with fruit trees (*ber*) can help in income and employment generation. Livestock husbandry in this zone is also equally important and synergy of cropping system with this component of agriculture ensured with by fodder availability should be given due importance.
- Strategies and approaches to be adopted for the watershed of semi-arid ecosystem can be:
    - adoption of cropping systems as per the quantum of rainfall and water holding capacity of the soil;
    - *in-situ* and inter plot rain water harvesting and its efficient utilization;
    - multiple water productivity through goatery, fisheries, dairying etc., with emphasis on organic farming of commercial and high value crops viz. seed species, medicinal and aromatic plants;
    - safe disposal of excess water and its utilization to enhance cropping intensity in the watershed area.

Procedures and Practices

In practice, a farmer's decisions with respect to choice of adoption of crops and cropping systems is influenced by several considerations viz. food, fodder and fuel security, income and employment generation, soil and water conservation and tradition wisdom. However, the development of HYV and input intensive agriculture has added the facets of productivity, sustainability, gender sensitivity and economic stability of farmer at micro and region at macro levels. The efficient crops and cropping systems and their management in context to these broader perspectives or briefed below:

Efficient Cropping Systems for Arid and Semi-Arid Regions

Cropping system is a management of natural and other farm resources for cropping activity in such a manner that their maximum efficiencies are harnessed to attain and sustain potential yield levels per unit of land area per unit time without causing any deterioration in quality of environment of any level of ecological hierarchy (Yadav et al. 1998). Cropping system approach, addresses the issues related to economic aspects of cropping activity, available resources and micro-environment at farm level in holistic manner. However, in practice mixed crop stand is a feature of rain-fed agriculture. This helps to distribute the risk over the seasonal adversities. But the system is more towards survival than sustained progress. The important contribution of cropping system research is to modify the traditional subsistence cropping systems into highly productive, remunerative and sustainable one.

In general, while designing efficient cropping systems three main approaches viz. crop intensification, crop diversification and cultivars options should be taken into account. In fact, they are the building blocks of the ideal cropping system. Considering the specific needs of arid and semi-arid regions concerted efforts have been in progress to design suitable cropping systems based on these three main approaches.

Crop Intensification

The cropping intensity in drylands of arid and semi-arid ecosystem is lesser than 100% because of fallow being the indispensable component of cropping sequence. However, the cropping intensity can be increased by intercropping and sequence cropping (Venkateswarlu et al. 1985). In areas where rainfall is less than 350 mm, with moisture storage capacity less than 80 mm and length of growing period (LGP) less than 60 days it is preferable to take arid legume/fodder based agri/silvi/pasture production systems, whereas in areas of 350-550 mm rainfall with moisture storage capacity less than 100 mm and LGP 75-140 days growing short duration cereals and pulses as sole crop or in intercropping system is preferable. However, for areas of rainfall between 600 and 750 mm with a surplus of one to two months period of moisture, intercropping in additive series of crops of differential LGP has been found to be the most important stabilizing factor in crop production. Besides, recently developed short duration varieties of *kharif* and *rabi* crops have also made efficient crop sequences possible in this region. The area receiving rainfall between 750 to 900 mm of rainfall with moisture storage capacity of about 200 mm and LGP 140-180 are the actual dryland areas of intensive agriculture viz. sequence cropping, multiple intercropping and agri-horti-silvi production systems of high productive potential. The promising cropping sequences/intercropping system for arid and semi-arid areas are discussed below.

Cropping Sequences

The cropping intensity in rain-fed areas is close to unity. More or less part of the land is kept as fallow for various reasons like recuperation of productivity, absentee ownership, lack of resources etc. Promising cropping sequences for selected areas of semi-arid and arid areas are:

Region	Cropping system
A. Semi arid region	
1. Vidarbha	Greengram –safflower, sorghum-chickpea
2. Telengana and Deccan region of Maharashtra	Greengram – sorghum
3. Sub mountain region of Punjab, black soils area of S-E Rajasthan	Maize – chickpea, maize – mustard
4. Bagelkhand region of MP	Sorghum – chickpea, blackgram – wheat
5. Eastern UP	Blackgram – mustard
6. Malwa pleateau region	Soybean – safflower, maize – chickpea, Sorghum – safflower, sorghum – chickpea
7. Orissa and northern Circus (AP)	Finger millet – horsegram
8. Bundelkhand region of UP	Cowpea (fodder) – mustard, sorghum
B. Arid regions	
1. Jodhpur, Nagaur, Pali	Pearl millet – fallow, pearl millet – mustard/ chickpea (for > 500 mm rain and deep medium soils),
2. Hisar	Pearl millet – chickpea, mungbean – mustard

Source: Yadav RL (1998), Venkateswarlu J (2004), Singh et al. (1999)..

Intercropping Systems

Mixed cropping is growing two or more crops simultaneously with no distinct row arrangement (Roy and Braun, 1983) whereas intercropping implies growing of two or more crops simultaneously on the same field with crop intensification in both temporal and spatial dimensions and with crop competition during all or part of crop growth (Francis, 1989). The intercropping can provide substantial yield advantages to sole crop leading to greater stability in dryland agriculture (Willy 1979). However, Jodha (1979) opined that intercropping/mixed cropping systems are more prevalent with small farmers especially because of coverage of weather aberrations, food, fodder & income security and maintenance of soil productivity. In general the intercropping systems were more suitable in *kharif* crops (LER 1.22 to 1.80) than rabi crops (LER 1.07). Hence it was concluded that intercropping systems have great promise in increasing the productivity of drylands in Indian conditions (Chatterjee and Maiti, 1984, Hosmani et al. 1990). Land use efficient and profitable intercropping systems for different regions of the country have been identified under the AICRP on Dryland Agriculture (Singh et al. 1999) and AICRP on Cropping Systems (Yadav et al. 1998). The most promising intercropping systems for semi arid and arid regions of the country are given in table below:

Efficient intercropping systems at various locations of semi-arid regions

Location	Intercropping system	Row ratio	Income equivalent ratio
Semi-arid region			
Udaipur	Sorghum + pigeonpea	1:1	1.23
	Maize + pigeonpea	1:1	1.42
	Chickpea + mustard	4 or 7.1	1.22
Bijapur	Pearl millet + pigeonpea	2:1	2.44
	Groundnut + pigeonpea	2:1	1.78
	Chickpea + safflower	3:1	1.40
Solapur	Pearl millet + pigeonpea	2:1	2.62
	Sunflower + pigeonpea	2:1	1.67
	Chickpea + safflower	3:1	1.12
Akola	Sorghum + greengram	2:1	1.58
	Sorghum + pigeonpea	2:1	1.16
	Cotton + soyabean	1:1	1.55
	Pearl millet + pigeonpea	2:1	3.47
Rajkot	Groundnut + castor	3:1	1.82
	Pearl millet + castor	4:1	1.93
	Pearl millet + pigeonpea	4:1	2.04
Anantpur	Groundnut + pigeonpea	3:1	1.01
	Groundnut + castor	2:1	1.21
Hyderabad	Sorghum + pigeonpea	2:1	1.69
	Castor + clusterbean	2:2	-
Jhansi	Sorghum + pigeonpea	2:1	1.54
	Pearl millet + fodder legumes	1:1	-
Agra	Pearl millet + Pigeonpea	2:1	1.17

Contd...

Contd...

Location	Intercropping system	Row ratio	Income equivalent ratio
	Chickpea + Mustard	5:1	1.22
	Pearl millet + Clusterbean	2:1	1.41
Arid Regions:Jodhpur	Pearl millet + Greengram	1:2	1.24
	Pearl millet + Clusterbean	1:2	2.07
	C.ciliaris + Arid legumes	1:2	1.5-1.7
	L.sindicus + arid legumes	1:2	1.2-1.4
	D.annulatum + arid legumes	1:2	1.34-1.81
Sardarkrushinagar	Pearl millet + Greengram	1:3	1.32
	Pearl millet + Clusterbean	2:1	1.30
	Clusterbean + Greengram	2:1	-
Hisar	Blackgram + clusterbean	1:1	2.48
	Pearl millet + Blackgram	2:1	1.40

Available research evidence shows that in semi-arid regions for intercropping to be successful mostly requires optimum population of base crop achieved through row arrangements (paired rows, closer rows etc.) coupled with near optimal population (60-75%) of companion crop. However in arid areas inter/mixed cropping system is recommended more for risk coverage, diversified agricultural produce including fodder, surface crust management and minimization of blowing hot winds damages. Further, due to lack of moisture availability the population of base crop has to be sacrificed (30-50%) for attainment of these objectives. Sustainability index (SI) of different cropping systems was calculated by Vittal et al. (2003) and it was higher in greengram + castor (0.58), pearl millet + pigeonpea (0.62), sorghum + cowpea (0.64) over sole crops at Dantiwada, Solapur and Arjia locations of ACRIPDA, respectively.

Some useful observations about various aspects intercropping systems and their management are:

Fertilizer Management:

- It was noted that higher level of nitrogen to cereal or non-legume component may result vigorous growth and may adversely affect the yield of legume component. Alternatively at low level of N, the plant growth was not enough to achieve the production (Umarani and Subba Reddy, 1999).
- Advantage of growing short season legume (soyabean/urd bean) in terms of N-fertilization in intercropping system with cereal (maize) was apparent and yield advantage by 15-20% of cereal was recorded (Singh et al. 1986).

- Optimum levels of fertilizer to the base crop was adequate to get better crop production and IER in intercropping systems (Umarani and Subba Reddy, 1999).

Rainfall Pattern

- Over time several crops/cropping systems were developed based on amount and distribution of rainfall. However with the introduction of hybrids/HYV there is need to reinvent the suitable intercropping systems matching with the rainfall pattern and crop varieties.
- Reduced advantage of inter sequence cropping system was observed in arid and dry semi arid regions as compared to sub-humid areas because of the smaller LGP of these regions (Gupta et al. 2000). However, intercropping led to maximum WUE in replacement series of intercropping systems (Baldy & Stigler 1997). Similarly Reddy and Willey (1981) also found high WUE of millet – groundnut intercropping system then sole crops.

Pest and Diseases

- Pigeonpea + sorghum intercropping system, which is extensively practiced in Karnataka, Maharashtra and Andhra Pradesh, is known to reduce weed intensity by 25% (Rao and Shetty 1996). Besides, sorghum intercropping with green gram and blackgram smoothers the weeds to the extent of 60-70% (Venkateswarlu and Ahlawat 1986).
- Raheja (1973) reported that sorghum earhead fly damage could be substantially reduced when it was alternated with red gram. He also reported reduced incidences of *Rhizoctoria solani* in cotton when it was intercropped with mothbean (*Vigna aconitifolia*).
- Verma et al. (1987) reported prevention of top borer attack in sugarcane when it was grown in association with coriander/garlic/fennel.
- Raheja and Tewari (1996) and Nagarajan et al. (1996) compiled the information on control of insect pest and diseases in various intercropping systems viz. *Helicoverpa armigers* control in chickpea + mustard/wheat, Diamond black moth, leaf webber, aphids in mustard + cabbage, stem borer in maize + cowpea, jassids in cotton + mungbean.

Crop Genotypes: For intercropping system to be successful the genotypes of both base and component crops should be compatible. Further in the system they must have high cumulative resource use efficiency, sustainability and economic stability. In pearl millet + arid legume based systems at Jodhpur the genotypes Maru Moth and Jwala of dewgram, FS277, HG-75 of clusterbean, 288-8, S-8 of greengram and C-152 and Charodi-1 of cowpea indicated higher magnitude of LER and net returns (Daulay et al. 2000, 2006). However, the varietal development is a continuous process and intercropping systems have to be evolved on the basis of varietal characteristics of base and companion crops, and research work on this aspect needs further intensification.

Crop Diversification and Alternate Land Use Systems

To cushion the adverse effect weather aberrations and drought, mixed sowing of dryland crops is a common practice with the farmers of arid and semi arid regions. Bhati and Singh (2002) observed that in western Rajasthan the common crop mixtures are Pearl millet + mungbean + mothbean + clusterbean + sesame (48%), followed by mixture of same crops without sesame (24%). Irrespective of the categories of farmers (small, marginal and medium) the mixing of seed of dryland crops was common and it was largely because of wider risk coverage and higher economic gains (Rs. 4638 to Rs 5200 ha^{-1}) as compared to pulse and oilseed mixture (Rs. 3085 ha^{-1}) and sole cropping of clusterbean (Rs. 3793 ha^{-1}). However, with the development of HYV of these crops the practice is fast diminishing and farmers are switching over to the monocropping systems mostly without adoption of suitable crop rotations resulting in loss of soil fertility and allelopaethic effects (Kathju, 2005). Therefore, to take advantage of mixed cropping and the higher yields through HYV of crops under resource efficient management systems, the crop diversification can be an important alternative. CAZRI based on 100 years of climatic analysis (biomodel rainfall pattern and a drought year in every 2.5 years) and changing food habits of the people over last two decades have came out with a viable model viz. Pearl millet (40%), *kharif* legumes (3%), oilseeds (15%) and forage crops (15%). The model can be adopted either in strip cropping system or in recommended intercropping systems with added advantages of soil and water conservation both from turbulent winds and flow of water (Bhati and Faroda, 1996, Pratap Narain and Bhati, 2005). The diversification of crops and cropping system is the only option of sustainability where the farmers are cultivating their land only in rainy season. The percentage of such farmers in Thar Desert is quite high (60%). However, remaining 40% of farming community have made their dwelling on the farm or are living in hamlets. For such farmers alternate land use systems are more feasible. The promising multipurpose trees, fruit, crop and grasses for various agroforestry systems in dryland areas of arid and semi arid regions are summarized below:

Zone	System	Promising species		
		Forestry plants	Fruit trees	Crops/grasses
Arid	Agri-silviculture	*Prosopis cineraria, Tecomella undulata, Hardwickia binata, Ziziphus rotundifolia*	*Ziziphus mauritiana* (*ber*), Datepalm	Mungbean, mothbean, cowpea, clusterbean, pearl millet, sesame
	Silvi-pasture	*Colophospermum mopane, Ziziphus nummularia, Hardwickia binata*	*Capparis decidua* (kair), *Z. mauritiana* (*ber*), *P cineraria* (khejri)	*Cenchrus ciliaris, Cenchrus setigerus, Lasiurus sindicus, Dicanthium annulatum*
	Shelterbelts	*Acacia tortilis, Cassia siamea, Prosopis juliflora, Albizzia lebbek, Azadirachta indica*	-	-
Semi-arid	Agrisilviculture	*Acacia nilotica, Ailanthus exelsa, Dalbergia sissoo, P cineraria, A indica, Populas deltroides, H binata*	*Ber*, mango, guava, citrus, aonla, bael	Pearl millet, sorghum, clusterbean, pigeonpea, cowpea, mungbean, sesame, groundnut
	Silvi-pasture	*Acacia nilotica, Dalbergia sissoo, P cineraria, A leucophloea*	-	Seasonal grasses, *Sehima neurosalm, P annulatum, C ciliaris*
	Farm boundary	*A. nilotica, Eucalyptus spp. P detoides, Madhuca latiofolia, D sissoo*	-	-

Source: Venkateswarlu J, 2004.

Grain legume followed by coarse cereal (greengram – Maghi - Sorghum) and alternatively staple crop (maize) followed by *rabi*-pulse (chickpea) are very promising and need to be backed up with the improved dryland farming technology. Other important crop sequences recommended for farmers of various sub-regions of semi-arid ecosystem are greengram - safflower and sorghum-chickpea in Vidarbha; maize/sorghum - chickpea/safflower, soyabean- safflower in Malwa plateau; maize-chickpea/mustard in S-E Rajasthan and part of Punjab; greengram - sorghum in Telengana and Deccan region of Maharashtra, whereas, for arid regions the recommended cropping sequences are clusterbean - pearl millet, pearl millet –

fallow - mungbean/mothbean -Pearl millet - clusterbean for moderate aridity area of western Rajasthan; Pearl millet - chickpea/mustard/wheat for medium soils and moderate climate area (400-550 mm rainfall) of arid Rajasthan. *Khadins* are recommended.

However, the recommendations of intercropping and cropping sequences need to be adopted in water centered holistic approaches like watershed/index catchment.

Recommendations for the Practitioners

- For area receiving rainfall below 350 mm per annum the dryland crop cultivation should be integrated with trees, shrubs and grasses for sustainable agriculture and livestock production, drought proofing, natural resource conservation thereby to ensure economic stability and balanced socio-economic development.
- Livestock husbandry should still be the focal issue in areas receiving 350 to 550 mm rainfall, however, cropping system diversification, vis-à-vis alternate land use systems live agroforestry, agro-horticulture and agri-pasture (ley farming) etc. assume importance for sustain agricultural productivity and drought mitigation.
- In area receiving rainfall between 550 mm and 800 mm intercropping of cereals (Pearl millet, sorghum, maize) with pigeonpea and other *kharif* pulses in appropriate combination, and density should be adopted by the farmers for higher yield stability and economic gains. Besides the intercropping of cotton and *kharif* pulses (mungbean and blackgram/soyabean and castor + groundnut have also been very promising. For parts of these regions where soils are deep and of medium texture with LGP 180-210 days the crop sequencing coupled with integrated area development approaches should be followed so as to enable the farming community to fight against natural calamities viz. drought, famine, flood etc. more effectively for success and sustainability. These agriculture development strategies should be back up with appropriate market value chains for agricultural products and other socio-economic upliftment programs for balanced growth of different public and private sectors.

Investment Needs for Adoption

- Investments are urgently needed by the governments and other donor agencies to make the quality seed/seedlings/inputs available to the farmers at doorstep.
- Capacity building institutions (GOs and NGOs) should be equipped and energized to help in metamorphosis of the farming community from subsistence to professional thereby for development of agriculture as well as industry.

- To strengthen public-private-partnership (P-P-P) the village level institutions like *gram panchayat* at SHG, FIG, UG, etc., should be geared up and empowered.
- Investment support on farm implements to the farmers is needed for execution of recommended intercropping systems and crop sequences.

Policy and Financial Incentives

- Water should declared as national asset and efforts should be made to resolve the issues related to water use in agriculture and other sectors.
- Minimum support price system for the dryland farmers of fragile arid and semi arid agro-ecosystems should be strengthened.
- For arid agro-ecosystem a clear policy on livestock husbandry should be chalked out and the government should support forage production programs pertaining to grazing lands and cultivated fields.
- State level policy on breed improvement, distribution and management of livestock is required in arid Rajasthan. Livestock-based land use policy/watershed based livestock system needs to be developed in arid and semi arid areas of the country.
- Implementation of fodder bank concept for creation of permanent feed and fodder resources in the drought prone areas is required for maintenance of livestock in lean period and drought years.
- Gender empowerment to ensure equal partnership in farm management at household level and integrated agriculture development at village or even on larger context should be given top priority.

Conclusion

Sustainable crop production for drylands is difficult but achievable proportion. The crop productivity of farm lands of fragile arid and semi-arid ecosystems can be enhanced manifold (2-4 times) through adoption of resource efficient crops and cropping systems raised with package of improved dryland farming technology. However, to make them less vulnerable to frequent weather aberrations their drought proofing with efficient rainwater management systems like *in-situ* and interplot water management and integration with suitable MPTS/grasses/livestock is essential. Further to achieve the natural goal of efficient and sustainable use of natural endowment of drylands these efficient crops and cropping system should become important component of GOI supported ambitious land management programs like watershed/index catchment/*khadins*/cluster development and in future should be evolved in farmer's participatory research perspective for their refinement and higher replicability.

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Case Studies

Cropping System for Special Land Use

In Deccan area with 30-45 cm deep soils *kharif* rains are very uncertain and 70-75% land is diverted to fallow. On fallow *rabi* sorghum is taken but due to low WHC of the soil productivity is very low. Hence it is recommended to divert about 15% of this land to *kharif* cropping which is although risky but more profitable than rabi sorghum. In *kharif* pearl millet + pigeonpea intercropping system was found more remunerative and profitable.

Source: 50 Years of Dryland Agricultural Research in India, CRIDA, Hyderabad, pp. 112-113.

Farming Systems Approach on Vertisols of India

In Vertisols, farming systems approach of maize – coriander – chickpea and integrating with two buffaloes yielded higher benefit : cost ratio (3.2), followed by maize + pigeonpea (2.4) and coriander – chickpea (2.3) system. Equally higher returns were obtained with maize – pigeonpea – cotton system with two buffaloes in <1 ha farm.

Source: Vision 2025 – CRIDA, Hyderabad, pp. 11

Farming Systems for Alfisols

In Alfisols, maize + pigeonpea cropping system recorded very high B: C ratio (2.5). In small farms inclusion of sorghum and castor further added stability and more remunerated to the cropping system.

Source: Vision 2025, CRIDA, Hyderabad, pp. 11

Alternate Land Use Systems(Self Supporting and Eco-friendly

1. In semi arid regions of Maharashtra, Karnataka and Andhra Pradesh, alley cropping of Laucaena at 20 m distance and its repeated pruning (4-5 times) and spread between sorghum/pearl millet rows could give response equivalent to 80 kg N ha-1, besides enhancement in availability of N, P, K, soil moisture and organic build up.
2. In arid areas of western Rajasthan P cineraria (50-150 p ha^{-1}) based agroforestry systems could sustain 1.5 to 2.5 ACU ha^{-1}, besides increasing the availability of N, P, K and micro nutrients in the soil thereby enhancing the yield of pearl millet and *kharif* legumes by 25-30%. The system also improved the physico-chemical properties and enhanced WHC of soil. The shade for trees ameliorated the micro-climate for crops and helped alleviate adversities of moisture stress and intense heat.
3. Agro-horticulture system with *ber* (150 to 200 p ha^{-1}) was highly remunerative (Rs. 15000 to 2000 ha^{-1}) in arid ecosystem. Besides higher yield (15-20%) of dryland crops (*kharif* legumes) the system could sustain grazing of 700 to 1000 sheep/goat days/ha along with the fruit (40-50 q ha^{-1}) and fuel availability (20-30 q ha^{-1}). The system helped the farm family in self support with respect to fuel, fodder, grain, nutritional and economic security on the basis of SLM strategies.

Source: 50 years of Dryland Agriculture in India and Pratap Narain and Bhati, 2005.

9. Crop Diversification and Alternate Land Use Systems in Watershed Management

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Abstract

About 70 m ha out of the total 100 m ha area under rain-fed agriculture is facing serious problems of land degradation. To meet the increasing demand of food and fodder and also conserve natural resources, a diversified cropping and land use systems strategy need to be adopted in different agro-ecological regions of the country as an alternative to conventional cropping systems. This paper ties to analyse the crop diversification and alternate land use systems in semi arid regions of India.

Keywords: Watershed, crop diversity, resource conservation, vegetables, agroforestry

Introduction

Crop production in rain-fed areas is characterized by low and unstable productivity, and poor economic returns. These areas suffer from various forms of degradation mainly due to poor vegetal cover and improper management practices. About 70 m ha out of the total 100 m ha area under rain-fed agriculture is facing serious problems of land degradation. To cope with up increasing population of both human and livestock and rising demand for food, fodder and fibre, more and more marginal, sub-marginal lands are brought under cultivation. These lands are unable to sustain productivity and cultivation on such lands leads to serious imbalances in the ecosystem. To meet the increasing demand of food and fodder and also conserve natural resources, a diversified cropping and land use systems strategy need to be adopted in different agro-ecological regions of the country as an alternative to conventional cropping systems. Through this approach, the biological productivity and the quality of resource base of such degraded eco systems can be significantly enhanced. Such a strategy would also help in employment generation, minimize erosion, utilize off-season rainfall and restore balance in the ecosystem. This chapter deals with appropriate technologies to promote alternate cropping and land use systems in rain-fed agro eco system, particularly in marginal and sub marginal lands.

Alternative Land Use Systems

When a land is put under an alternative production system in order to match its capability more appropriately to the new land use and achieve more sustainable biological and economic productivity on a long term, it is known as alternative land use. Depending on the components of the alternative production system, various types of alternative land uses are recognized.

Agroforestry

Agroforestry is a practice of raising annual crops in association with woody perennials (Katyal et al. 1994). Agroforestry can be further classified into agrisilvi culture, alley cropping, agri horticulture, silvipasture and hortipasture, etc., depending on the nature of the components in the system. Tree farming, social forestry are other alternative land uses, which are meant to improve the degraded natural resource base besides providing economic products to the community. Agroforestry systems are aimed at optimizing the use of resources through the principles of recycling, internalize the input production, reducing risk and conserving natural resources. It reduces erosivity of rainfall and erodibility of soil through dissipation of energy of raindrops by canopy at low heights, surface litter, obstructing runoff, root binding and improves soil organic matter, physico-chemical and biological properties. Alley cropping with Leucaena/Glyricidia hedges and grass barriers have been found effective in controlling erosion up to 30% slope under humid, sub-humid and sub-tropical climatic conditions. Contour paired rows of Leucaena as hedge, Leucaena and Eucalyptus trees and 0.75 m wide grass barriers at 1.0 m vertical interval in maize at 4% slope reduced runoff from 40 to 30% and soil loss from 21 to 8 t ha^{-1} yr^{-1} (Table-1) under high rainfall conditions of Doon Valley (Narain and Grewal, 1994).

Table 1. Effect of paired rows of barrier hedges, grass strips and trees on runoff and soil loss in maize at 4% slope

Treatment	Runoff (%)	Soil loss (t ha^{-1} yr^{-1})
Maize on contour	40.0	21.0
Leucaena hedge	21.3	12.1
Panicum grass (0.75 m wide)	36.7	7.0
Bhabar grass (0.75 m wide)	42.7	10.0
Vetiveria (0.75 m wide)	39.6	8.1
Leucaena trees (6-8 yrs)	20.4	8.4
Eucalyptus trees (6-8 yrs)	16.3	5.8
Agroforestry land uses (mean)	30.0	8.7

Agro-Horticulture Systems

Among the various agro-forestry systems, agri horticulture system is the most important in terms of economic returns to the farmers and their preferences. For eg, based on a long term economic analysis of different alternate land use systems evaluated in semi -arid alfisol region of Andhra Pradesh, agri horticulture was found to be the most profitable (Reddy and Sudha, 1988) giving a CB ratio of 1:5.53, followed by silvipasture and agri- silviculture (Table 2).

Table 2. Benefit cost ratio of different alternate land use systems in semi-arid Alfisols

Agroforestry system	Period (seasons)	Benefit cost ratio
Arable farming (crops)	1	1.34
Agroforestry	10	1.65
Agri-horticulture	30	5.53
Silvi-agriculture	10	1.99
Silvi-pastoral	10	2.43

(Reddy and Sudha, 1988)

In the sub-montane regions at Dehradun, peach based agri-horticultural system showed significantly higher returns over sole tree (Table 3). The highest returns were with peach + turmeric among the combination of perennial components, while peach + sesame gave highest returns among the fruit tree + crop combinations. Annual crops like cowpea and sesame could be grown as intercrops with peach upto 6 years beyond which the yield of the fruit declined making the system uneconomic (Arora and Mohan, 1986).

Table 3. Production potential of various peach based agri-horticulture systems under rain-fed conditions at Dehradun

Agri-horti system	Fruit yield (t ha^{-1})	Yield of component crops (q ha^{-1})	Net returns (Rs.ha^{-1})
Annual companion crops (mean of 3 yrs)			
Peach + cowpea	7.2	5.8	6,000
Peach + soybean	8.6	Failed	4,800
Peach + sesame	6.8	3.0	6,500
Sole peach (control)	6.6	-	
Perennial companion crops (mean of 10 yrs)			
Peach + pineapple	12.4	2.1	8,000
Peach + turmeric	11.8	38.5	10,000
Peach + lemon grass	7.4	201.6 (green leaves) (20 kg oil)	6,000
Sole peach	9.2	-	5,000

An agri horticultural system of kinnow-turmeric in V-shaped micro-catchment with Morus alba on field bunds produced 4.34 t ha^{-1} of kinnow fruits, 1.11 t ha^{-1} of turmeric from interspaces and 2.24 t ha^{-1} of canes (for basket making) along with 2.16 t ha^{-1} of wood and 0.69 t ha^{-1} of mulberry leaves for sericulture. The system appeared to be an effective alternative land use for marginal (class II) rain-fed lands (Arora and Mohan, 1986). Similarly, plantation of kinnow at 4 m x 4 m spacing and Bhabar at 50 cm x 50 cm after minor leveling in Relmajra watershed provided early returns to the farmers and was highly profitable (Samra et al. 1995).

Evaluation of mango and litchi based agri-horticulture systems indicated that cowpea-toria sequence was quite remunerative with gross income of Rs. 17,775 ha^{-1} besides fruit yields of 11 kg and 33 kg per plant in 9^{th} year from mango and litchi, respectively in degraded bouldry lands of Doon Valley. Mixed vegetative barrier of one row of Guatemala grass and two rows of pineapple at 1.0 and 1.5 m vertical intervals were found the most promising under Cassava cultivated on sloping lands in Nilgiris in terms of minimizing runoff (4.6%) and soil loss (0.85 t ha^{-1}) in addition to returns from pineapple (Rs. 33,000/ha).

In semi arid regions of central and southern India, many agri horticultural systems have been evaluated and found more profitable than arable crops or fruit trees (Korwar, 2003). In Nagpur region of central India, orange-arable crops are a traditional agri-horticultural system. The other important fruits, which can be put in rain-fed areas are *ber*, *amla*, custard apple, guava, tamarind, *jamun,* etc., Mango also can be grown in this system, but with some protective irrigation. Agri-horti system involving ber under rain-fed regions is very common in parts of Maharashtra, Karnataka and Rajasthan. *Amla* based agri horticultural system is common in UP and Gujarat. Easy access to market and processing industries is a must to popularize perishable products like fruits. For some fruits like custard apple, research is underway to increase the shelf-life, which is required to make it an economical crop.

Among many legume intercrops tried in western Rajasthan with *ber*, clusterbean followed by greengram were found to be the best (Singh, 1984), Table 4 lists the most compatible and profitable intercrops with *ber* under arid and semi-arid conditions.

Table 4. Compatible intercrops with *ber* and custard apple in different locations

Centre	Tree-crop	Intercrops	Yields (q ha^{-1}) of intercrops
Solapur	*Ber*	Pearl millet + pigeonpea	24.6 + 1.2
	Custard apple	Pearl millet + pigeonpea	22.0 + 1.3
Rewa	*Ber*	Blackgram	4.50
	Custard apple	Blackgram	3.80
	Ber	Pigeonpea	13.9
	Custard apple	Pigeonpea	17.6
Dantiwada	Sole *ber*		32.0
	Ber	Castor	25.9 + 8.0
		Clusterbean	24.9 + 7.9
		Pearl millet	23.1 + 5.4
		Greengram	25.9 + 1.2
Agra	*Ber*	Greengram	3.70
		Cowpea	2.85
		Clusterbean	6.45
Hisar	*Ber*	Greengram	2.95
		Cowpea	2.90
		Clusterbean	3.02
Jhansi	*Ber*	Blackgram	3.74
		Greengram	2.67

In orchards of custard apple and aonla planted at 4 m x 4 m at Jhansi, all crop rotations such as maize – wheat – sorghum, maize – chickpea – sorghum, cowpea – wheat – sorghum and cowpea – chickpea – sorghum performed equally well (Gill and Gangwar, 1992), utilizing the interspaces profitably with fodder and grain crops. In Hyderabad, the yields of sorghum, groundnut and mungbean grown with pomegranate and custard apple were reduced by 23-26% compared to the respective sole crops (CRIDA, 1999). The yield reduction was higher in association with custard apple. Among the systems, groundnut grown in interspaces of either pomegranate or custard apple gave the highest gross income (Rs.19,540-19,770 ha^{-1}). Custard apple + mungbean system recorded the highest yield advantage (54%) compared to respective sole crops.

Guava is another fruit tree with which crops or fodders can be grown for 3-4 years. Besides greengram, cowpea and cluster bean, *Stylosanthes hamata,* and *Cenchrus ciliaris* can be cultivated successfully in the interspaces. However, keeping the basins clean atleast 3-4 times a year is essential. A dry fodder yield of 2-3 t ha^{-1} yr^{-1} of *Cenchrus* and 4-5 t ha^{-1} yr^{-1} of stylo can be harvested apart from yield from guava fruit (Rao, 1999).

Among different intercrops (groundnut, greengram and cowpea) tried in four year old mango orchard at Hyderabad, groundnut proved to be a successful intercrop (CRIDA, 1995). However, there was considerable reduction (53 – 56%) in pod yield of groundnut (506-539 kg ha^{-1}) in agri-horticultural system over sole groundnut (1148 kg ha^{-1}). Leguminous intercrops can be taken in mango orchard upto atleast 8 years after planting with minimum reduction in yields of annual crops. In young mango plantations in Karnataka, *ragi* and groundnut intercropping is very common (Rao and Sujatha, 2003).

Horti-Pastoral System

Horti-pastoral system is a combination of fruit trees and pasture grass or legume. It is an ideal alternative land use option for degraded lands. In guava based horti-pastoral system at CRIDA, yield reduction of stylo was less under widely spaced trees (8x5 m) compared to closer spacing (5x5m), indicating the necessity of wider spacing of fruit trees when grown with stylo (Osman and Rao, 1999). Buffel grass out yielded stylo and took less time for establishment (Table 5).

Table 5. Fresh yield of forage and fruit in 8 year old guava based horti-pastoral system

Spacing (m)	Forage yield (t ha^{-1})		Fruit yield (kg $plant^{-1}$)
	Stylo legume	Buffel grass	
5 x 5	5.22 (40.4)	2.45 (3.9)	95.4
8 x 5	6.56 (25.1)	2.14 (16.1)	99.7
Control	8.76	2.55	-
Mean	6.84	2.38	97.5
CD (0.05)	0.88	NS	N.S

Figures in parentheses indicate percent reduction in forage yield as compared to control (sole forage)

Tree and Grass Barriers for Resource Conservation

Trees, shrubs and perennial grasses can also play an important role in conservation of resources and biomass production when grown on the bunds along with arable crops. Grasses and leguminous shrubs, in particular when grown as vegetative barriers serve as good filter strips to check erosion and increase crop productivity in marginal lands. Use of Guatemala grass (*Tripsacum laxum*) in lateritic soils of south India in Nilgiri hills for formation of Puerto Rico or California type terraces is an example of the importance of a vegetative barrier (Chinnamani and Rege, 1965). Vegetative barriers in resource conservation and crop productivity on sloppy lands are found cost-effective, sustainable and as good as earthen bunds up to 1.5% slopy lands at Indore and up to 4% at Dehradun (Bhardwaj, 1997). The suitability of a vegetative barrier is highly location specific and no single barrier can be recommended for universal application. Prakash et al. (1999) have listed suitable vegetative barriers for different agro climatic regions of India.

When perennial plants are grown as hedge rows, they offer several benefits like controlling soil erosion and additional biomass production although they have marginal negative effects on crop yields which can be overcome with appropriate management of the hedge row (Narain et al. 1998a). The loss due to yield reduction can be compensated by the tree biomass (Narain et al. 1998b). Moreover, perennial plants as hedge rows help in checking runoff and soil loss. A study conducted at Dehradun indicated that sediment deposition along hedge rows during a period of three years and tree rows in nine years varied from 184 to 256 t ha^{-1} which is equivalent to 15 to 20 mm of soil depth (Table 6).

Table 6. Sediment deposition, along hedges and tree rows at Dehradun

Vegetative barrier	Year of existence	Sediment deposited ($t\ ha^{-1}\ yr^{-1}$)	Av. deposition ($t\ ha^{-1}\ yr^{-1}$)	Soil loss ($t\ ha^{-1}\ yr^{-1}$)
Leucaena hedges in turmeric field	3	47	16	7.6
Leucaena hedges in maize field	3	184	61	12
Leucaena trees in maize field	9	257	29	8.8
Eucalyptus trees in maize field	9	186	21	5.8
Leucaena trees in turmeric field	9	90	10	6.8
Eucalyptus trees in turmeric field	9	157	12	7.0

The average resource loss and returns due to biomass production from some important trees + grass hedge row systems are given below:

Eucalyptus + Bhabar grass: Eucalyptus tereticornis and Bhabar grass (Eulaliopsis binata) were raised in Shiwalik foothills in light textured soil @ 2500 trees ha^{-1} in paired rows with under storey grass planted at 50 cm x 50 cm spacings. The system allowed no soil loss with an annual return of about Rs. 4000 ha^{-1} yr^{-1} from commercial grass alone besides additional returns from Eucalyptus and proved to be more remunerative than traditional rain-fed crops.

Poplar + Leucaena + Bhabar grass: In a study on a sandy loam soil (with 2% slope) planted with Populus deltoides at 4m x 4m and Leucaena leucocephala at 2m x 2m and Bhabar grass (Eulaliopsis binata) at 0.5 m x 0.5 m spacings and bunding with 15 cm high tied ridges in Doon valleny, the mean runoff was 4.7% and soil loss 1.6 t ha^{-1} yr^{-1} from the system against 25-30% runoff and 5-10 t ha^{-1} yr^{-1} soil loss under traditional farming (Grewal, 1988). The average net return of Rs. 3,556 ha^{-1} yr^{-1} obtained from grass alone was higher than the returns from field crops in addition to returns from poplar and Leucaena.

Acacia + Bhabar grass: Seven Acacia spps were raised on 30-40% bouldery slopy land at 3m x 3m spacing by planting Bhabar grass (E.binata) at 75 cm x 75 cm spacing at Chandigarh. The average of 6 years production of air dry grass biomass varied from 2.2 t ha^{-1} in Acacia suma to 4.3 t ha^{-1} in Acacia senegal with net returns of Rs. 2,000 to Rs. 3,400 ha^{-1} yr^{-1} from a degraded marginal land recording only 1.5 t ha^{-1} soil loss in addition to returns from trees.

These 3 illustrations clearly indicate that silvi-pasture systems with a tree grass combination have immense potential for resource conservation and also provide higher economic returns as compared to crops in degraded lands.

Cropping Systems and Resource Conservation

Intercropping with low level canopy crops like greengram, blackgram, cowpea, soybean and groundnut in inter-row spaces of crops like maize, sorghum, Pearl millet and castor provides sufficient ground cover and thereby reduces soil erosion apart from insurance against weather aberrations in arable lands. These crop combinations can be used as alternative to the sole crop. Where economic returns are comparable, these inter cropping systems should be preferred by the farmers from soil conservation point of view. Similarly, mixed cropping also provides protection against soil erosion and ensures atleast one crop under adverse climatic conditions in semi-arid and hilly regions against complete crop failure. Cropping systems with higher conservation efficiency have been identified under different agro-climatic conditions (Table 7).

Intercropping of maize with cowpea and soybean was found promising in Doon Valley. In the NEH region, maize + rice intercropping reduced runoff by 29.8% and soil loss by 33.4% (Awasthi et al. 1990). The nitrogen dose to sorghum was reduced from 75 to 25 kg N ha^{-1} through intercropping of pigeonpea with sorghum at Kota in 1:1 ratio (Narain et al. 1980). Growing of maize and clusterbean in 9 m long alternate strips was 15% more remunerative over sole maize in the Shiwalik foothills (Mittal et al. 1988).

Table 7. Recommended alternate cropping systems and their conservation efficiencies over common land uses in different regions

Region	Rainfall (mm)	Soil type	Slope (%)	Common cropping system	Recommended cropping system	Conservation efficiency (%)	
						Runoff	Soil loss
Dehradun	1250	Alluvial	811	Maize	Maize+cowpea	18.4	46.1
				Maize	Maize+cowpea	21.9	17.9
				Maize	Maize+soybean	42.0	54.0
				Maize	Maize+sunnhemp for mulching		
Chandigarh	1000	Alluvial	1.5	Maize	Maize+blackgram	8.6	29.8
Agra	730	Alluvial	2	Bajra	Bajra+greengram	-	35.0
Kota	657	Black	1	Sorghum	Groundnut	28.2	58.3
				Sorghum	Sorghum+pigeonpea	44.6	-
					Sorghum+safflower	55.4	9.4
Vasad	790	Alluvial	2	*Bidi* tobacco	Sunnhemp-*bidi* tobacco	56.2	8.3
						27.9	4.3
					Bajra+greengram		
Deochanda	1002	Red	25	Maize	Maize+blackgram	0.0	11.8
				Maize	Maize+pigeonpea	-3.1	26.5
					Groundnut	0.3	41.1
Udhaga-mandalam	1130	Lateritic	25	Potato along the slope	Potato across the slope	44.2	62.3

Source: Bhan and Singh (1994), Khola and Saroj (1996), Samra and Narain (1998).

Slope Agricultural Land Technology (SALT)

The method of growing seasonal and perennial crops in 3 m to 5 m wide bands between contour rows of N fixing trees is called as Slope Agricultural Land Technology (SALT). The N fixing trees are thickly planted in double rows to make hedgerows. When a hedge is 1.5 to 2 m tall, it is lopped to about 40 cm height and the loppings are placed in alleys to serve as mulch cum manure. This practice improves soil organic matter and other physico-chemical properties in the hill and mountain ecosystem. Inclusion of animal and horticultural components makes the system more self-sustainable. Palmer (1991) reported that annual soil loss from the SALT system was only 3.4 t ha^{-1} which is well within the tolerance limits of 10-12 t ha^{-1} for the tropics.

Land Use Diversification for Sustaining Gains from Watershed Projects

Although, integrated watershed approach results in gains in terms of resource conservation and productivity, most often these gains are not sustainable beyond the project period. However, if perennial components like fodder trees, grasses and fruit species are part of the project interventions according to the land capability, the project gains continue even after discontinuation of the project. Evaluation of several watershed projects across the country revealed that the sustenance of the gains is higher with the introduction of fruit or fodder component. This is illustrated from the experiences of Fakot watershed in Tehri-Garhwal region of Uttarakhand (Table 8). The alternate land use systems continued to increase production of food, fodder and fruits even beyond the project period. It also decreased runoff and soil loss and the dependence of the community on forest fodder. Watershed community diversified from traditional low yielding crops of Mandua and Jhingora to other value added crops like fruits, vegetables, spices and floriculture as an alternate land use system.

Table 8. Impact of integrated watershed management and alternate land uses on production and protection at Fakot in Uttarakhand

Product	Pre-project	During interventions	After withdrawal of external interventions
	(1974-75)	(1975-86)	(1987-04)
Food crops (q)	88.2	4015	7502
Fruit (q)	Negligible	62	2562
Milk ('000 lit.)	57,000	184.8	342.9
Income from cash crops ('000 Rs.)	6.5	24.8	927.6
Animal grazing	Heavy open grazing	Partial grazing	Stall feeding
Dependency on forest fodder (%)	60	46	20
Runoff (%)	42	18	14
Soil loss (t ha^{-1} yr^{-1})	11.1	2.7	< 2

Evaluation of watershed management programs in 32 watersheds from 10 major agro-ecological regions of the country by Ram Babu et al. (1997) revealed that soil loss decreased by 10-80% and runoff by 2 to 40% with a simultaneous increase in productivity of arable lands. Crop diversification and alternate land uses particularly in non-arable lands played a significant role in affecting these gains.

Impact of Alternated Land Uses in Watershed Programs

In the integrated watershed development projects (IWDP) of ministry of rural development, a number of watersheds were developed across the country where alternate land uses like planting of perennial grasses and fruit plants on the bunds and hedge rows of multipurpose shrubs and trees were critical components. These include Aganpur Bhagwasi in Patiala (Punjab), Antisar in Kheda (Gujrat), Badakheda in Bundi (Rajasthan), Bajni in Datia (MP), Kokriguda in Koraput (Orissa) and Salaiyur in Coimbatore (Tamil Nadu).

Impact analysis revealed that runoff from the watersheds reduced by 9 to 24% and soil loss by 72% on an average (Sharda et al., 2005). Overall Crop Productivity Index (CPI) increased by 12% to 45% with average increase in productivity by 28%. Crop Diversification Index (CDI) also increased by 6 to 79% in the watersheds with average increase of 22%, thereby minimizing risk of crop failure. Similarly, cultivated Land Utilization Index (CLUI) and Induced Watershed Eco Index (IWEI) also showed significant improvement during the 6 year period of the projects. The average annual income per family increased by 43% due to employment and income-generating activities. The projects were economically viable with overall B:C ratio of more than 1.14. Although the exact contribution of perennial vegetation used for resource conservation and biomass production in these watersheds cannot be delineated in the overall profitability, it can be clearly stated that these interventions were critical for the success of the above watersheds.

Alternate Land Uses Systems for Problem Soils/Areas

Large area in the country suffers from site specific environmental constraints with significant costs for rehabilitation and loss in productivity. Mechanical and engineering methods for rehabilitating such lands are not only expensive but also time consuming. Bio engineering or vegetation based rehabilitation approaches are better alternatives for such problem areas. The following account gives the successful bio-engineering approaches for a wide variety of problem areas in the country.

Degraded Riverbeds: Riverbeds generally comprise 65-80% boulders, stones and pebbles and 20-35% coarse and fine sand material. In Doon Valley, these riverbeds were best utilized for silvi-pastoral systems of Dalbergia sissoo and Chrysopogon fulvus realizing 3.37 t ha^{-1} yr^{-1} of wood and 5.5 t ha^{-1} yr^{-1} of air dry grass. Plantation of Albizia lebbeck at 4 m x 4 m with Chrysopogon fulvus at 1 m x 0.5 m produced oven dry lopped fodder of 75.7 q ha^{-1}, air dry fuel wood of 9.7 q ha^{-1} and oven dry grass of > 40 q ha^{-1}. Combinations of Eulaliopsis binata with Grewia and Bauhinia fodder trees were also found promising.

Minespoils: Degraded minespoil watersheds (64 ha) near Sahastradhara in Doon Valley could be rehabilitated with bio-engineering measures and geo-jute at a cost of Rs. 15,000 ha^{-1}. Mass erosion reduced from 550 to 8 t ha^{-1} and runoff from 57% to 37% with increased lean period flow in streams from 60 days to 240 days due to enhanced vegetative cover from 10% to 80%. Sustainable yield of grasses and fodder was obtained by planting A.catechu, Cedrella toona, Leucaena, Lannea grandis, Salix etc., bushes (Ipomoea cornea, Vitex negundo, etc.) and grasses (Chrysopogon fulvus, Napier, Eulaliopsis binata, Saccharum spontaneum etc.). In addition, PWD icould save Rs. 1.0 lakh yr^{-1} which they used to spend for removing debris from the road leading to the tourist place. Similarly, CAZRI, Jodhpur, has developed a package of practices for rehabilitation of gypsum minespoils in western Rajasthan which is based on soil conservation and revegetation approaches.

Landslide Prone Areas: Areas affected by landslide problems in the Himalayan region can be reclaimed and utilized for biomass production by adopting suitable technology. The Nalota Nala landslide watershed in Mussoorie hills was rehabilitated by training the lower reaches of the torrent and stabilizing the debris cone in the middle reaches, landslips and landslides. Bare erodible slopes were protected by planting deep rooted shrubs and grasses such as Pennisetum purpureum, Ipomoea cornea, Vitex negundo and Pueraria hirsuta which proved to be very effective. Conservation measures like gabion check dams, toe walls, spurs, drop structures, mulching, contour wattling, plantations coupled with social fencing proved to be very successful (Table 9).

Shifting Cultivation Areas: Shifting cultivation, locally called as jhuming, is extensively practiced in NEH region, Andhra Pradesh, Madhya Pradesh and Bihar. The total area under shifting cultivation is about 2.38 m ha-1, out of which NEH alone accounts for more than 2.0 m ha. This practice results in heavy soil losses, particularly in short fallow cycles. In NEH region, shifting cultivation at 50 to 60% slope recorded 146.6, 170.2 t ha^{-1} yr^{-1} of soil loss in first and second years of cultivation, respectively and 30.2 and 8.2 t ha^{-1} yr^{-1} in abandoned fields and bamboo forest, respectively.

Table 9. Stabilization of landslide affected area in Nalota Nala watershed through bio-engineering measures

Particulars	Pre-treatment (1964)	After treatment (1994)
Runoff (mm)	55	38
Dry weather flow (days)	100	250
Sediment load (t ha^{-1} yr^{-1})	320	5.5
Vegetation cover (%)	< 5	> 95
Nala bed slope (%)		
Lower reach	12	7
Middle reach	23	14
Upper reach	54	44
Toe cutting	Severe	Nil

As an alternative to shifting cultivation, a silvi-agri-horticulture model wherein 35% hill top is allotted to forestry, middle 30% to horticulture, lower 35% to agriculture and farm pond including valley land. In agri-horticulture system, lower 1/3rd area is bench terraced for agriculture and upper 2/3rd area with half moon shaped terraces is used for horticulture. The model reduced runoff from 144 mm and soil loss from 49 t ha^{-1} yr^{-1} under shifting cultivation to 57mm and 3.0 t ha^{-1} in agro-horticulture and 95 mm and 2.3 t ha^{-1} under agriculture, respectively, besides increased productivity of land.

Degraded Shiwalik Areas: In the Shiwaliks, along with other mechanical measures, planting of trees and grasses in the catchment area played an important role not only in conservation of resources but also in providing food, fuel, fodder and fruit to the community. The contribution of bhabhar grass in particular has been highly significant. It gave a boost to livestock production where large animals replaced the small ruminants and the milk production increased.

Degraded Ravine Lands: Studies at regional Centres Agra, Kota and Vasad of CSWCRTI on Yamuna (UP), Chambal (Rajasthan) and Mahi (Gujarat) rivers, respectively have shown that 2.68 m ha ravines, which are extremely eroded and do not support vegetation systems can be stocked with lushgreen fuel-fodder plantations following integrated land use planning with soil and water conservation measures. Conservation techniques for rehabilitation of degraded ravines are:

i. closure of ravines from biotic interference;
ii. construction of diversion bund at a distance two times the depth of gully and allowing water to enter the ravine through chute spillways;
iii. construction of series of vegetative checks at 0.9 m VI with pipe outlets;

iv. plantation of hump top with A.nilotica, Prosopis juliflora, slopes with Cenchrus ciliaris or Dichanthium annulatum and beds with Dendrocalamus strictus following approved soil working techniques.

In Kota and Vasad, due to thinning of 30% culms of bamboo after three years of planting farmers got an yield of Rs. 2800 ha^{-1} yr^{-1} during the severe drought years. Besides fodder grass, fuel wood could be obtained from ravines. Total income from well managed ravines was as much as from good rain-fed agriculture lands. Once the vegetation has been established, grazing of 3-4 goats ha^{-1} has no adverse effect on the ecology of the area. Ravinous catchments of Chambal at Kota planted with Acacia + D.annulatum and D.annulatum alone generated 5.8 and 2.6% of runoff and 1.26 and 0.62 t ha^{-1} of soil loss, respectively compared to 14.7% of runoff and 3 t ha^{-1} of soil loss from agricultural catchments. Production of 4.5 t ha^{-1} of air dry grass + firewood from such degraded lands proved the effectiveness of grasses and trees as an alternative land use for protection and productive utilization of degraded ravine lands.

Degraded Lands of Southern Peninsula: Silvipasture is an ideal land use for the degraded lands in the peninsular region. Leucaena leucocephala + Stylosanthes hamata/Cenchrus ciliaris system was found very productive and profitable in these situations. The average annual yield of under-storey Cenchrus was 2.5 t ha^{-1} and that of stylo was 4.4 t ha^{-1} (DW basis). With a cutting cycle of 8 years, Leucaena yielded 60 t ha^{-1} ha pulpwood (FW) after 8 yrs, the yield of other non-pulp biomass was about 60 tons per ha. The Leucaena wood was marketed for paper pulp. The pulpwood was sold at Rs.621 per ton (1997) at farm gate excluding cost of cutting, loading and transport. The system also brought about improvement in the soil fertility (G.R.Korwar, CRIDA personal communication, 1998). This system needs protection from the stray cattle during the off-season. In extremely denuded common lands, allowing natural regeneration involving PRI institutions was adopted as a successful strategy by NGOs (FES, 2005). Such approach ensured community participation in restoration of degraded lands and sense of ownership.

Degraded Lands in Arid Zone: About 10.46 m ha area of the country is under arid zone of Thar Desert covering states of Rajasthan, Gujarat and Haryana, of which 62% is in western Rajasthan experiencing extreme aridity with rainfall as low as 120 mm and temperature as high as 45^{o}C. CAZRI, Jodhpur, has evolved viable technology for afforestation of sand dunes, which includes perennial trees and grasses as the most critical components.

Prosopis cineraria is the most preferred tree by the farmers due to its synergetic effect on grasses. An average plant yields 15 kg dry leaf fodder and 5 kg dry pods per year. Other species are Ziziphus nummularia, A.tortilis, Albizia lebbeck and Calligonum polygonoides. Sand dunes may be used by creating check-board or parallel hedges of brushwood with vegetative barriers of P chilensis, A tortilis, P cineraria, Agave and Ziziphus nummularia with Lasirus sindicus and P antidotale.

Salt-Affected Areas: Agroforestry has emerged as an ideal option at Karnal for saline-alkali lands of northern Indo-Gangetic plains, which are reported to generate 44-87% of runoff. About 20 years old plantations of Prosopis, Acacia, Temtinali albizzia and Eucalyptus reduced pH from 10.5 to 8.01 and EC from 1.75 to 0.45 ds/m, improved organic carbon and physical properties making such lands fit for agriculture. Central Soil Salinity Research Institute, Karnal, has developed technology for rehabilitation of salt-affected lands. An economic auger hole technique has been perfected for afforesting these lands. Promising trees for alkali lands are: Prosopis juliflora, Acacia nilotica, Casuarina equisatifolia, Terminalia arjuna and Tamarix articulata and grasses are: Leptochloa fusca, Chloris gayana and Brachiaria mutica. Tree based fencing with E tereticornis, A nilotica and Perkinsonia aculeate planted on ridges with parallel trenches conserved entire runoff and soil, which lasted for 128 to 157 days. The most promising system evolved is planting alkali lands with P juliflora (2 m x 2 m) +L fusca, which produced 161 t ha^{-1} of biomass and 56 t ha^{-1} of grass in six years while reclaiming such lands appreciably.

In another study by Singh et.al (1997), Populus deltoids (Poplar), Eucalyptus tereticornis, Acacia nilotica and Tectona grandis were identified as suitable trees for agroforestry in reclaimed alkali lands in north west India. The suitable intercrops during establishment stage identified were: rice-berseem and rice-wheat. From third year onwards shade loving species like berseem, guinea grass, turmeric and Colacasia performed better than rice and wheat. Populus based agroforestry proved more remunerative because of its faster growth and high wood price compared to Eucalyptus and Acacia based systems. In addition to better economic returns, these also resulted in better fertility and organic matter build up in the soil (Table 10).

Table 10. Effect of land use systems on chemical properties of moderately alkaline soil

Land use system based on	pH	EC (dS/m)	OC (%)	Available N (kg ha^{-1})
Acacia	-0.26	-0.26	+0.20	+31
Populus	-0.80	-0.25	+0.12	+25
Eucalyptus	-0.67	-0.29	+0.12	+21
Agriculture	-0.45	-0.11	+0.07	+10

+ denotes increase – denotes decrease (Singh et al. 1997)

Alternate Land Use Systems and Organic Farming

Organic farming is emerging as an important production system particularly for low input rain-fed areas. Based on the natural resource endowments and the level of input use, hilly, tribal and rain-fed areas are reported to have better potential for organic farming. Venkateswarlu (2004) has outlined certain important requirements for successful organic farming in rain-fed areas. The two most critical components are soil and moisture conservation, and biomass production for recycling. Agroforestry and bund farming are ideal land uses to promote organic farming on watershed basis. Rupela et al. (2006) clearly brought out the potential of biomass production on the bunds as an important input for organic production of rain-fed crops based on a long term experiments under semi-arid conditions. It is desirable to take up certified organic production in the entire watershed since the chemical contamination due to runoff will effect the crop quality if such production is taken up in isolated pockets within the watersheds. The available knowledge on agroforestry, particularly the biomass production strategies have to be integrated with organic farming in these areas. In other words, organic estates can be developed in selected watersheds in hilly and tribal areas by careful selection of crops, which have export demand and application of the knowledge of integrated watershed management that includes soil and water conservation, biomass production, fodder development and livestock production.

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10. Farming Systems in Watersheds

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Abstract

This paper tries to understand how the farming systems approach to land use could be a strategy that ensures the efficient utilisation of all resources and maintains stability in production and yields high net returns. The superimposition farming systems in watershed development attains therefore significance as it leads to increased farm productivity through improved water use efficiency.

Keywords: Farming systems, crop-livestock, watershed, self helf group, income.

Introduction

India supports 16% of the human population of the world with only 2.4% of the earth's geographical area. This situation is further aggravated by the presence of 18% of the cattle population of the world. Vast areas of land in the country are in a highly degraded state because of loss of vegetal cover, erosion, over-exploitation and inadequacy of overall management strategies. Consequently, 57% of the total geographical area of 329 million ha is afflicted by some form of land degradation. The detailed district-wise mapping of the National Remote Sensing Agency has identified 63.85 million ha as degraded land, which is commonly known as wasteland. The situation demands appropriate treatment of degraded lands to increase their productivity so that the standards of living of those who depend on such resources can be improved. The principal contributory factors to low farm productivity in India are the twin constraints of degraded land and insufficient water availability. It has been proven conclusively that this situation can be overcome by micro-watershed based development.

Although species diversity was an inherent characteristic of most traditional farm production systems, they lacked systematic arrangement of the components. As a result, there was inefficiency in the utilisation of physical and environmental resources, leading to low productivity. Technologies introduced over the years to intensify farm production deviated away from the traditional practice of maintaining species diversity. The outcome was the short-term increase in productivity followed by decline of crop yields in the longer term. The current farming systems approach strives to integrate the component species in such a way that productivity is maximised without compromising on the sustainability of production in the long run. Another key requirement for increasing productivity is the management of natural resources of the farm. Of particular interest in this regard is the management of soil and water, which is addressed by the large-scale implementation of watershed development projects in various parts of the country. Thus, the combination of farming systems introduction and watershed development has the potential to boost small farm productivity under resource-limited conditions.

Strategies and Approach

Concepts of Farming System and Watershed

A farming system is defined as a population of individual farm systems having comparable resource base, enterprise pattern, livelihood and constraints for which almost similar development strategies and interventions would be appropriate. Depending upon the scale of the analysis, a farming system can encompass a few dozen to millions of households (Subba Reddy and Ramakrishna, 2005). A farming system primarily comprises structural components such as crops, trees and livestock, and the functional inter-relationships among them. The system also includes the natural resources within the command of the farmer in the form of land types, water bodies and access to common property resources (Dixon et al. 2001). The level of success of the interaction of the components with the resources determines the farm output. Crop-livestock mixed farming systems are popularly practised in India, particularly by smallholders (Singh, 2005). The farming systems approach to land use is a strategy that ensures the efficient utilisation of all resources and maintains stability in production and yields high net returns. It is in this regard the superimposition farming systems in watershed development attains significance as it leads to increased farm productivity through improved water use efficiency.

Watershed is a geo-hydrological and biological unit draining through a common outlet. Because watershed development encompasses the living and non-living entities of a dynamic system, a complete understanding of the overall system and its sub-systems is necessary. Moreover, watershed development should address those aspects of physical and biological elements that are required for sustainable self-reliance as well as inter-dependence. Hence the inclusion of all the elements of a watershed is necessary while planning its development. It is natural for soil and water conservation to be the core activities. Soil conservation is aimed at protecting the soil from wind and water erosion, besides improving the microbial activities in the soil to make it a living entity. Water conservation is achieved through both engineering and biological measures. In addition to soil and water conservation, watershed development should address issues related to achieving sustainable development. The water resources created in the watershed program have to be gainfully utilized and farming systems approach further strengthens this cause. Improved fodder resources created as a consequence of watershed programs will have additive role in development of milch animals. The alternate livelihood options, viz. fishing, etc., would add to watershed plus activities.

Functional Overlap between Farming System and Watershed Activities

There are many components within a farm such as soil characteristics and water bodies that are common to both farming system and watershed. Therefore, any development initiative on one aspect will directly or indirectly will influence the other. For example, enhancement in soil organic matter as a result of introducing a tree-based farming system will increase the water holding capacity of the soil. Such an improvement in soil water status and the associated water use efficiency is also a benefit sought through watershed development. Similarly, growth in the number of farm enterprises stemming from greater availability of water can be attributed to both farming systems approach as well as watershed development. As described below, other key strategies adopted in watershed development have strong relevance to farming systems approach. Period of activity (of farmers) on the farmland would be extended beyond seasonal cropping period, possibly year round activity, thus leading to better soil and crop care.

Being a livelihood system, watershed development should satisfy the basic human needs. In the watershed development projects implemented in the country during the last fifteen years, the emphasis has been on soil and water conservation. Although it is implied, the complete livelihood support system is seldom taken into account while planning and implementing watershed development projects. Thus, the basic needs relating to livelihood may or may not be satisfied even after the watershed project is implemented. In order to address these issues, additional activities have been introduced after soil and water conservation activities are completed. This set of activities, known as watershed plus, cannot be looked at separately from a watershed development project. Watershed development design should incorporate all such measures that provide livelihood support to the dependent households. Hence, activities that are essentially farming system components like improved agricultural practices including horticulture and tree based farming, development of livestock, enhancing fodder production, fishery, on-farm and off-farm enterprises become a part of the watershed plus project design. Thus the family labour would be gainfully utilized on the farm. Basically the goal of a watershed project and also that of a farming systems project are to achieve at least food, water, fodder, fuel and employment security. The other priorities may include drinking water supply and sanitation, agricultural and domestic waste recycling through accelerated composting methods, waste water recycling through kitchen gardening or passing through aquatic grasses and trees, market linkage for the local produce, health and hygiene.

Procedures and Practices

There is no standardised set of procedures or practices for combining farming systems and watershed development. There are multiple products as insurance against drought/price fluctuations/glut, etc., improvement in livelihoods and quality of life. Utilization of products/by-products of one component into the other on the farm itself and mutual benefit (positive interaction) are among the different components avoiding clash for labour and other inputs. The strategy successfully adopted by BAIF Development Research Foundation, a non-government organisation based in Pune, is detailed in this section, but other alternatives are also possible. BAIF has been engaged in popularising farming systems approach to improve the livelihood and quality of life of socially and economically backward communities. Initially, farming systems strategy was adopted for livelihood improvement through family-focused interventions such as livestock development, tree based farming, processing and marketing of agricultural produce. Subsequently, in some project areas, this farming systems program was integrated with watershed development. The biophysical and socio-economic characteristics of these project locations in different parts of the country had many similarities in the form of degraded wastelands, erratic rainfall, drinking water scarcity, single season rain-fed agriculture, low farm income and dependence on off-farm employment to mitigate poverty. BAIF's development initiatives under such circumstances focus on the rehabilitation of natural resources through people's participation and build their capacities for the sustainable management of their assets. This is achieved by the formation of people's organisations at the beginning of the project itself so that they had a decisive role during the implementation phase and then the responsibility of maintenance and sharing of the resources during the post-project stage. The principal features of the project implementation process of BAIF are described below.

Micro-Plan Preparation

The first stage in the development planning is to draw up a micro-plan for each farm that will be participating in the project. This micro planning is done jointly by the project implementing agency and the stakeholders. The treatments or plans are prepared based on the status of natural resources (land, water, vegetation and livestock), field boundaries, slope of the land, drainage, land use and cropping pattern. Activities are selected in such a way that benefits accrue to the landowner as well as the watershed as a whole. The broad steps involved in micro planning are as follows:

- keeping in mind the broad objectives of the project, make a checklist of information to be gathered through participatory rural appraisals (PRAs) and secondary data sources;
- develop formats for collecting information at survey/gut number level as well as watershed level;
- facilitate PRAs, with appropriate guidelines from experienced professionals;
- keep the following maps ready - village map (cadastral map) toposheet, satellite image (if available), drainage map, geological and hydro-geological maps/ information, land capability, land use information and PRA outputs;
- collect field level (individual farmer level/survey number level) information with the help of the land owners (both male and female) and other community representatives. This includes information on land area, land slope field boundaries, soil type, present land use, cropping pattern, water availability, vegetation (fruits and forestry trees, grasses) and livestock;
- based on the collected information, prepare the detailed plan for conservation of soil and water as well as efficient land and water use for optimum and sustainable productivity;
- develop free hand sketches for each individual farm showing the present status and proposed treatment measures;
- in consultation with the community, develop similar plans for common and forestlands within the watershed.

Although the plans for farming systems and watershed cannot be totally independent of each other, the individual farm plan will have a greater emphasis on the farming system while the overall plan will be for the watershed. Based on land capability class and resources available with the households the resource management and utilisation plans are prepared. Non-arable slopes are generally brought under forestry or silvipasture, agri-horti-forestry is planned in the midlands and intensive agriculture in the lowlands.

Implementation

Area treatment measures are implemented with the ridge to valley principle. In addition to the basic soil and water conservation measures, the non-farm lands are treated in such way that fodder availability for livestock in the villages is substantially improved. Planning and implementation of water resources is undertaken to make its optimum use for increasing the area under irrigation and also making it available for domestic and livestock uses. Along with the area-based activities, individual farm development measures are also implemented as per the micro-plans. The project team consisting of the implementing agency and the participants are assigned specific responsibilities so that several activities get carried out simultaneously.

The physical development for individual farms and the watershed as a whole are accompanied by activities that are aimed at community mobilisation and capacity building. A major initiative in this regard is the empowerment of women through the organisation of self help groups (SHGs). Consisting of 10-20 individuals, these groups build up a corpus fund with their subscriptions, which is then made use of to avail micro-credit to meet their consumptive and production needs. Additionally, the groups are trained to take up income generation activities such as fruit and forestry nursery management, mushroom production, vermicomposting, vegetable production, sericulture, share cropping on lands owned by non-participating families, food processing and backyard poultry and piggery. Youth from landless and small holding families are selected for training in employment-oriented skills such as carpentry, masonry, processing of fruits and vegetables and marketing. Such activities help the participating families improve their skills and capabilities useful for self-employment and income generation. In order to ensure the sustainability of the initiatives, it is necessary to set in place post-harvest requirements like processing and establishment of market links. Moreover, cooperatives of project participants are established to facilitate action for input procurement, value addition, and marketing of produce.

Development Experiences (Case Studies/Success Stories)

The experiences narrated by beneficiaries of farming systems-watershed programs are usually similar. Before the implementation of these programs, their livelihood depended on a single rain-fed crop. Development activities that brought about improvement in soil and water conditions as well as agronomic practices resulted in a majority of the beneficiaries growing two crops. Moreover, it is now common to grow a third crop during the summer. The vegetation component also increased in diversity by the inclusion of horticultural crops like mango and multipurpose trees while the livestock component transformed from free-grazing native cattle to stall-fed crossbred animals. The change in cropping intensity in projects implemented by BAIF in Gujarat is presented in Table. 1.

Table 1. Cropping intensity before and after watershed development.

Stage	Season	Tribal farmers	Non-tribal farmers
Before watershed	*Kharif* (%)	87.0	79.4
	Rabi (%)	11.0	35.6
	Summer (%)	5.0	5.0
	Total	103.0	120.0
After watershed	*Kharif* (%)	91.1	75.7
	Rabi (%)	26.7	44.9
	Summer (%)	10.0	10.0
	Total	127.8	130.6
Percentage increase in cropping intensity (%)		24.8	10.6

Although increase in cropping intensity and the inclusion of livestock are the common features of most farming systems, there are others that have been very successful in India. Fish is raised in a rain-fed rice-based production system in Orissa by collecting the downstream water in ponds (James et al. 2005). The average fish yield in this system was 1100 kg ha^{-1} in six months, which is an additional return for the rice farm. Similarly, the net returns of Rs. 59,500 from a rice-fish-wheat system in Ranchi were several times higher than the rice only system (TAR-IVLP, 2004).

In nutritive cereal based production system, the cropping pattern with 35.39% of food grains and 25.71% of pulses 20.7% of oilseeds, 17.3% of commercial crops and 1.17% of fodder crops in total holdings of small farmers with backyard poultry (6 birds) helped the farmers to stabilize the farm income at Dharwad (TAR-IVLP, 2005).

Agri-sheep farming with 10 lambs and growing crops and use of farm by products in one ha of marginal lands gave the net returns of Rs. 8700 ha^{-1} as compared to growing cotton alone at Warangal in Andhra Pradesh (Rs. 27500 ha^{-1}) under cotton based production system (TAR-IVLP, 2003).

Studies at Kovilpatti indicated that farming system module crop + goat + poultry + sheep + dairy recorded the highest gross income (Rs. 35301) followed by crop + goat + poultry + dairy (Rs. 30807), while the conventional system having a crop cultivation alone gave only Rs. 5860 ha^{-1} as gross income. Employment has been increased from 75 man-days in conventional cropping system to 272 man days in IFS model D involving crop + goat + poultry + sheep + dairy and 227 man days in IFS model B involving crop + goat + poultry + dairy. (AICRPDA, Kovilpatti, 2006).

A tree-based farming system has been highly successful in the rehabilitation of wasteland owned by poor small farmers in several states. The vegetation in this particular model is arranged in such a way that species such as mango and cashew are planted at their recommended spacing ranging from 6.0 to 10 m apart in both directions and annual crops are grown in the interspaces. The entire farm or the plot where these crops are grown is enclosed in a live fencing with multipurpose tree species like leucaena and Glyricidia. The farming system in this case is made up of the above components, besides other resources and enterprises of the farmer. These include livestock that may be housed in the homestead and private or community water bodies. Combining farming systems approach with watershed development activity yields several-fold increase in returns to participating farmers.

Recommendation for Practitioners

Select appropriate agroforestry systems/species (including fruit species), animals looking into adaptability, demand for the products and marketing avenues for the same; the total input requirements of the components should be calculated in advance, as far as possible; the products of one component are input for the other component.

Investment Needs by Local/Government

Investment needs and infrastructure development by the local bodies/government is needed in the following areas/facilities:

- seed and other input availability;
- processing facilities;
- storage facilities;
- marketing.

Policy and Financial Incentives

- Incentives for farm produced inputs viz. vermicompost, green manure, green leaf manure, firewood, etc.
- Laws for protection of trees planted in common/private lands from stray animals.
- Making available common lands and other common property resources (CPRs) physically for use by the village community including the landless.
- Financial support at lower interest rates support prices for all commodities including perishables.

Conclusion

Farming systems (FS) approach in watersheds (WS) would give a logical end to the watershed program and would have economic advantage, resulting in increased, sustainable and stable income to all the stakeholders. Improved livelihoods, quality of life, year round income, activity and gainful employment of family labour are another positive features of FS in WS. While WS program is more towards community approach, the FS program is more towards individual effort.

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11. Integrated Nutrient Management Sustainable for Land Use in Watersheds

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Abstract

Apart from water shortage, the productivity in rain-fed systems is also constrained by low soil fertility. The soils in the SAT regions generally have low organic matter and nutrient reserves. Extensive survey of the farmers' fields in the SAT regions of India revealed that the deficiencies of sulfur, boron and zinc are very widespread and in most cases 80-100% farmers' fields were found critically deficient in these nutrients. This paper underscores the need to integrate soil and water conserving practices with balanced nutrition of crops by adopting INM.

Keywords: Community participation, watersheds, knowledge sharing, entry point activity.

Introduction

Increasing needs of food, feed, fuel and fiber for the ever increasing population in the semi-arid tropical (SAT) regions of the developing world is putting pressure on the rain-fed areas to make greater contribution from the vast area under dryland agriculture. The smallholder farmers rely on the dryland subsistence productivity for their livelihood and the productivity of dryland systems remains low due to low and erratic distribution of rainfall coupled with low to negligible inputs of nutrients. Maintenance of soil organic matter is a challenge, because of competing uses of organic materials and crop residues. Organic matter is not just the source of nutrients, but is essential for preserving soil's physical, chemical and biological integrity for the soil to perform upto its productivity, health and environment-related functions on a continuing basis. With little investment in the management of soils, large area under dryland agriculture is in various stages of physical, chemical and biological degradation. Thus combating land degradation and increasing productivity of drylands is a major challenge for conserving the integrity of dryland soils (Singh et al. 2004). To achieve sustainable improvement in dryland productivity, there is need to have a holistic approach in which soil and water conservation practices are implemented along with integrated nutrient management strategy (INM) (Wani et al. 2003, 2005).

Fertility–Related Constraints

Diagnosis of Soil Fertility Problems for Enhancing Crop Production

Farm holdings in the SAT are not only distinct in terms of size, shape and location on a toposequence but also vary widely for the cropping patterns, quality and quantity of nutrients used for cop production. Major constraint is the timely availability of knowledge and right information about soil health for the farmers. As described below, farmers do not know what is ailing their farm in general. It is of utmost importance to establish soil quality analytical laboratories in each district of a state to provide timely and correct information to the farmers relating to the diagnosis of soil fertility constraints and physical and biological conditions.

Apart from water shortage, the productivity in rain-fed systems is also constrained by low soil fertility. The soils in the SAT regions generally have low organic matter and nutrient reserves. Soil erosion removes the top soil layer, which not only results in the loss of soil but also in loss of organic matter and plant nutrients, which largely are stored in the top soil layer (Wani et al. 2003). Among the major nutrients, nitrogen is universally deficient and phosphorus deficiency ranks only next to nitrogen in most of the SAT soils. Our work has also shown that potassium reserves in the SAT soils are generally adequate (Rego et al. 2007). Most of the SAT soils have low to moderate phosphorus absorption capacity and most of the rain-fed systems require low to moderate rates of phosphorus applications to meet their phosphorus requirements, considering residual benefits also (Sahrawat et al. 1995; Sahrawat 1999, 2000). Many of the farmers' fields in the SAT regions of India are deficient in secondary and micronutrients. Our extensive survey of the farmers' fields in the SAT regions of India revealed that the deficiencies of sulfur, boron and zinc are very widespread and in most cases 80-100% farmers' fields were found critically deficient in these nutrients (Table 1) (Rego et al. 2007).

To enhance and sustain SAT agricultural productivity and food security there is a need to adopt (INM) strategy.

Table 1. Chemical characteristics of 924 soil samples collected from farmers' fields in three districts of Andhra Pradesh, India, 2002-04

District	No of fields		pH	Organic C	Total N	Olsen -P	Exch. K	Extractable nutrient elements (mg kg^{-1})		
				g kg-1	--------mg kg^{-1}-------			S	B	Zn
Nalgonda	256	Range	5.7-9.2	1.2–13.6	144-947	0.7-37.6	34-784	1.4-93.0	0.02-1.48	0.08-16.00
		Mean	7.7	4.0	410	8.5	135	7.00	0.26	0.73
		% deficient[a]						86	93	73
Mahabu-bnagar	359	Range	5.5-9.1	0.8–12.0	123-783	0.7-61.0	25-487	1.1-44.0	0.02-1.62	0.12-35.60
		Mean	7.1	3.6	342	9.1	117	11.5	0.22	1.34
		% deficient						73	94	62
Kurnool	309	Range	5.6-9.7	0.9–10.6	26-966	0.4-36.4	33-508	1.3-68.2	0.04-1.64	0.08-4.92
		Mean	7.8	3.4	295	7.9	142	5.6	0.34	0.42
		% deficient						88	83	94

[a]The critical limits in the soil used : 8-10 mg kg^{-1} for calcium chloride extractable S; 0.58 mg kg^{-1} for hot water extractable B;0.75 mg kg^{-1} for DTPA extractable Zn.

Strategy for Productivity Enhancement and Fertility Maintenance

INM Strategy

The INM strategy includes maintenance or adjustment of soil fertility and plant nutrient supply to sustain the desired level of crop productivity using all available sources of nutrients eg, soil organic matter, soil reserves, biological nitrogen fixation (BNF), organic manures, composts non-toxic organic wastes mineral fertilizers, and nutrients supplied via precipitation and irrigation water. INM is a holistic system approach focusing on the cropping system rather than on individual crop. INM also focuses on the farming system rather than on individual field. It does not preclude the use of renewable nutrient sources such as BNF and organic manures and minimal use of mineral fertilizers.

Strategies to Manage Soil Organic Matter

Organic matter is not just the reservoir of plant nutrients; organic matter also favorably influences physical and biological properties, productivity of soils. High prevailing temperatures in the tropics coupled with low net primary productivity in the dry regions, results in low organic matter reserves in the SAT soils.

Organic Inputs for Nutrient Management

Organic manures are of two types: bulky farm yard manure (FYM), composts (rural and town), crop residues; *in-situ* green manuring and *concentrated*- oilcakes, poultry manure, slaughter house waste, etc. FYM is the most commonly used organic manure particularly for high-value crops. It is prepared from animal-shed wastes and crop residues including stover and contains 0.5-1.0%N, 0.2-0.3 and 0.5-1.0% P and 0.03-0.35% K. Crops residues can be recycled by composting, and its nutrient enrichment through organic/inorganic amendments by using rock phosphate, pyrites, microbial cultures, vermicompositing, mulching and direct incorporation. Based on N content, organic manures are less efficient than mineral fertilizers; however combined use of these nutrient sources is superior than using mineral fertilizer or organic manure alone. A combination of crop residue restitution (based on the availability), fallowing or green manuring can be used to maintain organic matter levels in the soil.

In farms as well as in homes large quantities of organic wastes are generated regularly. Besides agricultural wastes, large quantities of domestic wastes are generated in cities and rural areas which are wasted by burning or used as land fillings. These valuable nutrients in residues can be effectively used for increasing the agricultural productivity using earthworms to convert the residues into valuable source of plant nutrients. The chemical changes in the degradation of organic matter occur through enzymatic digestion and enrichment materials. The burrowing and channeling habits of earthworms result in better soil aeration, drainage and structure. The dominance of earthworms innate capacity to improve soil fertility and their ability to multiply rapidly has led to the development of vermicomposting (Table 2). The process of preparing valuable manure from all kinds of organic residues with the help of earthworms is called "vermicomposting" and this manure is called vermicompost.

Types of Organic Materials

Vermicompost can be prepared from all types of organic residues such as agricultural residues, sericultural residues, animal manures, dairy and poultry wastes, food industry wastes, municipal solid wastes, biogas-sludge, and bagasse from sugarcane factories.

Vermicompost Preparation

Vermicompost can be prepared by different methods in shaded areas:

(i) on the floor in a heap; (ii) in pits (up to 1 m depth); (iii) in an enclosure with a wall (1 m height) constructed with soil and rocks or brick material or cement; and (iv) in cement rings. The procedure for preparation of vermicompost is similar for all the methods (Figure 1).


Figure1. Farm women learning (vermicompost preparation).

Step-Wise Procedure

- Cover the bottom portion of a cement ring with a polythene sheet.
- Spread a layer (15–20 cm thick) of organic waste material on the sheet.
- Sprinkle rock phosphate on this layer.
- Prepare cowdung slurry.
- Sprinkle powdered the slurry as a layer.
- Fill the ring completely with the materials in layers.
- Paste the top portion of the ring with cowdung or soil.
- Allow the material to decompose for 20 days.
- After 20 days, release selected earthworms (non-burrowing types eg., Eisonia spp, Eudrilus spp) through the cracks.
- Cover the ring with wire mesh or gunny bags to prevent birds from picking the earthworms.
- Sprinkle water on the surface of the compositing material at 3-day intervals to maintain adequate moisture and body temperature of the earthworms.
- Check compost after about 2 months:
  - vermicompost is ready in 2–2½ months, and
  - it is black and light, and has no smell.
- When the compost is ready, remove from the ring and heap as a cone.
- Leave the heap undisturbed for 2 to 3 hours to allow the earthworms to move down the heap slowly.
- Separate the upper portion of the heap.

- Sieve the lower portion of the heap to separate the earthworms, which can be used again for preparation of vermicompost.
- Pack the compost in bags and store these in a cool place.

Repeat Process

About 20 days before removing the compost from cement rings, place the organic waste, rock phosphate and cowdung slurry in layers in another set of rings. Follow the step-wise procedure and use the earthworms separated from the compost as mentioned above.

Precautions

- Use only plant materials such as vegetable peelings, leaves, or grass.
- Remove glass, metal, and plastic materials from the organic material.
- Protect against birds by covering mesh on the rings.
- Sprinkle the water intermittently and maintain adequate moisture.
- Prepare compost under shade to protect from sun and rain.
- Avoid pesticide/toxic chemicals

Usage

Vermicompost can be used for agricultural, horticultural, ornamental, and vegetable crops and any stage of the crop. Vermicompost is a rich source of major and micro plant nutrients (Table 2) and can be applied in varying doses in the field.

Table 2. Nutrient composition of vermicompost

Nutrient element	Vermicompost (%)
Organic carbon	9.8–13.4
Nitrogen	0.51–1.61
Phosphorus	0.19–1.02
Potassium	0.5–0.73
Calcium	1.18–7.61
Magnesium	0.093–0.568
Sodium	0.058–0.158
Zinc	0.0042–0.110
Copper	0.0026–0.0048
Iron	0.2050–1.3313
Manganese	0.0105–0.2038

Enriched Compost Production Technology

Most of the Indian soils are deficient in Phosphorus. Also, yearly removal of P is more than its addition through P fertilizers during continuous and intensive cropping. Bio-solids produced in cities, agro-industries and at farms normally have low nutrient value, particularly of P content. Compost production from these bio-degradable wastes is presently not an economically viable proposition. The traditional technology of composting, if improved in terms of nutrients content, may help in arresting trends of nutrient depletion to a greater extent. Further, the use of mineral additives such as rock phosphate and pyrites during composting has been found beneficial. A phosphocompost/N-enriched phosphocompost technology has, thus, been developed using phosphate solubilizing microorganisms, namely, *Aspergillus awamori*, *Pseudomonas straita* and *Bacillus megaterium*; phosphate rock, pyrite and bio-solids to increase the manurial value compared to ordinary FYM and compost (Misra et al. 2003).

Method

- For the production of one ton of phosphocompost, materials such as 1900 kg organic/vegetable wastes/straw, 200 kg cow-dung (dry weight basis) and 250 kg phosphate rock (18% P_2O_5) are used.
- Prepare a base of the heap out of hard, woody materials such as sticks, bamboo sticks etc., This base should be 15 cm thick and 3 m width and 3 m length depending upon the quantity of materials to be composted.
- Place bio-solids over the base made above. The layer should be around 30 cm to10 cm thick.
- Sprinkle slurry prepared by mixing cow dung and rock phosphate over the crop residues to moisten the material.
- Make another layer of crop residue and moisten it with slurry.
- Continue with alternate layer of crop residue (30 cm) and slurry until the heap is 1.5 m high. Reduce the area of each layer so that the heap tapers by about 0.5 m high. Reduce the area of each layer so that the heap tapers by about 0.5 m at the top. Add water to the heap so that moisture remains about 60 to 70%.
- Cover the heap with soil or polythene and mix the material after 15 days. Give two turnings after 30 and 45 days. Add water at each turning to maintain the moisture content about 60-70%.
- The compost becomes ready for field application within 90-100 days period.

Nutritional Quality

- The phosphocompost contains 2-3.5% P and 17-18 C:N ratio.

Table 2. Nutrient composition of manure and phosphocompost			
Manure	Total N (%)	Total P (%)	C:N ratio
FYM	0.5-0.8	0.32-0.55	22.0-25.0
Ordinary Compost	0.6-0.8	0.55-0.60	22.0-25.0
Phospho-compost	1.2-1.4	2.00-3.50	17.0-18.0

Yield Advantage

Field experiments conducted across different states under AICRP on microbiological decomposition under irrigated and rain-fed situations revealed that use of phosphocompost can fulfill the P requirement of various crops and farmers can do away with the use of phosphatic fertilizers. In view of the multi-nutrient deficiency of Indian soils, an effort has been made to enrich manurial value particularly sulphur and N content of the compost.

- To prepare N-enriched phospho-compost, nitrogen as urea at 0.5-1% (w/w), rock phosphate (12.5% w/w) and pyrite at10% (w/w) are added into the composting mixture.
- The N-enriched phospho-compost contains 1.4-1.6% N and 15-20 C:N ratio.
- Field testing of the N-enriched phospho-compost revealed that when 25% of fertilizer NPK was substituted by Nitro-Phospho-Sulpho-Compost yield advantage over NPK fertilizer was 11.5% in soybean and 2.5% in sorghum. This had also significant residual effect on yield of succeeding wheat crop.

In-situ Generation of Organic Matter

Short supply of organic manures and competitive uses of farm residues as feed and fuel make it difficult to apply these materials to soil at desired rates. Green leaf manuring is one of the important farming practices for increasing organic matter content in the soil. Green leaf manure plants such as *Susbania, Sunnhemp, Glyricidia, Cassia, Leucaena* can play an important role in tropical farming systems for increasing the soil fertility. Growing *Glyricidia* plants on farm bunds serves dual purpose of producing green leaf manure, rich in N, under field conditions and also helps in conserving soil through reduced soil erosion (Figure 2).

Figure 2. Glyricidia plants grown on border of chickpea field under rain-fed situation in India.

Characteristics of Glyricidia

- *Glyricidia* is a *woody,* green leaf manure tree about 12 m in height.
- The foliage can be used as green manure (natural fertilizer).
- Glyricidia is a root-nodulating N_2-fixing multipurpose legume.
- It grows fast and is tolerant to pruning.
- It can thrive in dry, moist, acidic soils or even poor degraded, infertile soils under rain-fed conditions.
- The leaves contain nutrients: N (2.4%), phosphorus (P) (0.2%), potash (K) (1.8%), Calcium (Ca), and Magnesium (Mg).
- *Glyricidia* adds plant nutrients and organic matter to the soil and increases crop productivity on infertile and degraded soils.
- *Glyricidia* can be propagated through stem cuttings or seed.

Glyricidia cuttings are taken from stems of at least one-year-old plants from mature branches 2–6 cm in diameter and 30–100 cm in length, which are brownish-green in bark color. It is normally cut obliquely at both ends, discarding the younger tips and base inserted 20-50 cm into the soil. The cuttings are planted on bunds in the rainy season, immediately after cutting from the stems. The hedges can be periodically pruned to provide fodder, green manure, firewood or stakes for new fences. Alternatively, Glyricidia seeds are soaked in water for 8 – 10 hours preferably overnight and are sown in small polythene bags filled with soil, and watered regularly. Generally, 3 - to 4-months old seedlings can be planted on bunds in the rainy season

Pruning

One year after planting, harvesting of the green biomass can be started by lopping the plants at 75 cm above the ground. For good management, plants should be pruned at appropriate times. Pruning should be done at least thrice during the year; ie, June (before sowing of the rainy season crop), in November (before sowing of the postrainy season crop) and in March (before sowing of the summer crop). *Glyricidia* loppings add valuable nutrients such as N, P, K, Ca and Mg to the soil. *Glyricidia* plants planted on 700-m long bunds can provide about 30 kg N ha^{-1} yr^{-1}. This practice also reduces environmental risks associated with chemical fertilizers. Use of *Glyricidia* as green manure minimizes the usage of chemical fertilizers that are very expensive and also environmentally unfriendly. It also acts as a barrier and filter to the rainwater running down the surface of a slope. *Glyricidia* roots stabilize lands with high slopes.

Biological Inputs for Nutrient Management

Several microorganisms in the soil decompose plant and animal residues and several groups of microorganisms are involved in important biological processes. Microorganisms regulate nutrient flow in the soil by assimilating nutrients and producing soil biomass (immobilization) and converting carbon, nitrogen, phosphorus and sulphur in to mineral forms (mineralization).

Beneficial Micro-organisms

- Symbiotic nitrogen fixers–symbiotic partnership between bacteria (*Rhizobium/ Bradyrhizobium*) and legumes contributes substantially (up to 450 kg N ha^{-1} yr^{-1}) to total BNF.
- Non-symbiotic and associative nitrogen fixers-inoculation with bacteria (*Aztobacter and Azospirillum*) reduces N requirement of cereals or non-legume crops up to 20 kg ha^{-1}.
- Plant growth promoting rhizobacteria (PGPR) – these improve plant growth through hormonal effects and reduce disease severity.
- Phosphate solubilising micro-organisms – these bacteria and fungi solubilise inorganic phosphates and make them available to plants in usable form and improve P use efficiency of plants.
- Vesicular-arbuscular mycorrhizae (VAM)-these help in the increased uptake of nutrients such as P,S,Cu, Zn, etc., and improve plant growth besides helping in overcoming several root borne pathogens. Mycorrhizal infection helps the plant to overcome water stress during drought conditions through root ramification process.

BNF

- BNF is an economically attractive and ecologically-sound process and is an integral part of nitrogen cycling in nature

- *Rhizobium* inoculation is practiced to ensure adequate nodulation and BNF.
- Efficient strains of *Rhizobium/Bradyrhizobium* supplied as inoculants are used as biofertilisers through seed or soil inoculation.
- Use of stem nodulating rhizobia like *Azorhizobium caulirodous* in crops like Susbenia rostrata help in enriching the soil with N.
- Blue Green Algae (BGA) are the potential BNF under waterlogged rice fields. They are good source of vitamin B_{12} and are known to produce growth promoting substances for the benefit of crop growth.
- Azolla symbiosis is another good example for BNF under submerged soil conditions. Efficient exploitation of the symbiosis can result in fixation of N to an extent of 100-150 kg N ha^{-1} yr^{-1} and helps to increase the yields by 10-15%.
- Use of Frankia in trees like casurina, Alnus help in harnessing more atmospheric nitrogen for plant growth.
- Dual/triple inoculation of microorganisms to crop and use of multifunctional organisms like *Trichoderma, Pseudomonas sp* are of immense use in crop growth and for soil fertility sustainence.

Recent results from a long-term study conducted under rain-fed conditions on a Vertisol for 12 years, demonstrated that the inclusion of grain legumes such as pigeonpea and chickpea in the production systems not only provided extra income, but also increased the productivity of succeeding or intercropped cereal such as sorghum and maize. Such systems also maintained the soil N status (Rego and Rao 2000). Nitrogen mineralization potential of soil under legume-based systems was two folds higher than only cereal-cereal system (Wani et al. 1995). Another long-term study showed that cropping systems involving legumes, land and water management factors, such as the broad-bed and furrow landform and use of inorganic fertilizers, increased the organic matter, available nitrogen and phosphorus status of soils along with improvement in soil physical and biological properties (Table 3). Results also showed that in the improved system higher carbon was sequestered and the biological properties of the soil were improved, leading to higher systems' productivity and carrying capacity of land (both of men and of animals). The application of P to the improved system increased the amount of carbon sequestered by 7.4 t carbon ha^{-1} in 24 years (Wani et al. 2003).

Use of Biofertiliser by Seed Inoculation

- Different crops require different rhizobia.
- Select the right type of biofertiliser (inoculant).
- The inoculant must be fresh and within the expiry date limit.
- Use well-tested inoculants produced by reputable manufacturers.
- Users in India must insist on quality inoculants with ISI mark.

- Prepare inoculum slurry using a sticking agent such as jaggery, rice porridge, gum Arabic, etc.
- Mix seeds with inoculum slurry by hand.
- Dry seeds on a plastic sheet kept under a shade.
- Sow seeds within 48 hours after inoculation.

Management Practices to Improve Plant Growth and BNF in Soil

- Use high nitrogen-fixing crops/varieties.
- Practice mixed and intercropping (row and strip) with legumes.
- Use appropriate tillage practices, landform treatments and nutrient amendments including application of oilcakes neemcake/pogamia cake.

Mineral Fertilizers

Use appropriate mineral fertilizers in amounts to meet the nutrients requirements. Ensure that efficiency of applied fertilizers is optimized through adoption of suitable practices.

Table 3. Biological and chemical properties of semi-arid tropical Vertisols in 1998 after 24 years of cropping under improved and traditional systems in catchments at ICRISAT Center, Patancheru, India.

Properties	System	Soil depth (cm)		SE± *
		0-60	60-120	
Soil respiration	Improved	723	342	7.8
(kg C ha^{-1})	traditional	260	98	
Microbial biomass C (kg C ha^{-1})	Improved	2676	2137	48.0
	traditional	1462	1088	
Organic carbon (t C ha^{-1})	Improved	27.4	19.4	0.89
	traditional	21.4	18.1	
Mineral N (kg N ha^{-1})	Improved	28.2	10.3	2.88
	traditional	15.4	26.0	
Net N mineralization (kg N ha^{-1})	Improved	-3.3	-6.3	4.22
	traditional	32.6	15.4	
Microbial biomass N (kg N ha^{-1})	Improved	86.4	39.2	2.3
	traditional	42.1	25.8	
Non-microbial organic N	Improved	2569	1879	156.9
(kg N ha^{-1})	traditional	2218	1832	
Total N (kg N ha^{-1})	Improved	2684	1928	156.6
	traditional	2276	1884	
Olsen P (kg P ha^{-1})	Improved	6.1	1.6	0.36
	traditional	1.5	1.0	

* SE=Standard error of mean

Fertilizer Application

- Form or type – as recommended for the crop.
- Method – furrow placement and covering with soil instead of broadcasting.
- Time - split N doses instead of one application
- Quantity - just sufficient to meet plant demand without adversely affecting biological nitrogen fixation

On-farm studies made on smallholder farms for three seasons in the SAT region of Zimbabwe showed that the applications of of fertilizer N (8.5 kg N ha^{-1}) in combination with manure application at 3 or 6 t ha^{-1} has the potential to improve the livelihoods of farmers through the use of small rates of manure in conjunction with fertilizer N under semi-arid conditions. The maize yields of the crop were drastically increased by the applications of manure and N at small rates (Ncube et al. 2007).

Our recent on-farm research in the SAT regions of India showed that balanced nutrition of rain-fed crops is crucial for sustainable increase in productivity and maintenance of fertility. For example, in the SAT regions of India where most of the farmers' fields were found deficient not only in nitrogen, phosphorus, but also in sulfur, boron and zinc, the application of sulfur, boron and zinc with nitrogen and phosphorus significantly increased the yield (30-120%) of field crops including sorghum, maize, castor, sunflower and groundnut (Rego et al. 2007). Complementary use of organic manures with fertilizers helps to correct micronutrient deficiencies in addition to other benefits.

Recommendations for Practioners

- Undertake detailed soil analysis to identify soil fertility constraints limiting crop production
- Develop suitable nutrient management recommendations based on soil analysis results and crop requirement and share knowledge with the farmers and stress the need for adopting INM strategy to maintain fertility and productivity.
- Optimize and harness full potential of available biological and organic sources and use chemical fertilizers only to supplement the gap in the nutrient requirements of the production system.
- Adopt holistic rather than compartmental approach for sustainable development and for eg., water management, weed management, fertility management, pest management, through biological agents, microbial biocontrol and by using plant extract derivatives, improved cultivars etc. As all these components are synergistically interlinked with sustainable land management.

Investment Needs by Local/National Governments or Other Donors

- Investments are urgently needed in establishing high-quality, reliable and functional soil-plant analytical laboratories in the developing countries. The cost to provide analystical support for the analysis of soil and plant samples could range from US $ 20,000 to 100,000 depending on the extent of automation and the number of samples to be analyzed in a year.
- Enhancing awareness amongst the farmers, development agents and policy makers to discuss soil health and adopt sustainable INM practices. For minimizing land degradation, continued investments in capacity building and training of personnel involved are needed.
- Investments to enhance the use of biological and organic resources through incentives for increased adoption are needed for sustainable land management.

Policy and Financial Incentives

- Enabling policies and incentive mechanisms for greater adoption of INM practices.
- Timely availability of quality products and knowledge on quality products and sustainable INM practices to the farmers, by establishing appropriate institutions.
- Enabling policies and mechanisms to produce, distribute and use various sources of different plant nutrients.

Conclusions

The rain-fed production systems have two major constraints in the form of water shortages and general low soil fertility. To make these systems sustainable at reasonable productivity levels, there is need to integrate soil and water conserving practices with balanced nutrition of crops by adopting INM. The knowledge available about different sources of nutrients such as BNF, organic manures and mineral fertilizers can be used to develop a suitable strategy for INM to sustain crop productivity. INM strategy is realistic, attractive and environment-friendly. INM will enhance the efficiency of biological, organic and mineral inputs for sustaining productivity of SAT soils. Judicious and balanced use of nutrients through biological sources, mineral fertilizers, and organic matter is a prerequisite to make the rain-fed agriculture efficient through increased rainfall use efficiency.

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12. Integrated Pest Management Options for Better Crop Production.

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Abstract

Every one is greedy and wants to produce more and more at the cost of the nature and the natural resources. The present day natural resource management is a perfect example of how Indian agriculture is affecting the eco-systems. The excessive dependence on chemical pesticides led to the development of resistance in pests to pesticides, out breaks of secondary pests and pathogens/biotypes, and occurrence of residues in food chain. To overcome such situations and minimize damage to human-and animal-health, several organizations have started advocating the concept of IPM with better profits. This chapter is aimed to discuss the importance of various insect pests and diseases of economic importance of major crops in India and their eco-friendly management strategies in watershed perspective.

Keywords: Crop production, IPM, bio-control, watersheds, bio-safety.

Introduction

Agricultural sector in India has long been recognized for its dependence on chemical control for the management of biotic stresses (insect, diseases, and weeds). The increasing population often demands more and more food grain production. The crop yields in farms are generally low and there are wide gaps between the farmers' yields and the potential yields of several crops. Though reliable estimates on crop losses are limited, Oerke et al. (1995) brought out about 42 % loss in global output due to insect pests, diseases and weeds despite the use of plant protection options. The loss could have been up to 70% in the absence of plant protection. In India, the pre-harvest loss was up to 30% in cereals and pulses and it can be up to 50% in cotton and oil seeds crops (Dhaliwal and Arora, 1993). Annual Economic loss due to *Helicoverpa* alone was estimated at Rs. 2,000 crores despite the use of pesticides worth Rs. 500 crores (Pawar, 1998). Kishor (1997) indicated about 15% gross agricultural loss in Andhra Pradesh due to *Helicoverpa* epidemic in cotton growing areas during 1988. In India, the losses due to a 5% increase in neck blast caused loss of grain yield of about 6% (Kapoor and Singh, 1983) whereas bacterial blight can cause grain losses ranged from 60-70% in rice Raina et al. 1981). Stripe disease of barley caused 70-72% yield loss (Pant and Bisht, 1983). Yellow mosaic virus caused yield losses in greengram and blackgram by 67% (Jain et al. 1995). In groundnut, collar rot caused losses ranging from 28-47%. In the past five decades there was a steady increase in the chemical utilization from 2.2 gm ha^{-1} of active ingredient (ai) in 1950 to the current level of 650 gm ha^{-1} which is a 300 fold increase (David, 1995). In recent years farmers' incomes are declining particularly due to increased cost of plant protection in puts. Among various pesticides, the use of insecticides was much in India compared to the global scenario (Verma, 1998).

The excessive dependence on chemical pesticides led to the development of resistance in pests to pesticides, out breaks of secondary pests and pathogens/ biotypes, and occurrence of residues in food chain. To overcome such situations and minimize damage to human - and animal-health, several organizations have started advocating the concept of IPM with better profits. Besides damage to human health, total dependence on chemical pesticides has eliminated bio-diversity, resulting in the reduction of natural enemies. Though Indian plant protection in the modern age is making larger strides of progress, it is necessary to consider the treasure of ancient knowledge, particularly the use of safer pesticides for the development of integrated water shed development. In fact this is not new, and there was ample evidence that our ancestors had the knowledge and experience and lived under healthier environments than the present generations. It is envisaged that an innovative integrated plant protection can change the fortunes of the farming communities.

Integrated watershed Management with IPM as one of the components has been considered in all watershed programs in India with the primary goal as:

- To increase the productivity with reduced pesticide risk to the producers, consumers and the environment.
- Conserve the biodiversity through augmenting natural enemies of biotic stresses.
- Encourage eco-friendly approach of pest management
- Ensure farm productivity and profitability with reduced inputs on plant protection.
- Empower farmers through periodic training and exposure visits to improve their decision making process.

Integrated Pest Management

Integrated pest management can be defined as `One or more management options adopted by farmers to maintain the density of potential pest populations below threshold levels for enhanced productivity and profitability of the farming system as a whole, the health of the farm family and its livestock, and the quality of immediate and downstream environments'.

IPM Options Followed in Watersheds

Among various plant protection options, the watershed team has chosen to promote the following eco-friendly approaches for use by farming communities.

- Diagnostic surveys and farmers interactions for determining the economic importance of various pests.
- Training farmers in the diagnosis and management of pests.
- Periodic monitoring of biotic stresses.
- Incorporation of agronomically suitable resistant varieties into the system.
- Building knowledge on the role of cultural practices.
- Enhancing the role of natural enemies through augmentation.
- Encouraging the production and adoption of bio-pesticides at village level.
- Need based application of chemical pesticides.
- Adoption of bio-safety and protective clothing while using chemicals.
- Networking farmers across watersheds for sharing information inputs and market intelligence.

Diagnostic Surveys

Before initiating biotic stress management at watershed level, one should take up in-depth farmer participatory appraisal (PRA) for diagnosis and categorize various biotic stresses to design appropriate management strategies. To achieve this, general PRA needs to be organized at each location and the results should be discussed with the group. The whole farming community needs to be involved at every level of decision making. The biotic stress atlases should be developed and updated at regular intervals. These atlases should be in a language that could be easily communicated to the farmers.

Scouting squads should be constituted by drawing the educated rural youth for regular monitoring of the fields. The information from surveys should be consolidated to draw meaningful conclusions on the pest/disease scenario. The risk due to severity of the pests should be communicated to the farmers from time to time through various communication systems such as farmer field schools, radio, television and modern information and communication technology (ICT) tools.

Capacity Building

After PRAs and diagnostic surveys, an in-depth training in the diagnosis and management options to address the biotic constraints has to be taken up either at headquarters or at village level to cover maximum number of beneficiaries. To achieve maximum impact, audio visual aids such as videos, handouts in local languages would be of immense value. After this exercise, periodic crop monitoring from sowing to crop harvest and evaluation of various constraints has to be taken up with the help of trained resident guide involving key farmers of the village. Pest monitoring tools such as pheromone traps, light traps, sticky traps and weather monitoring apparatus need to be established at every watershed. This information would be of strategic value and acts as a historic database to assist farmers in decision making process.

Bio-Safety

The present day Indian agriculture totally ignored the bio-safety over the past five decades and majority of the farmers have not adopted even protective clothing to avoid the chemical toxicity, operational hazards and food safety. This area has been given high priority to avoid chemical induced accidents and to provide better health and environment.

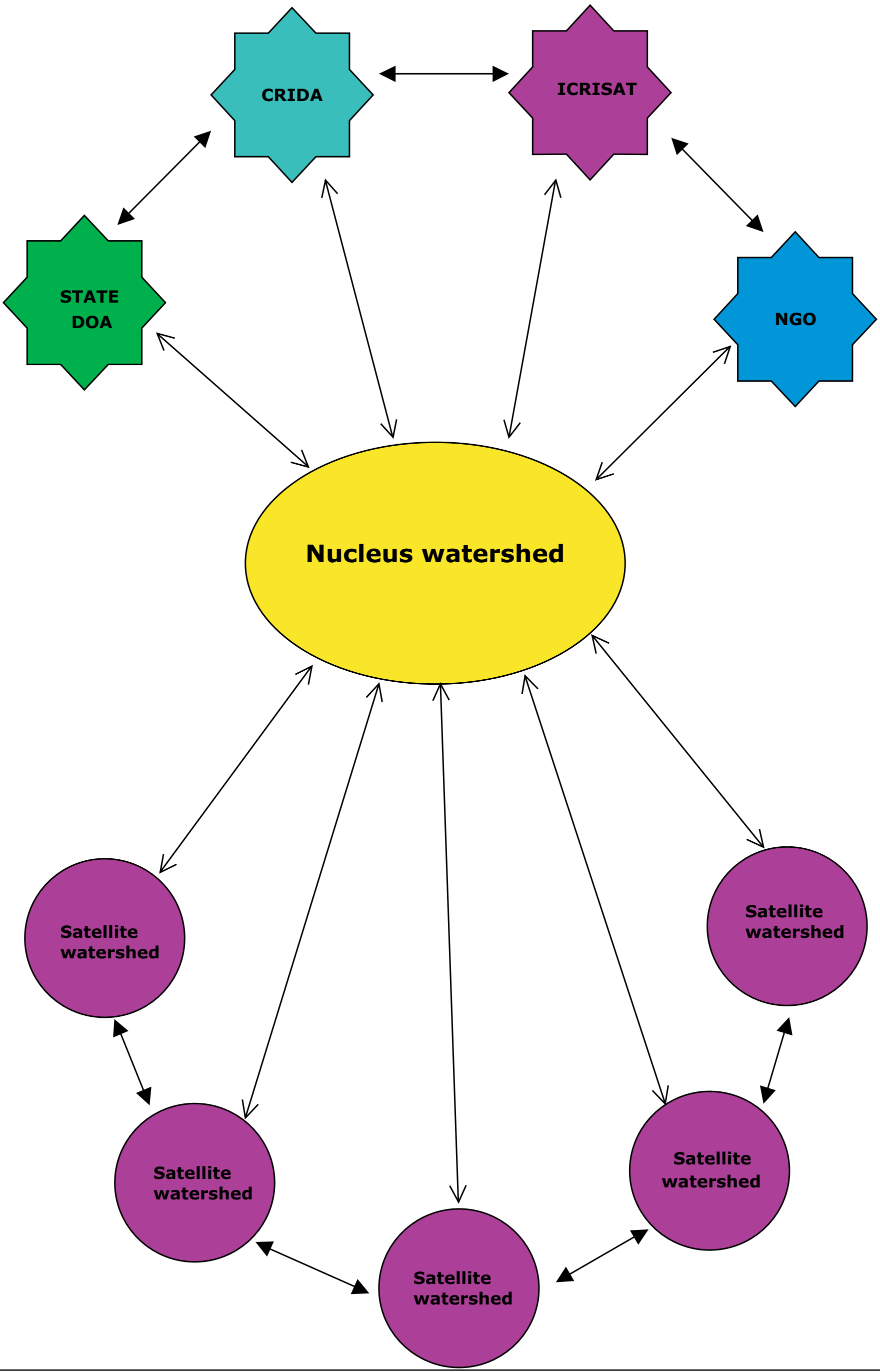
Networks

Though importance of farmers' networks is known for a decade in Indian agriculture, the implementation is far away from the reality. In developing integrated watersheds, in a systems approach, initiation of networks across watersheds in the district, state and nation wide is of immense value to update and create information flow across the farming community.

The Process

The proposed integrated watershed management has been taken up in a consortium approach involving government, non-governmental and international organizations with farmer participatory approach. This multidisciplinary, multi-organizational approach provides a platform between different organizations and farmers. Various developmental activities have been taken up with farmer initially in nucleus watersheds in the first year. After strengthening these nucleus watersheds, in terms of technology exchange and capacity building, the activities were scaled up to satellite watershed with the active involvement of trained farmers from nucleus watersheds. The impact of this approach was studied by comparing various outputs including enhanced productivity, increased profits, and reduced inputs on pesticides and

Organizational Structure of Integrated Watershed Management



minimum disturbance to the environment in contact and non-contract watersheds groups.

Monitoring Insect Pests

The insect pest population can be monitored following either direct or indirect techniques. The technique selected mostly depends on the type of insect being studied and its behavior. In case of direct sampling, insect pests are monitored by counting insects through direct observation. This can be either absolute or relative estimates.

A selection of sampling techniques suitable for various types of pest are shown below

Insect	Sampling method
Whiteflies, midges, adult foliage beetles	Sweep net, direct observation and counting
Lepidopteran adults (*Spodoptera, Helicoverpa, Aproaerema* etc.,)	Light trap (night flying insects); pheromone trap; sweep net
Lepidopteran larvae	Direct observation and counting, beating/ shaking with ground cloth
Ground beetles (adult and larvae)	Pitfall trap soil sample
Thrips	Direct observation and counting
Leaf miner larvae	Direct observation and counting
Aphids	Colored sticky trap; direct counting of colonies.
Leaf hoppers	Colored sticky trap; sweep net
Beneficial insects	Sweep net, pitfall traps, insect rearing, de-vac

Disease Monitoring

Disease monitoring involves studying the disease progress curves based on the incidence and intensity of the diseases recorded at regular intervals. In case of multiple-cycled diseases, monitoring of the spore population in the near vicinity of the crop and microclimate of the crop helps in developing prediction models. For monitoring the spore fauna, spore-sampling devices such as spore collectors could be used.

The disease management system currently recommended in groundnut is in the form of a package and not precisely tailor-made based on actual information on host-pathogen dynamics in relation to weather and time. The Indian farmer is denied of a reliable as well as dependable disease prediction system (as against peanut farmers in the US), in absence of which the sudden outbreak of these diseases do not give enough time to take timely initiative to contain the rate of spread of the disease.

Recently, leaf wetness has been used as a parameter to forecast foliar disease incidence. Some efforts were made in the past, to work on the epidemiology of rust pathogen. Practically no concerted efforts have so far been made to develop the prediction systems for diseases either for a agro-climatic region or over regions. Very little efforts have been made to collect information on weather parameters influencing disease incidence and severity and develop forecasting models.

Pest and Disease Scenario in India

Among various pests, yellow stem borer, brown plant hopper, and gall midge on rice; *Pyrella* on sugarcane; *Helicoverpa* on legumes; white fly, boll worms on cotton; aphids on mustard; hoppers on mangoes; codling moth and mites on apples; scale insects and fruit flies on citrus; fruit and stem borer in brinjal; tobacco caterpillar on tobacco and vegetables; diamond back moth on crucifers continue to pose severe threat to the main field crops and became major yield reducing factor. In the storage, rice weevil, rice moth on cereals; bruchids on pulses and *Caryedon* on groundnut are of economic importance. The details are given in Table 1.

Table 1. Economically important pests of major crops in India

Crop	Common name	Scientific name	ETLs	Existing control methods
Cereals				
Rice	Stem borer	*Scirpophaga incertulus* Walker	5% white ears/ One egg mass sqm^{-1}	IPM
	Brown plant hopper	*Nilaparvata lugens stal.*	10 hoppers per clump.	IPM
	Gall Midge	Orseolia oryzae wood-mason	5-10% silver shoots	Host plant resistance(HPR)
	Leaf folder	*Cnaphalocrocis medinalis* guen	10-15% webbed foliage	HPR
Wheat	Aphid	*Schizaphis graminum* (rondani)	5-10% of plants with infestation	HPR
Maize	Stem borer	*Chilo partellus* (swinhoe)	5-10% infestation	Chemical
	Shoot fly	*Atherigona* spp.	5-10% dead hearts	Chemical
	Earworm	*Helicoverpa armigera* hubner	25-30% damage to cobs	Chemical

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Crop	Common name	Scientific name	ETLs	Existing control methods
Legumes				
Pigeonpea	Pod borer	*Helicoverpa armigera* (hubner)	5 eggs or 3 small larvae per plant	IPM
	Pod fly	*Melanagromyza obtusa* (malloach)	In all endemic locations	Chemical
	Leaf webber	*Maruca vitrata* (geyer)	5 webs per plant	Chemical
	Pod sucking bugs	*Clavigralla gibbosa spinola*	One egg mass per plant	Chemical
Chickpea	Pod borer	*Helicoverpa armigera* (hubner)	3 eggs or 2 small larvae per plant	IPM
	Cutworm	*Agrotis ipsilon* (hufnagel)	5% plant mortality	Chemical
Soybean	Stem fly	*Ophiomyia phasioli* (tryon)	5% plant infestation	Chemical
	Girdle beetle	*Obereopsis brevis* (swed)	5% incidence	Chemical
	Hairy caterpillar	*Spilosoma obliqua* (walker)	5 larvae meter row	Chemical
Oil Seeds				
Groundnut	Leaf miner	*Aproaerema midicella* deventer	5 mines per plant at 30 days of crop age	IPM
	Tobacco caterpillar	*Spodoptera litura* (fab)	20-25% defoliation at 40days	IPM
	Thrips	*Scirtothrips dorsalis* hood	5 thrips/terminal at seedling stage	Chemical
	Aphids	*Aphis craccivora* kouch	5-10 aphids per terminal at seedling stage stage in dry spells onlyin rainy season	IPM
Sunflower	Gram pod borer	*Helicoverpa armigera* hubner	One larva per head	Chemical
Sesame	Leaf webber	*Antigastra catalaunalis* dub	2-5 webbs per plant	Chemical
Rapeseed	Aphids	*Lipaphis erysimi* (Kalt)	5-10 aphids per plant	Chemical

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Crop	Common name	Scientific name	ETLs	Existing control methods
Vegetables				
Brinjal	Fruit and stem borer	*Leucinodes orbanalis*	1-5% shoot/ fruit infestation	IPM
Cabbage & Cauliflower	Dimond back moth	Plutella *xylostella* linn	1-5% incidence	IPM
	Tobacco caterpillar	*Spodoptera litura* (fab)	1-5% incidence	IPM
Tomato	Fruit worm	*Helicoverpa armigera* hubner	1-5% fruit damage	IPM
Fruits				
Apple	San Jose Scale	*Quadraspidiotus perniciosus* (comstock)	Appearance of pest in 5% trees	Chemical & miscible oils
	Codling moth	*Cydia pomonella* (L.)	1-2% incidence	IPM
	Phytophagous mites	*Panonychus ulmi (koch)*	5-10% foliage infestation	Miscible oil & IPM
Grapes	Flea beetle	*Scelodonta stricollis* (mots.)	20% foliar damage	Chemical
	Thrips	*Retithrips syriacus* (mayet)	5 thrips/young leaf	Chemical
	Mealy bugs	*Maconellicoccus hirstutus* green	1% bunch infestation	Chemical
Oranges	Fruit flies	*Carpomyia vesuviana* costa.	1-2% incidence	Chemical
	Defoliators	*Papilio demoleus L.*	20-30 % foliar damage	Chemical
Mango	Hopper	*Amritodes atkinsoni* leth.	2-5 hoppers per inflorescence	Chemical
	Leaf webber	*Orthaga exvinacea*	10% incidence	Chemical
	Stem borer	*Batocera rufomaculatus* deg	Appearance of the pest	Chemical
Cash Crops				
Cotton	American bollworm	*Helicoverpa armigera* hub.	5-10 % boll infestation	IPM
	Pink bollworm	*Pectinophora gossipiella* saund	5-10% boll infestation	IPM
	Whitefly	Bemisia tabaci genn.	8-10 adults/leaf	IPM
	Spoted bollworm	Earias insulana boisd.	5-10% boll infestation	IPM

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Crop	Common name	Scientific name	ETLs	Existing control methods
Sugarcane	Stem borer	*Chilo sacchariphagus indicus* (kapur).	10% shoot damage at tillering phase	IPM
	Scale insect	*Melanapsis glomerata* (green)	20-30% canes with scale incidence	IPM
Tobacco	Tobacco caterpillar	*Spodoptera litura* fab.	5-10% leaves with damage	IPM
	Whiteflies	*Bemisia tabaci* genn.	5-10 flies/leaf	IPM
Storage pests				
Cereals	Rice weevil	*Sytophilus* oryzae	Appearance of live insects	Chemical
	Paddy moth	*Sitotroga cerealella*	Appearance of adult moths	Chemical
	Rice moth	*Corcyra cephalonica*	Appearance of adult moths	Chemical
	Red flour beetle	*Tribolium castaneum*	Appearance of adult beetles	Chemical
Pulses	Bruchids	*Bruchus* sp.	Appearance of adult insects	Chemical
Oil seeds				
Groundnut	Groundnut bruchid	*Caryedon serratus*	Appearance of adult beetles	Chemical

Several pathogens have been reported to cause serious diseases in many crops in India. Some of the economically important diseases of major crops in India are blast and blight in rice; rust and karnal bunt in wheat; leaf blight, rust, wilt and stem and cob rots in maize; wilt, root rots and blights in legumes; stem and pod rots and foliar diseases in groundnut; gray mold, A*lternaria* and bacterial blights, downy and powdery mildews in oil seeds; damping-off, wilt and powdery mildew in vegetables; downy and powdery mildews in mango, grapes and oranges; wilt and leaf spots in cotton; red rot and smut in sugarcane; damping-off and frog eye spot in tobacco. Fungi like *Alternaria, Aspergillus* and *Fusarium* species are also very important in storage and spoils quality and viability of grains, fruits and seeds. The details of economically important diseases and their causal agents and the available management strategies are furnished in Table 2.

Table 2. Economically important diseases of major crops in India			
Crop	Disease name	Causal organism	Existing control methods
Cereals			
Rice	Blast	*Pyricularia oryzae*	IDM
	Sheath blight	*Rhizoctonia solani*	IDM
	Bacterial leaf blight	*Xanthomonas oryzae*	IDM
Wheat	Leaf or brown rust	*Puccinia recondite* f.sp. *tritici*	HPR & IDM
	Stem or black rust	*Puccinia graminis* f.sp. *tritici*	HPR & IDM
	Karnal bunt	*Neovossia indica*	HPR & IDM
	Loose smut	*Ustilago segetum*	IDM
Maize	Maydis leaf blight	*Cochliobolus heterostrophus*	HPR &chemical
	Common rust	*Puccinia sorghi*	HPR & chemical
	Downy mildew	*Peronosclerospora sp*	Chemical
	Fusarium wilt & stalk rot	*Fusarium moniliforme*	HPR
	Charcoal rot	*Macrophomina phaseolina*	HPR
Legumes			
Pigeonpea	Wilt	*Fusarium udum*	HPR
	Phytophthora blight	*Phytophthora drechsleri f.sp. cajani*	IDM
	Sterility mosaic	Sterility mosaic virus transmitted by *Aceria cajani*	HPR
Chickpea	Wilt	*Fusarium oxysporum f.sp. ciceri*	HPR
	Dry root rot	*Rhizoctinia bataticola*	HPR
	Collar rot	*Sclerotium rolfsii*	HPR
	Ascochyta blight	*Ascochyta rabiei*	IDM
	Botrytis gray mold	*Botrytis cinerea*	IDM
	Stunt	Bean leaf roll virus	HPR
Soybean	Pod blight	*Colletotrichum dematium* f. sp. *truncata*	Chemical & HPR
	Bacterial pustule	*Xanthomonas campestris*	HPR
	Bacterial Blight	*Pseudomonas sps*	Cultural & HPR
	Charcoal rot	*Macrophomina phaseolina*	Cultural & HPR
	Collar rot	Sclerotium rolfsii	HPR

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Crop	Disease name	Causal organism	Existing control methods
Oil Seeds			
Groundnut	Crown rot	*Aspergillus niger*	Chemical
	Stem & pod rots	*Sclerotium rolfsii*	HPR & cultural
	Aflatoxin	*Aspergillus flavus*	Integrated management
	Early leaf spot	*Cercospora arachidicola*	IDM
	Late leaf spot	*Phaeoisariopsis personata*	IDM
	Rust	*Puccinia arachidis*	HPR & IDM
Sunflowers	Gray mold	*Botrytis cinerea*	Chemical
	Alternaria blight	*Alternaria helianthi*	Chemical
	Wilt	*Verticillum dahliae*	HPR
	Scorch	*Maacrophomina phaseoli*	HPR
Sesame	Phytophthora blight	*Phytophthora parasitica*	Chemical
	Charcoal rot	*Macrophomina phaseolina*	HPR
	.Wilt	*Fusarium oxysporum* f. sp. *sesami*	HPR
	Cercospora leaf spot	*Cercospora sesami*	HPR
	Alternaria leaf spot	*Alternaria sesami*	HPR
	Bacterial blight	*Xanthomonas campestris*	HPR
Rapeseed	Alternaria blight	*Alternaria brassicae*	HPR
	Downy mildew	*Peronospora parasitica*	HPR
	Powdery mildew	*Erysiphe cruciferarum*	HPR
Vegetables			
Brinjal	Damping-off	*Phytophthora or Pythium sp*	Chemical
	Wilt	*Fusarium ozonium*	HPR
	Phomopsis blight	*Phomopsis vexans*	HPR
Cabbage	Downy mildew	*Perenospora parasitica*	Chemical
	Alternaria blight	*Alternaria solani*	Chemical
	Black rot	*Xanthomonas campestris*	Chemical
Cauliflower	Stalk rot	*Sclerotinia sclerotiorum*	Chemical
Tomato	Late blight	*Phytophthora infestans*	Chemical
	Leaf blight	*Septoria lycopersici*	Chemical
	Tomato spotted wilt	*Vial disease*	HPR + cultural
	Wilt	*Psuedomonas solanacearum*	HPR

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Crop	Disease name	Causal organism	Existing control methods
Fruits			
Apple	Scab	*Venturia inaequalis*	HPR + Chemical
Grapes	Anthracnose	*Gloeosporium ampelophagum*	Chemical
	Downy mildew	*Plasmopara viticola*	Chemical
	Powdery mildew	*Uncinula necator*	Chemical
Oranges	Canker	*Xanthomonas campestris* pr. *citri*	Chemical
	Gummosis	*Diaporthe citri*	Chemical
Mango	Powdery mildew	*Oidium mangiferae*	Chemical
	Anthracnose	*Colletitrichum gloeosporiodes*	Chemical
Cash Crops			
Cotton	Verticillium wilt	*Verticillium dahliae*	HPR
	Root rot	*Rhizoctonia sps*	HPR
	Alternaria leaf spot	*Alternaria macrospora*	IDM
	Anthracnose	*Colletotrichum gossypii*	Chemical
Sugarcane	Red rot	*Colletotrichum falcatum*	HPR
	Smut	*Ustilago scitaminea*	HPR
	Wilt	*Fusarium sacchari*	HPR
Tobacco	Damping-off	*Pythium aphanidermatum*	Chemical
	Frog-eye spot	*Cercospora nicotianae*	Chemical

Resurgence

As mentioned by Professor Matthews (2001), Imperial College of Science, UK. Three R's (resurgence, resistance and residues) are the main focus of the present day plant protection in all developing countries. In recent years wide spread resurgence of whitefly in cotton in the state of Andhra Pradesh, Gujarat, Karnataka, Tamil Nadu and Maharashtra have been reported, which was mainly due to the indiscriminate use of the insecticides (Rajak 1993). Of the several reasons for pest resurgence, misuse of pesticides, application of imbalanced micro-nutrients for plant nutrition, use of sub-lethal doses of insecticides, destruction of natural enemies, lack of bio- diversity due to changes in cropping systems and favorable environmental factors play critical role in outbreaks. This resulted in pesticide tread mill with increased investments on pesticides and eroded profits and severely impact on the environment.

Like insects, resurgence in pathogens also has become a normal phenomenon because of misuse and abuse of fungicides during last two decades. During the process of resurgence, the previously controlled diseases/pathogens remerge as a virulent and fungicide resistant strain, devastating the crops. The classical example of pathogen resurgence is the late blight of potato caused by *Phytophthora infestns*.

Development of Resistance to Pesticides

The abuse of pesticides on cotton over the past several years resulted in the development of resistance in *Helicoverpa* to a wide range of insecticides, 23-8022 fold resistance to cypermethrin, 10-17 fold resistance to cyclodiene (endosulfan), and 82 fold resistance to chlorpyriphos. In case of pink boll worm recent reports indicated 23-57 fold resistance to endosulfan. *Spodoptera litura* from southern part of India exhibited 45-129 fold resistance to chlorpyriphos. There are high levels of insecticidal resistance in *Bamisia tabaci* and cypermethrin than endosulfan and chlorpyriphos (Kranthi et al. 2001). Studies conducted on *Spodoptera* showed various levels of resistance to commonly used insecticides (Armes et al. 1997, Kranthi et al. 2001). Previous reports also suggested the occurrence of resistance in 14 pests of public health importance, 6 pests of stored grains and 7 pests of field crops (Rajak, 1993).

Similarly like insect pests, development of resistance against several systemic fungicides is observed in many pathogens. With the excessive and intensive use of a fungicide, the resistant strains may become a dominant part of population and result in the loss of fungicide effectiveness (Delp, 1990). Thus the resistance to fungicide is observed in pathogens like *Alternaria, Botrytis, Cercospora,* and *Phytophthora,* etc.

Pesticide Residues

The basic problem is the negligence of safety intervals after sprays and also the lack of residue monitoring in the products. There are many reports about the presence of insecticide and fungicides residues in the environment, food, fodder as well as in human bodies 86% contamination of DDT and 89% HCH in dairy milk from different states. The samples of mother's milk from eight districts of Tamil Nadu also revealed 87% contamination with HCH and 100% with DDT (Handa, 1995). Fungicide residues of benlate, captan, chlorothalonil and vinclozolin fall above admissible levels. To minimize the hazards due to pesticide residues strict regulatory measures need to be implemented at all levels of pesticide handling.

Development of ETLs for Major Pests

Under Indian conditions, most of the crops are grown in varied climatic conditions and hence there is a need for the development of appropriate ETLs to meet specific crop-pest-situation under different agro-climatic regions. A simple manipulations in ETLs to minimize the misuse of chemical pesticides need to be given high priority.

Development of Forewarning Systems for Insect-Pests and Diseases

In a watershed area, for the effective implementation of the IPM programs, forewarning systems for the pests would be handy as they not only help in deployment of timely pest management options but also reduce the cost of cultivation. Development of forewarning sytems needs information in threshold levels for pests and diseases, and conditions congenial for the development of epidemics.

Very few foliar/blight diseases of few crops have simulation models to predict or forecast the occurrence of diseases based on weather parameters and symptoms appearance to initiate or take up disease control measures. The best example of this prediction models is weather based advisory system (WBAS) using leaf wetness to predict onset of foliar diseases in groundnut.

Implications of Pesticides Usage in Plant Protection

Every one is greedy and wants to produce more and more at the cost of the nature and the natural resources. The present day natural resource management is a perfect example of how Indian agriculture is affecting the eco-systems. One must realize the responsibility in exploiting the natural resource beyond the optimum levels. If the present trend continues for some more years, one has to pay severe price and may ruin the natural balance to an irreparable level

During 1998, the Montreal, international delegation passed out the judgment to phase out the one dozen harmful compounds called “dirty dozen” including eight insecticides (Aldrin, DDT, chlordane, dieldrin, endrin, heptachlor, mirex and toxaphene). At this stage it is essential to emphasize that no chemical pesticide is safe to human health or environment. The word “safe” is a relative term. Some chemicals may harm us in short periods while others may affect in long-run. That is the only difference amongst them.

Adarsha Watershed, Kothapally: A Case Study

Adarsha watershed is located in Kothapally village (78° E and 17° N) in Ranga Reddy district of Andhra Pradesh, India and is 50 km northwest of Hyderabad. The total area under cultivation is about 430 ha, out of which 160 ha were irrigated. The farmers grow several crops including cotton, maize, sorghum , pigeonpea intercropped with maize, chickpea, vegetables, and paddy. Among various agricultural constraints insect pests were well recognized but the farmers were aware of only the chemical control. The farmers in this village were investing about US $ 50,000 in plant protection annually. Hence this study was initiated during the cropping season 2000-01 in order to develop an eco-friendly alternative to chemicals for the effective management of pests.

Methodology Followed at Kothapally Watershed

These studies were conducted in the village under farmer participatory integrated watershed management approach. Population dynamics of adult *Helicoverpa armigera* was monitored by using pheromone traps for the first time during 2000-2002. Five farmers each for pigeonpea and chickpea with 0.4 ha area participated in these on-farm bio-intensive pest management (BIPM) studies during the year 2000-01 and 2001-02. The results from these fields were compared with adjacent five farmers fields where repeated application of chemicals were used (non-IPM). During 2000-01, the pigeonpea BIPM farmers applied one spray each of neem and HNPV, followed by manual shaking (3-5 times) and have not applied any chemicals. Non-IPM farmers sprayed 3-4 times with chemicals. During 2001-02 season, BIPM farmers used one spray each of neem and HNPV followed by manual shaking (2-4 times), while non-IPM farmers used 2-3 rounds of chemical sprays. In chickpea, during post rainy season 2000-01 the BIPM plots received 1-3 sprays of HNPV while the non-IPM farmers did not apply any plant protection measures to their crops. During 2001-02, BIPM farmers applied one spray of neem and two sprays of HNPV, while non-IPM farmers used 2 sprays of chemicals.

The cotton BIPM was initiated during 2003-04 and continued for the next two seasons ie, up to 2006. Synthetic chemicals were not used in this BIPM protocol. The bio-intensive pest management protocol was evaluated by 17 farmers during 2003-04, followed by 9 farmers during 2004-05 and 5 farmers during the year 2005-06. Each contact farmer was asked to divide a given field in to two halves, one each for BIPM and farmer practice (FP/Non-IPM). The BIPM protocol involved five items, and small changes in agronomy. The first two are extracts of two botanicals, neem (*Azadirachta indica*) and *Glyricidia sepium* (a leguminous tree), prepared using a biological method. The third is a research product of ICRISAT – the bacterium *Bacillus subtilis* strain BCB19/the fungus *Metarrhizium anisopliae*. The last two components were items that farmers have traditionally usedcow-urine solution, and curd recipe, that involves mixing specific quantities of curd, jaggery (concentrated sugarcane juice) and bread yeast – all mixed in water and sprayed. (Rupela et al.2006).

Results

Monitoring of *Helicoverpa*

Pheromone trap catches clearly indicated two good peaks during August-September with 27 and 23 moths trap^{-1} in the standard weeks 34 and 38, respectively. There was another small peak during standard week 49 (ie, 3-9 December) with 9 moth strap^{-1}. Later the population declined drastically. These adult populations corresponded with peak pest activity during boll formation of cotton and flowering of pigeonpea in October-November months.

Pigeonpea

During 2000-01 season the oviposition of *Helicoverpa* was at its peak during the first fortnight of November with 6 eggs plant^{-1} and it declined to almost one on 10 plants by crop maturity stage ie, the end of December. *Helicoverpa* larval population was at its peak with 10 larvae plant^{-1} during the first fortnight of November and decreased to 2.6 larvae plant^{-1} by end of December. The larval population in BIPM plots was always found lower than those of non-IPM plots, where farmers applied 3-4 sprays of chemicals. IPM interventions resulted in substantial decrease in borer damage to pods and seeds. BIPM plots had 34% pod damage compared to 61% in non-IPM plots. The seed damage was also low in BIPM plots (21%) compared to non-IPM plots (39%). This lower pod borer damage in BIPM plots also reflected in higher yield of 0.77 t ha^{-1} when compared to 0.53 t ha^{-1} in farmer's practice.

The observations on egg and larval population during 2001-02 indicated similar trend as in the previous season. The BIPM interventions resulted in 33% and 55% reduction in pod and seed damage respectively. The BIPM plots yielded 0.55 t ha^{-1} compared to 0.23 t ha^{-1} in non-IPM plots even though the overall yield levels were low.

Chickpea

Observations on egg and larval population during 2000-01indicated the onset of the pests during the first fortnight of November when the crop was around 30 days old (with one egg plant^{-1}), and the number continued to increase until the first fortnight of December when the crop attained podding stage and later declined by the end of January. The difference in plant protection practices between BIPM and non-IPM plots was clearly reflected in low larval population in BIPM fields through out the vulnerable phase of the crop. The BIPM farmers also harvested 3 times higher yields with 0.78 t ha^{-1} compared to 0.25 t ha^{-1} in non-IPM fields which was primarily due to the effective pest management and adoption of improved variety (ICCV 37) developed at ICRISAT.

During the second year, the larval population at vegetative and flowering stages was more in non-IPM plots, and at pod maturity stage the population reached below economic threshold level (<1 larva $plant^{-1}$) in both the treatments. This differential population resulted in small reduction in pod damage (4%) and 19% increase in grain yield in BIPM plots. Thus two years data revealed the advantage of BIPM modules over the chemical management of insect pests.

Cotton

During 2003-04, twelve out of 17 BIPM farmers obtained 20-80% higher yields, while four farmers realized 0-20% better yields and in only one farmer's field the yield was lower (4%) in BIPM treatment compared to farmers practice. When all the farmers' yields are considered the BIPM fields yielded 30% better than non-IPM fields. In the next season (2004-05) 4 out of 9 farmers obtained >20% yield (range 20-45%), two out of nine received 5-6% higher yield and three farmers realized less yield in BIPM plots. In the third year three out of six farmers realized 33-74% higher yield and two out of six farmers got 9-12% better yields, while one farmer obtained 3% lower yield in BIPM plots. In general, majority of farmers harvested higher yields through BIPM compared to complete chemical based farmers practice (Table 3).

After realizing the good impact from BIPM in cotton, six farmers from this village adopted the same technology in protecting tomato from insect pests. During 2005, BIPM farmers realized 2-322% yield gain over the plots covered with conventional chemical pest management. The productivity of tomatoes varied from 1.68–7.93 t ha^{-1} in BIPM compared to 1.31–5.34 t ha^{-1} in chemical management. It was also clear from the observations that the difference in productivity varied with the level of inputs put forth by various farmers (Table 4). This clearly indicated the economic feasibility of bio-intensive options over conventional chemicals.

Table 3. Cotton yields in BIPM and FP plots in Kothapally village during 2003-06 (three seasons).

Season (No. of farmers)	Mean yield (t ha^{-1})		
	BIPM	FP	SE±
2003/04 (17)	2.43	1.87	0.080
2004/05 (9)	0.74	0.68	0.058
2005/06 (6)	1.74	1.38	0.096

Table 4. Tomato yields in BIPM and FP treatments in six farmer's fields in Kothapally village during 2005.

Name of farmer	Yield (t ha^{-1})		Yield increase over control (%)	Cost of plant protection (Rs ha^{-1})	
	BIPM	FP		BIPM	Non-IPM
T. Pochaiah	5.53	1.31	322	2870	2929
B. Narayan Reddy	7.93	5.34	49	2154	2344
Md. Yousuf	3.21	2.35	37	1848	2344
T. Kishtayya	2.12	1.85	15	3144	2929
K. Laxminarayana	2.42	2.22	9	1764	2344
K. Permaiah	1.68	1.65	2	561	2929
Mean	3.82	2.45	55.9	2057	2637
SE ±	0.488				

The BIPM plots always registered higher natural enemy population compared to farmers' practice. There were two coccinellids and one spider in every ten plants in BIPM plots compared to none in FP plots, indicating the congenial conditions provide by BIPM treatments for the augmentation of the natural enemies. Crops generally remained productive for about three weeks longer than the FP plots. That generally senesced suddenly.

Bio-Pesticide Production at Village Level

Realizing the non-availability of good quality bio-pesticides at farm level as the basic constraint, this concept aimed to address this problem through imparting training and establishing the production units at village level. Six farmers and one extension worker from this village were given training on HNPV production, storage, and usage. The villagers quickly adopted the technology and produced 2000 larval equivalents (LE) of virus during 2000-01. Two women of a self-help group (who showed interest) were identified and trained in preparing the wash of compost of neem and *Glyricida*. After two days of training at ICRISAT, the facility for producing the neem and G*lyricidia* compost washes was established in the village during 2004-05. Thus, this approach empowered farmers to produce good quality product at field level with proper guidance.

Way Forward

- In view of the availability of natural resources and the productivity, the plant protection in upstream and downstream systems need to be developed appropriately to avoid pest buildup in the whole system.
- Data on toxic residues on all food, feed and water bodies is of high priority.
- Develop capacity at farm level to impart better knowledge in soil, water, nutrient and pest management in an integrated approach.
- Intensive monitoring of crops at their vulnerable stages by effective means such as pheromones and weather based advisory system.
- Periodic pests and diseases surveys to update the incidence, distribution, economic importance in different geographic regions.
- Crop varieties with resistance to biotic stresses need to be identified and made available to farmers through farmers networks.
- Effective agronomic practices for augmenting natural enemies should be of high priority.
- Use of bio-rationales and indigenous technologies as an alternative to toxic chemicals need to be encouraged.
- Encourage community involvement with effective teams.
- Strategic research generated at the research stations need to be shared periodically through farmer participatory approach.
- Provide input and output market intelligence.
- Establish farm clinics for greater sustainability.

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13. Integrated Water Resource Management for Increasing Productivity and Water Use Efficiency in the Rain-fed Areas of India

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Abstract

Climate variability is the major cause of fluctuations in food production in the semi-arid tropical (SAT) regions of India leading to food insecurity, malnutrition and poverty. Although the total amount of rainfall in the SAT regions is adequate to meet the water requirements of the crops and cropping systems, its erratic distribution results in periods of excess and deficit water availability, leading to low productivity and degradation of natural resources. Therefore, an integrated water resources management approach comprising *in-situ* water conservation, harvesting of excess water in ponds and groundwater recharging and its efficient use through appropriate supplemental irrigation methods, improved crop varieties and cropping systems, balanced nutrition of crops, crop diversification and intensification with high value crops and crop protection is needed to produce more food and income per unit of rainfall. The paper describes the achievements made by ICRISAT in collaboration with its partners in enhancing crop productivity and rainfall use efficiency by implementing improved technologies in on-station and on-farm community watersheds in India.

Keywords. Rain-fed agriculture, community watersheds, integrated genetic and natural resource management, food security, rural livelihoods.

Introduction

Water is the inherently limiting resource in the semi-arid tropics (SAT) for agricultural production on which the human and animal populations are dependent. Erratic rainfall results in widely fluctuating production, leading to production deficit and causing land degradation through soil erosion and reduced groundwater recharge. Population growth accompanied by increased demand for natural resources to produce food and to meet needs of the other sectors of the economy, further exacerbates the existing problems. Thus, a process of progressive degradation of resources sets in, which intensifies with every drought and the period following it.

If not checked timely and effectively, it leads to permanent damage manifested as loss of biodiversity and degradation of natural resources (Wani et al. 2006). Unless the nexus between drought, land degradation and poverty is addressed, improving the livelihoods that are dependant mainly upon natural resources can be farfetched. Water is the key factor and through efficient and sustainable management of water resources, entry could be made to break the nexus (Wani et al. 2003). In rain-fed regions, this would mean enhancing the supply of water through soil and water conservation, water harvesting in ponds and recharging the groundwater and on the demand side, enhancing its efficient use by adopting integrated soil water, crop, and nutrient and pest management practices.

This paper describes an integrated water resource management approach adopted by ICRISAT to enhance the goal of increasing crop production and improving rural livelihoods through sustainable and efficient use of water resources in rain-fed areas of India and elsewhere.

An Integrated Approach for Enhancing Productivity and Water Use Efficiency

ICRISAT has adopted an integrated genetic and natural resource management (IGNRM) approach to enhance agricultural productivity in rain-fed areas, which is a powerful integrative strategy of enhancing agricultural productivity. ICRISAT has learnt that converging different agro-technologies at field level showed greater impact on agricultural productivity and water use efficiency in the farmers' holdings and rather than compartmentalized testing of individual technologies. This was achieved through adoption of integrated watershed management approach, which is holistic in nature to achieve the desired goals of enhancing productivity, reducing land degradation and protecting the environment, which ultimately results in increased economic benefit to rural communities to alleviate poverty. In our on-station and on-farm research, integrated package of technologies were evaluated on watershed scale in India. The contribution of both individual and combined effects of improved technologies on productivity enhancement and water use efficiency is presented here.

Enhancing Productivity and Water Use Efficiency in Watersheds

In-Situ Soil and Water Conservation

Implementation of the type of land and water management system depends on the characteristics of the soil, climate, farm size, capital and availability of human and power resources. Land smoothening and forming field drains are basic component of land and water management for conserving and safe removal of excess water. Broad-bed and furrow (BBF) system is an improved *in-situ* soil and water conservation and drainage technology for the Vertisols. The system consists of relatively flat bed approximately 100 cm wide and shallow furrow about 50 cm wide laid out in the field with a slope of 0.4 to 0.8 per cent. BBF system helps for safe disposal of excess water through furrows when there is high intensity rainfall with minimal soil erosion, while at the same time it serves as land surface treatment for *in-situ* moisture conservation. Contour farming is practiced on lands having medium slope (0.5-2 per cent) and permeable soils, where farming operations such as ploughing, sowing are carried out along the contour. The system helps to reduce the velocity of runoff by impounding water in series of depressions and thus decrease the chance of developing rills in the fields. Contour bunding is recommended for medium to low rainfall areas (<700 mm) on permeable soils with less than 6 per cent slope. It consists of series of narrow trapezoidal embankments along the contour to reduce and store runoff in the fields. Conservation furrows is another promising technology in red soils receiving rainfall of 500-600 mm with moderate slope (0.2-0.4 per cent). It comprises series of dead furrows across the slope at 3-5 m intervals, where the size of furrows is about 20 cm wide and 15 cm deep.

On-farm trials on land management of Vertisols of central India revealed that BBF system resulted in 35 per cent yield increase in soybean during rainy season and yield advantage of 21 per cent in chickpea during postrainy season when compared with the farmers' practice. Similar yield advantage was recorded in maize and wheat rotation under BBF system (Table 1). Yield advantage of 15 to 20 per cent was recorded in maize, soybean and groundnut with conservation furrows on Alfisols over farmers' practices of Haveri, Dharwad and Tumkur watersheds in Karnataka (Table 2). Yield advantage in terms of rainfall use efficiency (RUE) were also reflected in cropping system involving soybean-chickpea, maize-chickpea, soybean/maize - chickpea under improved land management systems. The RUE ranged from 10.9 to 11.6 kg ha^{-1} mm^{-1} under BBF systems across various cropping systems compared to 8.2 to 8.9 kg ha^{-1} mm^{-1} with flat on grade system of cultivation on Vertisols (Table 3).

Table 1. Effect of land configuration on productivity of soybean and maize-based system in the watersheds of Madhya Pradesh, 2001-05.

Watershed location	Crop	Grain yield (t ha^{-1})		
		Farmer's practice	BBF system	% Increase in yield
Vidisha and Guna	Soybean	1.27	1.72	35
	Chickpea	0.80	1.01	21
Bhopal	Maize	2.81	3.65	30
	Wheat	3.30	3.25	16

Table 2. Effect of improved land and water management on crop productivity in Sujala watersheds of Karnataka during 2006-07

Watershed	Crop	Grain yield (t ha^{-1})		
		Farmers' practice	Conservation furrows	% increase in yield
Haveri	Maize	3.57	4.10	15
Dharwad	Soybean	1.50	1.80	20
Kolar	Groundnut	1.05	1.22	16
Tumkur	Groundnut	1.29	1.49	15

Table 3. Rainfall use efficiency of different cropping systems under improved land management practices in Bhopal, Madhya Pradesh, India

Cropping system	Rainfall use efficiency (kg ha^{-1} mm^{-1})	
	Flat-on-grade	Broadbed and furrow
Soybean - chickpea	8.2	11.6
Maize - chickpea	8.9	11.6
Soybean/maize - chickpea	8.9	10.9

- = Sequential system; / = Intercrop system.

Water Harvesting and Groundwater Recharge

In medium to high rainfall areas, despite following the *in-situ* moisture conservation practices, rainfall runoff due to high intensity storms or water surplus after filling up the soil profile, does exists. This excess water needs to be harvested in surface ponds for recycling through supplemental irrigation or to recharge the groundwater for later use in the postrainy season. For example, in Adarsha watershed in Kothapally village in Andhra Pradesh various types of water harvesting structures were built with the participation of farmers (Fig. 1). Water harvesting in these structures resulted in increase in groundwater levels (Fig. 2). Additional water resource thus created was used by the farmers in providing supplemental irrigation to the crops especially to provide come up irrigation to the postrainy season crop such as chickpea or to grow high value crops such as vegetables. Small and well distributed water harvesting structures in the watershed area provided equity and benefited more number of farmers than the large size structures, which benefit only a few farmers.

Figure 1. Water harvesting structure in Adarsha watershed Kothapally, Andhra Pradesh.

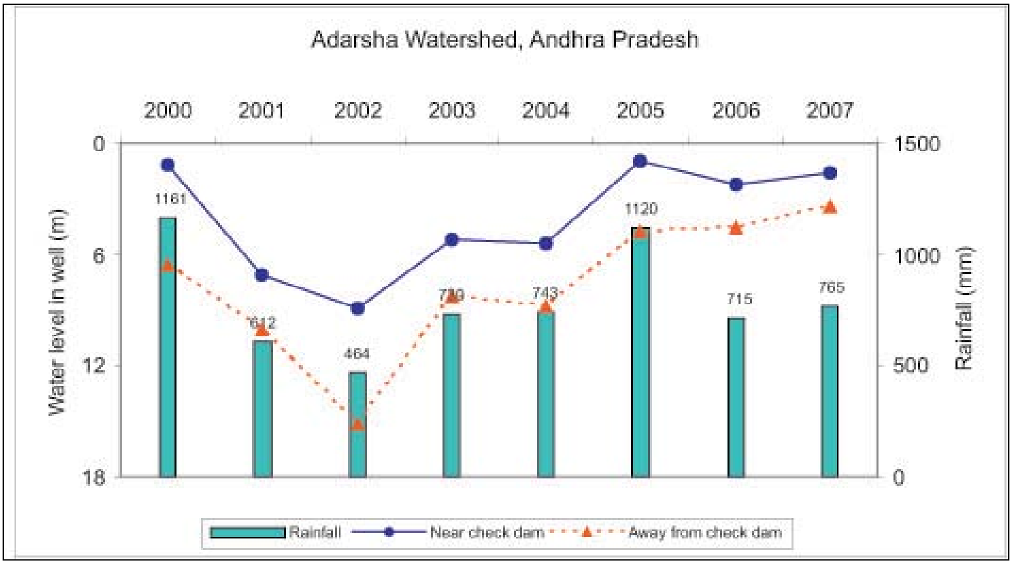

Figure 2. Impact water harvesting structures on groundwater levels in Adarsha watershed, Kothapally, Andhra Pradesh.

Efficient Use of Supplemental Irrigation Water

Once the surplus water has been harvested in surface ponds or the groundwater is recharged, its efficient use is important for increasing crop productivity in a sustainable manner. Efficient use of water involves both the timing of irrigation to the crop and efficient water application methods. Broadly, the methods used for application of irrigation water can be divided into two types viz. surface irrigation systems (border, basin and furrow) and pressurized irrigation systems (sprinkler and drip). In the surface irrigation system, the application of irrigation water can be divided in two parts – first, the conveyance of water from its source to the field and second, application of water in the field.

Conveyance of Water to the Field*:* In the most SAT areas, the water is carried to cultivated fields by open channel, which are usually unlined and therefore, a large amount of water is lost through seepage. On SAT Vertisols, generally there is no need of lining the open field channels as the seepage losses in these soils are low mainly due to very low saturated hydraulic conductivity in range of 0.3 to 1.2 mm hr^{-1} (El-Swaify et al. 1985). On Alfisols and other sandy soils having more than 75% sand, the lining of open field channel or use of irrigation pipes is necessary to reduce the high seepage water losses. The uses of closed conduits (plastic, rubber, metallic and cement pipes) are getting popular especially with farmers growing high value crops viz. vegetables and horticultural crops.

Efficient Application of Supplemental Water on SAT Vertisols: Formation of deep and wide cracks during soil drying is a common feature of SAT Vertisols. The abundance of cracks is responsible for high initial infiltration rates (as high as 100 mm hr^{-1}) in dry Vertisols (El-Swaify et al. 1985). This specific feature of Vertisols makes efficient application of limited supplemental water to the entire field a difficult task. Among the various systems studied at ICRISAT, the BBF system was found to be most appropriate for applying irrigation water on Vertisols. As compared to narrow ridge and furrow, the BBF saved 45% of the water without affecting crop yields. Compared to narrow ridge and furrow and flat systems, the BBF system had higher water application efficiency, water distribution uniformity and better soil wetting pattern. Studies conducted to evaluate the effect of shallow cultivation in furrow on efficiency of water application showed that the rate of water advance was substantially higher in cultivated furrows as compared to that in uncultivated furrows. Shallow cultivation in moderately cracked furrows before the application of irrigation water, reduce the water required by about 27% with no significant difference in chickpea yields (Table 4).

Table 4. Grain yield of chickpea in different treatments, Vertisols, ICRISAT Center

Treatment	Mean depth of water application (cm)	Grain yield (kg ha^{-1})
No supplemental irrigation	0	690
One supplemental irrigation on uncultivated furrows	6.3	920
One supplemental irrigation on cultivated furrow	4.6	912
SEM		19
CV%		5.55

Efficient Application of Supplemental Water on SAT Alfisols: On Alfisols, surface irrigation on flat cultivated fields results in very poor distribution of water and high water loss. At ICRISAT research station, Patancheru, India, experiments were conducted to find out the most appropriate land surface configuration for the application of supplemental water. The wave-shape broad-beds and furrows with checks at every 20 m length along the furrows, was found to be most appropriate for efficient application of supplemental water and increasing crop yields. It was observed that the moisture distribution across the beds was uniform, in case of wave-shape broad-beds with checks compared to normal broad-bed and furrow (BBF) system. The sorghum yield in wave-shape broad-beds with checks was higher at every length of run compared to normal BBF (Table 5). It was found that when irrigation water was applied in normal BBF system on Alfisols, the center of the broad-bed remained dry. The centre row crop did not get sufficient irrigation water, resulting in poor crop yields. In another experiment on Alfisols, normal BBF system (150 cm wide) was compared with narrow ridge and furrow system (75 cm wide). It was found that the narrow ridge and furrow system performed better than BBF system both in terms of uniform water application and higher crop yields. Therefore, for Alfisols, the wave-shape broad-bed with checks in furrow is the most appropriate land surface configuration for efficient application of supplemental irrigation water, followed by narrow ridge and furrow system.

Table 5. Sorghum grain yield (t ha^{-1}) as affected by the water distribution in different surface irrigation systems on Alfisols.

Length of run (m)	Normal BBF	Wave-shape broad-beds with checks in furrow
0	2.07	2.52
20	2.38	3.91
40	2.56	4.42
60	3.06	4.54
80	3.26	4.53
100	3.08	4.42

The modern irrigation methods viz. sprinklers and drip irrigation can play vital roles in improving water productivity. These irrigation systems are highly efficient in water application and have opened up opportunities to cultivate light textured soils with very low water-holding capacity and in irrigating undulating farm lands. The technology has also enabled regions facing limited water supplies to shift from low-value crops with high water requirements such as cereal to high value crops with moderate water requirements such as fruits, and vegetables (Sharma and Sharma, 2007). Implementation of these improved irrigation techniques can be used to save water, energy and increase crop yields. However, currently the use of these improved irrigation methods are limited, primarily due to the high initial cost. Favourable government policies and the availability of credit are essential for popularizing these irrigation methods.

Improved Crop Varieties and Cropping Systems

The adoption of improved varieties always generates significant field level impact on crop yield and stability. The yield advantage through the adoption of improved varieties has been recognized undoubtedly in farmer participatory trials across India under rain-fed systems. Recent trials during rainy season conducted across Kolar and Tumkur districts of Karnataka, India, revealed that mean yield advantage of 52 per cent in finger millet was achieved with high yielding varieties like GPU 28, MR 1, HR 911 and L 5 under farmers' management (traditional management and farmers' inputs) compared with use of local varieties and farmers' management (Table 6). These results showed the efficient use of available resources by the improved varieties reflected in grain yields under given situations. However, yield advantage of 103 per cent was reported in finger millet due to improved varieties under best-bet management practices (balanced nutrition including the application of Zn, B and S and crop protection). Similarly, use of improved groundnut variety ICGV 91114 resulted in pod yield of 2.32 t ha^{-1} under farmer management compared with local variety with similar inputs. The yields of improved varieties further improved by 83% over the local variety, due to improved management that included balanced application of nutrients.

Table 6. Effect of improved varieties of finger millet and groundnut under different levels of management in Kolar and Tumkur districts, Karnataka during 2005.

Finger millet yield (t ha^{-1})			Groundnut yield (t ha^{-1})		
Variety	Farmers' practice	Improved mgmt.	Variety	Farmers' practice	Improved mgmt.
Local	1.97	--	TMV 2 (local)	1.38	1.74
GPU 28	3.00	3.68	JL 24	1.92	2.80
MR 1	2.83	3.93	ICGV 91114	2.32	3.03
HR 911	2.90	3.66			
L 5	3.20	4.65			
Mean	3.00	4.00		1.88	2.52
% increase over local variety	52	103		36	83

Integrated Nutrient Management

Low fertility is one of the major constraints for the low productivity under rain-fed system besides water scarcity. The deficiency of N and P among the nutrients is considered as important issue in soil fertility management programs. However, ICRISAT-led watershed program across the sub-continent provided the opportunity to diagnose and understand the widespread deficiencies of secondary nutrients such as S, and micronutrients such as B and Zn in the soils of rain-fed areas (Sahrawat et al. 2007). On-farm survey across various states (Andhra Pradesh, Madhya Pradesh, Rajasthan, Gujarat, Haryana and Tamil Nadu), revealed that out of 1926 farmer's fields, 88 to 100 per cent were deficient in available S; 72-100 per cent in available B and 67-100 per cent in available Zn.

On-farm trials in Andhra Pradesh evaluated the response of crops to the application of S and micronutrients at the rate of 30 kg S, 0.5 kg B and 10 kg Zn ha^{-1}. The study revealed 79 per cent yield advantage in maize; 61 per cent in castor; 51 per cent in greengram and 28 per cent in groundnut compared to the yield levels without application of S and micronutrients (Table 7). Addition of micronutrients and S substantially increased productivity of crops and thus resulted in increased rainfall use efficiency (RUE). RUE of maize for grain yield under farmer inputs of nutrients was 5.2 kg mm^{-1} compared to 9.2 kg mm^{-1} with S, B and Zn application over and above the farmer nutrient inputs; respective values in the same order of treatment were 1.6 kg mm^{-1} and 2.8 kg mm^{-1} for groundnut and 1.7 kg mm^{-1} and 2.9 kg mm^{-1} in mung bean. However, addition of recommended dose of N and P along with S, B and Zn in legumes further increased agricultural productivity, RUE and incomes of the farmers (Table 8).

Table 7. Effect of sulfur and micronutrient amendments in different field crops

Crop	Crop yield (kg ha^{-1})		% increase over control
	Control	Sulfur + micronutrients	
Maize	2800	4560	79
Green gram	770	1110	51
Castor	470	760	61
Groundnut pod	1430	1825	28

Table 8. Effect of micronutrient application on rainfall use efficiency in various field crops in Andhra Pradesh, India

Crop	Rainwater use efficiency (kg mm^{-1} ha^{-1})	
	Farmers' practice	Farmers' practice + micronutrients
Andhra Pradesh (Kurnool, Mahabubnagar and Nalgonda districts)		
Maize	5.2	9.2
Groundnut	1.6	2.8
Mung bean	1.7	2.9
Sorghum	1.7	3.7

Integrated Pest Management

Integrated pest management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of available pest suppression techniques to keep the pest populations below the economic thresholds. In other words, IPM is a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health and environmental risks. New IPM products and methods are developed and extended to producers to maximize yields. On-farm trials on IPM were evaluated in Bundi watershed, Madhya Pradesh, which clearly demonstrated that IPM comprises suitable varieties, clean cultivation, scouting through pheromone traps, use of NPV against lepidopteron pests and installing bird perches resulted in yield advantage of 18 per cent and increased net returns by 39 per cent in green peas compared with practice of chemical control alone (Table 9).

Table 9. Effect of IPM on crop productivity and net returns in green peas, Bundi watershed, Rajasthan

Technology	Cost of cultivation (Rs ha^{-1})	Cost of pest management (Rs ha^{-1})	Yield (t ha^{-1})	Net returns (Rs ha^{-1})
Farmers' practice	8520	1800	3.53	10870
IPM	7800	1080	4.16	15070

Crop Intensification: A Case Study from Guna Watershed, Madhya Pradesh

The practice of fallowing Vertisols and associated soils in Madhya Pradesh has decreased after the introduction of soybean. However, it is estimated that about 2.02 M ha of cultivable land is still kept fallow in the central India, where there is a vast potential for having crop during *kharif* season. However, the survey indicated that the introduction of *kharif* crop is delaying the sowing of postrainy crop and frequent water-logging of crops during *kharif* season, which is a major problem forcing farmers to keep the cultivable lands fallow. Under such situations, ICRISAT demonstrated the avoidance of water-logging during initial crop growth period on Vertisols by preparing the fields to BBF along with grassed waterways. Simulation studies using SOYGRO model showed that early sowing of soybean in seven out of 10 years was possible by which soybean yields can be increased three-folds along with appropriate nutrient management. Hence, timely sowing with short-duration soybean genotypes would pave the way for successful postrainy crop where the moisture carrying capacity is sufficiently high to support successful postrainy crop. Yield maximization and alternate crops can be focused on postrainy season as there is assured moisture availability in Vertisol regions. On-station research was initiated with Indian Institute of Soil Science (IISS), Bhopal, to address issues related to soil, water and nutrient management practices for sustaining the productivity of soybean-based cropping systems in Madhya Pradesh. Then, the conceptual best-bet options were scaled up in farmers' fields and yield advantages were recorded to the tune of 30 to 40 per cent over the traditional system.

On-farm trials on soybean conducted by ICRISAT involving improved land configuration (BBF) and short-duration soybean varieties along with fertilizer application (including micronutrients) showed the yield increase of 1300 to 2070 kg ha^{-1} compared to 790 to 1150 kg ha^{-1} in Guna, Vidisha and Indore districts of Madhya Pradesh. Soybean varieties evaluated were Samrat, MAUS 47, NRC 12, Pusa 16, NRC 37, JS 335 and PK 1024 out of which performance of JS 335 was better in Guna watershed of Madhya Pradesh. Increased crop yields (40-200%) and incomes (up to 100%) were realized with landform treatment, new varieties and other best-bet management options.

Crop Diversification with Supplemental Irrigation

The primary constraints for food security in developing countries are low productivity per unit area, shrinking land and water resources available for cropping and escalating costs of crop production. Under these circumstances, crop diversification can be useful means to increase crop output under different settings of available resources either through broadening the base of the system by adding more crops coupled with efficient management practices or replacing traditional crops with high value crops. Crop diversification allows realization of the real value of improved water availability through watershed programs either through growing high value crops like vegetables or more number of crops with supplemental irrigation. However, crop diversification takes place automatically from traditional agriculture to high value/commercial agriculture at the field level once the water availability is improved. On-farm survey in Ringnodia watershed in Madhya Pradesh revealed the spread of high value crops like potato, coriander, garlic, etc., and increase in net income from farming activities once the scope for supplemental irrigation was established in the watershed (Table 10).

Table 10. Crop diversification with high value crops with supplemental irrigation in Ringnodia watershed, Madhya Pradesh

Crops	Area covered (ha)	Yield (t ha^{-1})	Net income (Rs ha^{-1})
Potato	8.3	17.5	29130
Onion	1.0	25.2	42000
Garlic	1.5	7.6	15750
Hybrid tomato	1.5	66.8	55000
Coriander	2.9	6.1	12700

Crop Diversification with Chickpea in Rice Fallows

It is estimated that about 11.4 m ha of rice fallows are available in India. The amount of soil moisture remaining in the dry season after rice crop is usually adequate for raising a short-duration legume crop. Despite low yields legumes grown after rice due to progressively increasing bio-physical stresses, their low-cost of production and higher market prices often results in greater returns to the farmer. Thus the twin benefits of income and nutrition could be realized from legumes rather than from rice in spite of moderate yields of legumes. Introduction of early maturing cool season chickpea in the rice fallows by addressing the crop establishment constraints will certainly improve cropping intensity and sustainability of the system. Main constraints to the production of legumes in rice fallows are low P in the soil, poor plant establishment, low or absence of native rhizobial population, root rot and terminal drought. On-farm trials in eastern states of India on growing of early maturing chickpea in rice fallows with suitable best-bet management practices revealed that chickpea grain yields in the range of 800 - 850 kg ha^{-1} can be obtained.

Molybdenum deficiency is considered rare in most agricultural cropping areas. However, our on-farm research since 2002 suggested that in the acid soils of rice fallows, molybdenum (Mo) is relatively unavailable and nodulation, growth and yield of chickpea can be improved by providing small amounts of molybdenum (Kumar Rao et al. 2008). The study revealed that seed priming with sodium molybdate resulted in the yield advantage of 2.6 to 13.7 per cent in rice fallow chickpea compared to control (Table 11). It is assumed that residual soil moisture after the harvest of rice in target regions could be 100 mm in the soil profile and hence moisture use efficiency of rice fallow chickpea is worked out to be in the range of 8.0 to 9.0 kg ha^{-1} mm^{-1}.

Table 11. Effect of seed priming with sodium molybdate on the performance of chickpea in rice fallows with residual moisture

States	Chickpea yield (kg ha^{-1})		
	Control	Seed priming with Mo	Yield advantage
Madhya Pradesh	814	917	12.7
Uttar Pradesh	2053	2207	7.5
Orissa	284	323	13.7
Jharkhand	664	663	--
West Bengal	309	317	2.6

Conclusion

It is evident from the above that to enhance crop production in a sustainable manner in the rain-fed areas on the SAT, we need to adopt an integrated approach of managing water resources. It comprises of *in-situ* rainwater conservation, water harvesting in ponds and groundwater recharging and its subsequent efficient use for enhancing productivity and reduced land degradation. Water harvesting in ponds and recharging of groundwater supported production of high value crops with supplemental irrigation. Crop diversification and intensification took place automatically at field level once the water availability was established, which in turn enhanced the system productivity and rainfall use efficiency. The major contributions to productivity enhancement came from adoption of improved crop varieties and integrated nutrient management and their interaction with soil and water conservation practices. Integrated pest management practices contributed more towards reducing cost of production and protecting the environment. The development and adoption of this new approach needs to be promoted for benefiting large number of farmers and to attain food security.

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14. Crop-Livestock Linkages in Watershed Villages of Andhra Pradesh

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Abstract

The focus of this study is to characterize the watersheds in terms of crop and livestock development. Watershed development while improving the crop sector is expected to improve the feed and fodder situation and thus facilitate dairy development. This study analyzes the economic conditions of the people living in six watershed villages in Andhra Pradesh in the first year of implementation of the watershed program under the Andhra Pradesh Rural Livelihood Program (APRLP).

Keywords: Crops, livestock, watershed, livelihood, fodder.

Introduction

Livestock sector plays an important role in the rural economy of India with a high contribution to the gross domestic product (GDP) and a high absorption of female labor. The sector accounts for 5.59% to the GDP and 27.7% of the income from agriculture in India in 2001–02. In absolute terms, the sector has contributed 84.6 million tons of milk, 50.7 million tons of meat and 34 billion eggs and significant amount of organic manure.

The agriculture sector in India witnessed a skewed development since early 70's with much of the development-taking place in the irrigated regions at the cost of rain-fed areas. For example, the green revolution was confined to the irrigated and better-endowed regions of the country. To make up for this lacuna and also because the dry lands account for more than 60% of the cropped area in the country, several programs have been initiated for the development of dryland agriculture, like for instance, the introduction of the Integrated Wasteland Development Program (IWDP) of 1989–90 and the National Watershed Development Program for Rain-fed Areas (NWDPRA) of 1990–91. Improving agricultural production and restoring ecological balance are the twin objectives of these programs. Watershed approach allows for a more holistic development of the agricultural sector ie, crop and allied sectors like, horticulture, livestock, fisheries, etc., with focus on integrated farming systems and management of common property resources to augment family income and improve nutritional levels of communities participating in watershed programs. The state of Andhra Pradesh in India has a very high coverage of watershed development program. Almost 30% of the total watersheds taken up in the country are located in this state and are taken up under various rural development programs. Another rural development program, Rural Infrastructure Development Fund (RIDF-VI) is implemented under the assistance of the National Bank for Agriculture and Rural Development (NABARD). The state government contributes only 10% of the cost of the project. This program covered 1345 watershed projects till the end of March 2004. Andhra Pradesh Hazard Mitigation and Emergence Cyclone Recovery Project (APHM & ECRP) was implemented during July 1997 and July 2002 in five districts viz., Adilabad, Chittoor, Anantapur, Nellore and Karimnagar. The project covered 20 watersheds in each district (Government of Andhra Pradesh, 2004). Thus, almost all the development programs are implemented on watershed basis.

To understand the impact of the watershed projects on the livelihoods of the people, a careful analysis of the base situation is essential. Such an analysis provides a baseline for concurrent evaluation to be carried out during the implementation of the project and impact evaluation to be taken up after the completion of the program.

This study analyzes the economic conditions of the people living in six watershed villages in Andhra Pradesh in the first year of implementation of the watershed program under the Andhra Pradesh Rural Livelihood Program (APRLP). The project is implemented under a consortium approach involving farmers, public sector organizations, private sector, NGOs and civil society organizations. There are few studies that closely examine the contribution of watershed programs on the livestock sector. This study with special focus on the livestock sector is to fill this gap in the literature.

Objectives of the Study

- Analyze the socio-economic features of the villages with watershed programs and characterize the farming and livestock production systems.
- Examine linkages between crop sector and livestock.
- Study the impact of watershed development on livestock sectors in terms of improving the livelihoods of the poor.

Methodology

The study uses the data collected from six villages in Andhra Pradesh where watershed program has been initiated under the APRLP. Particulars of sample villages and sample size of households in each village is shown in Table 1.

Table.1. Particulars of sample villages and sample size.

Village	Mandal	District	Households in the sample	Households in the village
Malleboinpally	Jadcherla	Mahabubnagar	60	230
Mentapally	Wanaparthy	Mahabubnagar	65	235
Thirumalapuram	Chintapally	Nalgonda	72	NA[1]
Kacharam	Yadagirigutta	Nalgonda	90	324
Nandavaram	Banaganapalli	Kurnool	63	1234
Devanakonda	Devanakonda	Kurnool	70	1798

1. NA = Data not available.

Data were collected for 2001–02, the year of initiation of the program. The characteristics of each village were recorded in terms of size distribution of landholdings, caste composition, availability of irrigation, rainfall, cropping pattern, size and composition of bovines, fodder availability, livestock feeding patterns, milk yield, income from different sources, income distribution and incidence of poverty.

The impact of watershed development on crop and livestock sectors is examined by analyzing the data pertaining to two villages in Medak district. One village is drawn where a watershed program has been on-going since last 5 years and the other is selected from outside the program area. This non-watershed village has the same agro-climatic features as the watershed village. A sample of 60 households is selected randomly from each of these villages.

A. Baseline Survey Findings: Six Watershed Villages

Agro-Economic Features: Six Watershed Villages

Social and Educational Characteristics

Of the six villages considered, Thirumalapuram has a very high proportion of scheduled castes (SCs) and scheduled tribes (STs) and Devanakonda has dominance of backward castes. The other four villages have a balanced distribution of castes. However, Nandavaram and Devanakonda have a low proportion of SCs and STs.

Malleboinpally, Mentapally and Thirumalapuram have low level of literacy among the heads of the households. However, a significant proportion of heads of households in Malleboinpally has secondary and above levels of education. Among the six villages, Nandavaram and Devanakonda have higher levels of education than the other four villages. These villages also have a low proportion of SCs and STs.

Rainfall and Irrigation

Four of the six villages (Malleboinpally, Mentapally, Nandavaram and Devanakonda) received about 600 mm per annum. One village (Thirumalapuram) receives as low as 571 mm per annum and one village (Kacharam) receives a high rainfall of more than 800 mm per annum. However, both these villages and Devanakonda suffered severe drought during 2002–03 with a shortfall of more than 40% in rainfall. Though the villages differ in terms of rainfall received per annum, all of them receive less than the state average rainfall of 940 mm in Andhra Pradesh.

All the six villages have very low irrigation ratio of less than 25%. However, two villages viz, Nandavaram and Devanakonda, have the lowest irrigation ratio of 3.9% and 14.7%. In the remaining four villages irrigated area forms about 20% of the net area sown. However, in the year of survey most of the wells were dried up. For more details on the above aspects, see Shiferaw et al. 2003)

Land Distribution and Cropping Pattern

Thirumalapuram has the highest proportion (more than 30%) of landless households followed by Malleboinpally, Kacharam and Devanakonda (10–14%). Menatapally and Nandavaram have an exceptionally low proportion of landless households (about 5%). Nanadavaram has very high land resource with 80% of the households belonging to the category of medium and large farmers. Devanakonda and Mentapally also have a high proportion of medium and large farmers. Malleboinpally has a high proportion of marginal and small farmers.

Pulses are the dominant crops accounting for 30 to 40% of the area in all the villages except Devanakonda. Paddy is insignificant in all the villages except Thirumalapuram and Malleboinpally where it has a share of more than 12%. Devanakonda has a high proportion of area (65%) under oilseeds and horticultural crops. In Nandavaram, horticultural crops and cotton are dominant. Oilseeds are important in Mentapally and Thirumalapuram.

Per Capita Income and Incidence of Poverty

Nandavaram has highest per capita income and the lowest incidence of poverty. The high proportion of large farmers and favorable monsoon are responsible for this high position. Thirumalapuram occupies second position in per capita income, but incidence of poverty is relatively high. The high proportion of the landless in this village appears to be responsible for high poverty. Kacharam has moderate level of per capita income, but incidence of poverty is relatively lower as compared to its per capita income. Dairying is highly developed in the village and it is responsible for low incidence of poverty with a moderate size of landholding. Livestock sector contributes 30% of the household income. Malleboinpally and Devanakonda have per capita income of Rs 7850 and Rs 7510, respectively, but the latter has significantly lower incidence of poverty than the former. This is because of the high proportion of medium and large farmers in Devanakonda. Malleboinpally has very low proportion of households belonging to the category of medium and large farmers. Mentapally occupied the lowest position among the six villages in per capita income and incidence of poverty. This is neither due to drought nor due to landlessness. Livestock sector is highly backward, contributing only 7% to household income.

Livestock Production Systems: Six Watershed Villages

Introduction

The six watershed villages under study have been found to be distinct in terms of agro-economic characteristics. These differences are likely to have an impact on the livestock sector. Livestock systems can be broadly divided into small ruminant and bovine systems. Bovine systems differ in the types of bovines maintained. Given the data available, it is possible to classify the bovine systems into milk, work and mixed systems. If a household maintains only milch animals and meets the draft power requirements with hired animal power or tractor power, the system is designated as milk system. If a household maintains only draft animals, the system is designated as work system. If both milch animals and work animals are maintained, the system is designated as mixed system. There is another system in which only calf or dry animal is maintained. However, it is not considered here separately as there are very few households in this category. This section examines the livestock production systems existing in the six villages.

Size and Composition of Livestock

Participation in Livestock Sector

Participation in livestock sector at household level is measured in terms of the proportion of households maintaining bovines and small ruminants. A wide variation is observed in the proportion of households owning bovines not only between districts but also between villages in each district. Participation is high in Nandavaram and Thirumalapuram with more than two-thirds of the households maintaining bovines and low in Malleboinpally and Devanakonda with only 50% of the households maintaining bovines. Kacharam and Mentapally have a moderate level of bovine activity with about 60% of the households maintaining bovines (Table 2).

Table. 2. Percentage of households maintaining bovines in sample villages.

Village	Bovine households	Non-bovine households
Malleboinpally	51.7	48.3
Mentapally	58.5	41.5
Thirumalapuram	67.6	33.8
Kacharam	62.9	38.2
Nandavaram	71.4	28.6
Devanakonda	47.1	52.9

Participation of the households in small ruminant production is substantially lower than their participation in the bovine sector. However, the activity is significant in three of the six villages viz, Thirumalapuram, Malleboinpally and Kacharam with 13 to 19% of the households maintaining small ruminants (Table 3). Further, maintenance rate is positively associated with size of landholding, indicating that the activity is biased towards resource-rich farmers.

Table 3. Percentage of households maintaining small ruminants.

Village	Marginal and small farmers	Medium and large farmers	All households
Malleboinpally	15.0	20.0	16.7
Mentapally	3.5	5.7	4.6
Thirumalapuram	22.2	21.9	19.4
Kacharam	13.6	14.3	13.3
Nandavaram	-	7.7	7.9
Devanakonda	3.7	5.6	4.3

Production Systems

Kacharam specializes in milk production. There is no work system in the village. All bovine holdings produce milk either in milk system or in mixed system. Thirumalapuram, Malleboinpally and Nandavaram have predominance of milk production with equal importance for milk and mixed systems. Devanakonda and Mentapally are backward in milk production with a high proportion of work animal holdings. The latter has very few holdings in milk system and milk production is taking place mostly in mixed system (Table 4).

Table 4. Percentage of households by production system.

Village	Milk	Mixed	Total milk	Work
Malleboinpally	54.8	32.3	87.1	12.9
Mentapally	10.5	44.7	55.2	44.7
Thirumalapuram	43.8	43.8	87.6	12.5
Kacharam	42.9	57.1	100.0	-
Nandavaram	17.8	57.8	75.6	24.4
Devanakonda	45.5	22.3	67.8	27.3

The size of bovine holding varies across villages. These differences partly arise due to variations in production systems. The average size of bovine holding is high in villages with a large proportion of mixed system. On the other hand, the size bovine of holding is small in villages with a large proportion of work system. Kacharam, Thirumalapuram and Malleboinpally have a high herd size of more than 5.6 and the other three villages have a low herd size of less than four.

Buffalo is the dominant milch animal in all the villages. However, the ratio of cows to buffaloes varies widely across the villages. Malleboinpally and Nandavaram specialize in buffalo milk production with only 12 to 14 cows per 100 buffaloes. On the other hand, Thirumalapuram has a significant proportion of cows (74 per 100 buffaloes) among milch animals. The remaining three villages, viz. Mentapally, Kacharam and Devanakonda have about 45 cows per 100 buffaloes (Table 5).

Table 5. Milch animals per holding and cow buffalo ratio.

Village	Milk		Mixed		All	
	Cows/100 buffaloes	Milch animals/ household	Cows/100 buffaloes	Milch animals/ household	Cows/100 buffaloes	Milch animals/ household
Malleboinpally	16	3.82	11	4.90	14	4.22
Mentapally	-	1.25	59	2.05	48	1.90
Thirumalapuram	161	1.85	47	3.29	74	2.57
Kacharam	15	2.17	68	3.57	47	2.97
Nandavaram	36	1.88	23	2.34	12	2.23
Devanakonda	29	2.07	60	1.78	38	1.97

Milk Production

Milk yield per animal is very high in Kacharam and Devanakonda and low in Thirumalapuram and Mentapally. Both the villages have crossbred cows. Buffalo is predominant in Malleboinpally and Nandavaram, which occupy the middle position in milk yield. Poor performance of Mentapally and Thirumalapuram is due to the predominance of local cows with very low milk yield. When milk production per household is considered, Kacharam again stands at the top and Malleboinpally occupies second position pushing Devanakonda to the third position.

The distribution of milch animals by milk yield indicates the development of the dairy sector. Only Kacharam has a large proportion (65%) of cows with yield more than 3 liters. In all the other villages average yield of most of the cows is less than 2 liters per day. Devanakonda shows its superiority in milk yield of buffalo milk with nearly one-half of the buffaloes producing more than 3 liters per day. Malleboinpally and Kacharam also have a significant proportion of buffaloes (more than 20%) with high milk yield. A majority of buffaloes in Malleboinpally, Thirumalapuram and Nandavaram produce 1–2 liters per day and a majority in Mentapally and Kacharam produce 2–3 liters per day.

Development of market is also an important contributory factor for the development of the dairy sector. Mentapally is highly backward in marketing with only 23.2% of the milk being disposed within the village. Malleboinpally is also backward in marketing despite its high performance in production. Thus, the two villages in Mahabubnagar district are backward in marketing. If the sector is highly developed, marketing facilities will be developed automatically. But in the villages with backward agriculture, intervention in the infrastructure and development of market should go hand in hand with the development of production for the development of the sector.

Draft Animals

In backward agriculture, bovines are maintained mainly for draft animal power and milk production is secondary. As fodder availability improve, milk production becomes equally important and farmers manage the draft animal needs with hire services. Studies have shown that the proportion of small farmers maintaining work animals is low (Subrahmanyam and Nageswara Rao 1995). In some areas bovines are maintained for manure production. This is possible when grazing land is available in plenty. Development of dairy sector is dependant on mechanization of agriculture. A low proportion of farmers maintaining work animals and a low density of work animals is an indication of mechanization of agriculture.

Density of draft animals is the highest in Mentapally (1.14 ha^{-1}) and the lowest in Nandavaram and Devanakonda (0.49 ha^{-1}). The other three villages occupy a middle position (0.74 ha^{-1}). Except in Thirumalapuram the density of draft animals is lower on small farms than on large farms. Though the need for animal draft is reduced through mechanization, there is no guarantee that dairy development takes place. Other conditions like availability of feed and fodder and demand for milk should also exist for the growth of dairy sector.

Feed Availability and Utilization

Information on feeding in the baseline survey is rough and collected at one point of time for the entire herd. However, data on crop residues is available that provides an indication about feed and fodder situations.

The quantity of feed per animal is calculated by converting all the animals into adult units treating young stock as 0.5 adult. All feeds are converted into dry matter by taking 0.25 of green fodder and 0.9 of dry fodder (crop residues) as well as concentrates. Information available reflects only stall-feeding, as the data on feed obtained through grazing is not available. The feeding levels are high in Kacharam and Nandavaram where the average quantity of dry fodder fed per adult animal is more than 2.5 kg day^{-1}. (Table 6). In Malleboinpally, Mentapally and Thirumalapuram the quantity of dry fodder as well as concentrates fed is low. The feeding of green fodder is high in Devanakonda and Kacharam, and close to zero in Mentapally and Nandavaram.

Table 6. Quantity (kg day^{-1}) of feeds fed per adult unit.

Village	Dry fodder	Green fodder	Concentrates	Dry matter
Malleboinpally	1.14	0.51	0.18	1.32
Mentapally	2.09	0.04	0.13	2.01
Thirumalapuram	1.76	0.34	0.02	1.69
Kacharam	2.52	0.96	0.35	2.83
Nandavaram	3.96	0.01	0.36	3.89
Devanakonda	2.00	1.48	0.42	2.54

For total feed on dry matter equivalent, Nandavaram, Kacharam, and Devanakonda top the list followed by Mentapally.

The distribution of bovine holdings according to the quantity fed per adult animal indicates the proportion of households facing feed scarcity. In the three villages with low feeding levels per animal as indicated in Table 7 only 10% of the households are able to feed their bovines with more than 4 kg day^{-1}and 50 to 74% of the households feed less than 2 kg day^{-1}. In the other three villages with higher feeding levels per animal 25 to 38% of the households feed more than 4 kg day^{-1}. However, there is a significant proportion of households (18 to 35%) with feeding levels less than 2 kg day^{-1} (Table 7).

Table 7. Percentage distribution of holdings by dry matter fed per day.				
Village	<2 kg	2-4 kg	≥4 kg	Total
Malleboinpally	74.2	16.1	9.7	100.00
Mentapally	48.7	41.0	10.3	100.00
Thirumalapuram	59.2	30.6	10.2	100.00
Kacharam	31.6	43.9	24.6	100.00
Nandavaram	17.8	44.4	37.8	100.00
Devanakonda	35.2	32.4	32.4	100.00

Impact of Watershed Program on Livestock Sector

Introduction

The watershed program focuses on soil and water conservation and is expected to improve crop yields and green fodder availability. This, in turn, is likely to have an impact on milk production. To understand the impact of the program, we adopted with and without approach and analyzed the data relating to a village that has been covered under watershed program since 1999 and a nearby village with the same agro-climatic conditions and not covered under the watershed program. The sample for each of the two categories consists of 60 households. The questionnaire canvassed for the baseline survey of the watershed villages is also used for these two areas. The socio-economic features of the two villages are compared considering caste, education and work participation rate. Then the performance of agriculture is examined to understand the impact of the watershed program on agriculture. Finally, the impact of the program on the performance of the livestock sector is considered. For this paper only the findings related to the impacts of the watershed on the livestock sector are discussed below.

Size and Composition of Livestock

The watershed village differs significantly from the control village in the size, composition and productivity of livestock. Firstly, bovine activity is higher in the watershed village indicating that improvement in soil and moisture conditions leads to development of the livestock sector. This is because of the improvement in the availability of green fodder after implementing the soil and moisture conservation measures undertaken as a part of the program. The proportion of households maintaining bovines increased from 60% in the control village to 68.3% in the watershed village (Table 8). Secondly, there is a shift from small ruminants to bovine activity. Studies show that small ruminant activity is confined to resource-poor areas (Hanumantha Rao, 1994). The shift from small ruminant to bovine activity in the watershed village indicates improvement in the resource base of the village due to the watershed program. The proportion of households maintaining small ruminants declined from 30.9% to 26.3% and this shift came because of the shift of small farmers from small ruminants to bovine sector. It is to be noted that though small ruminant production is more in resource-poor areas, it is not high among resource-poor farmers. The proportion of milch holdings increased from 22.2% to 39.0% and the proportion of work holdings declined from 47.2% to 22.0%. The share of mixed holdings also increased from 30.6% to 39.0%. As a result of these shifts, the proportion of bovine holdings producing milk increased steeply from 52.8% to 78.0%. Fourthly, the improvement in the bovine sector comes through productivity improvement and not through increase in the size of the herd.

Table 8. Livestock characteristics of the two villages.

Item	Watershed village	Control village
Percentage of households maintaining bovines		
Bovine	68.3	60.0
Non-bovine	31.7	40.0
Percentage of holdings maintaining small ruminants		
Small and marginal (<2 ha)	16.7	24.3
Medium and large (>2 ha)	37.0	38.9
All	26.3	30.9
Percentage of households by production system		
Pure milch	39.0	22.2
Pure work	22.0	47.2
Mixed	39.0	30.6
Total	100.00	100.0
Average number of bovines per holding		
Pure milch	2.1	2.3
Pure work	1.7	1.9
Mixed	4.3	4.1
Overall	2.0	1.6

Milk Production

The improvement in the green fodder availability in the watershed village improved milk production and this improvement came through spread of the activity and improvement in milk yield. There is no increase in the number of milch animals per household. In fact, the number of milch animals per household declined from 1.44 to 1.37. But the value of milk output per household increased by 14.7% from Rs 7630 to Rs 8750 and the proportion of households producing milk increased from 52.8 to 78.0% (Table 9). This increase in production per household, despite decline in the number of animals per household, is contributed by the improvement in yield per animal by 24.7% from 550 liters to 686 liters. Further, the entire improvement in the yield took place in the milk system. The mixed system has not gained in milk production because its priority is for animal power for agricultural operations and milk production is secondary.

Table 9. Quantity and value of annual milk production.

Production system	Number of animals		Milk yield (L)		Output values (Rs)	
	Watershed village	Control village	Watershed village	Control village	Watershed village	Control village
Milch	1.58	1.75	809	513	10982	7950
Mixed	1.20	1.22	556	596	6670	7280
All	1.37	1.44	686	550	8750	7630

Fodder Availability and Feeding Levels

Crop residues, an important component in the livestock feed, are available from food grain crops and groundnut. The yield of crop residues is expected to increase with increase in the crop yield and shift in cropping pattern. Cropping pattern is more favorable to livestock feed in the watershed village as compared to the control village. The share of food grains is higher in the watershed village than in the control village and this is due to a larger extent of area under maize. The availability of crop residues per ha of cultivated land as well as per adult bovine unit in the watershed village is twice that of the control village both due to shift in cropping pattern towards food grains and higher crop yields

Because of the higher levels of fodder availability in the watershed village as compared to the control village, feeding levels are also found to be high. While the proportion of farmers feeding concentrates and green fodder is almost the same in both the villages, the quantities fed per animal differ significantly. About 14.6% holdings in the watershed village and 11.1% holdings in the control village feed green fodder. About 19% holdings feed concentrates in both the villages.

In the watershed village there is a steep increase in the quantity of greens fed and decline in the quantity of concentrates. With significant improvement in the availability of green fodder in the watershed village, farmers substitute concentrates for green fodder. The level of feeding dry matter is higher by 75% in the watershed village than in the control village (Figure. 1). The improvement in the feeding of dry fodder is only 35%. Thus, feeding levels improved through mostly green fodder and a little bit of dry fodder. These two types of feeds more than compensated the decline in the feeding of concentrates. It should be noted that farmers always try to manage with home-grown feeds rather than purchased feeds. The watershed program is expected to reduce the demand for concentrates because of the higher availability of green fodder. As the quality of animals improves, demand for concentrates will again increase.

Conclusion

There is a close linkage between the crop and livestock sector in the selected watershed villages. Livestock sector makes a significant contribution to the income in villages with well developed dairy sector. The success of the dairy sector depends on several aspects but feed availability is one of the critical factors influencing dairy development.

Impact study for a completed watershed village indicates that due to implementation of watershed program the availability of feeds and fodder increases and in this case particularly green fodder that stimulated the growth of dairy sector. At the same time the feeding of concentrates has declined indicating farmers' preference for home grown feeds/fodder. Clearly the watershed program is beneficial to poor and small-scale livestock keepers.

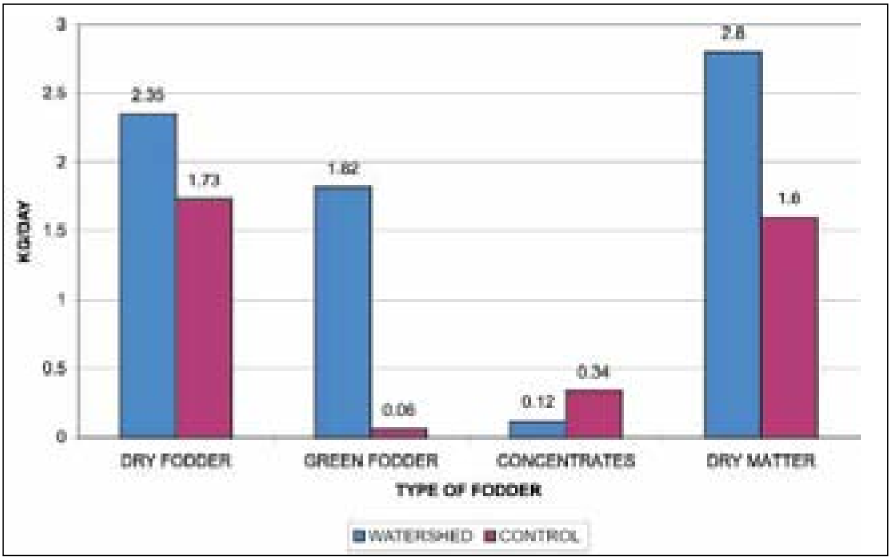

Figure 1. Quantity fed per adult unit.

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15. Rehabilitation of Degraded Lands in Watersheds

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Abstract

There are about 13 categories of wastelands identified in India, which constitute about 20.17% of total geographical area. The Govt. of India has identified 146 districts in 19 states for micro-planning of degraded lands. Nearly 83% of wastelands are in Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu and UP. This paper analyses the classes of wastelands and different approaches to reclamation of these lands.

Keywords: Watersheds, wasteland, livestock, land degradation, common property resources.

Introduction

The soil erosion, caused primarily by water and wind, is one of the major contributors to the land degradation. Livestock vis-à-vis overgrazing is yet another factor causing degradation of the existing common pool resources (CPRs). The existing CPRs, which include the natural grazing lands have very poor green cover to feed the livestock. Heavy grazing intensity reduces vigor of grazed plants, distort the plant growth pattern and change the biodiversity composition of the grazing land. The land degradation leads to the loss of soil, water, biota as well as nutrients from the topsoil. On the other hand improved practices result in efficient and accelerated nutrient recycling system, improved intake of rainwater and thus stimulate plant growth.

Extent of Degraded Lands

There are various estimates of wastelands ranging from 38.4 m ha to 187 m ha due to different methods employed (Table 1). There are about 13 categories of wastelands identified in India, which constitute about 20.17% of total geographical area (NRSA, 2000) (Table 2). The Govt. of India has identified 146 districts in 19 states for micro-planning of degraded lands. Nearly 83% of wastelands are in Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tamil Nadu and UP.

Table 1. Various estimates of wasteland in India (m. ha^{-1}).

Source	Area	% of total Geo. area
National Commission on Agriculture (NCA-1976)	175.0	53
Directorate of Economics & Statistics, Dept. of Agril & Cooperation	38.4	12
Ministry of Agriculture (1982)	175.0	53
Society for Promotion of Wasteland Development (SPWD-1984)	129.6	39
Department of Environment and Forests (BB Vohra, 1980)	95.0	29
National Wasteland Development Board (MoEF-1985)	123.0	37
National Bureau of Soil Survey & Land Use Planning (ICAR-1994)	187.0	57
National Remote Sensing Agency (NRSA-1995)	63.85	20
N.C. Saxena (Sec. RD-WD)	125.0	38

Source: V.B. Eswaran, Chairman SPWD, New Delhi, In Proc. of Seminar on Wasteland Development, March 2001, P-14

Table 2. Area under each category of wasteland in India.

Category	Area (Sq km)	% of total geographic area covered
1. Gullied and/or ravenous land	20553.4	0.65
2. Land with or without scrub	194014.3	6.13
3. Under utilized/degraded notified forest land	140652.3	4.44
4. Mining/industrial wasteland	1252.1	0.04
5. Barren rocky/stony waste/sheet rock area	64584.8	2.04
6. Steep sloping area	7656.3	0.24
7. Snow covered and/or glacial area	55788.5	1.76
8. Degraded pastures/grazing land	25978.9	0.82
9. Degraded land under plantation crop	5828.1	0.18
10. Sands-inland/coastal	50021.6	1.58
11. Water logged and marshy land	16568.5	0.52
12. Land affected by salinity/alkalinity-coastal-inland	20477.4	0.65
13. Shifting cultivation area	35142.2	1.11
Total wasteland area	638518.3	20.2

Note: 1,20,849 sq km in J&K is not mapped and hence not considered for calculating the percentage.
Source: NRSA (2000).

Harmonization of Databases for Decision Makers

Harmonizing databases for land use and land evaluation is essential to address the key issues related to land resources and sustainable development of degraded lands. There is a growing concern that various efforts are producing data sets, which are incompatible and figures do not match. This poses difficulties for decision makers to rely upon data emanating from different scientific organizations. Wastelands information of National Remote Sensing Agency (DOS) and soil degradation of National Bureau of Soil Survey and Land Use Planning (ICAR) form a good example. Therefore, there is a need for convergence of these data sets through harmonization to evolve a viable decision support system at policy maker's level.

The reported area under wastelands and their different categories by different organizations has been significantly varying. As per the Wasteland Atlas of India published recently by MoRD and NRSA, the area under wastelands is 63.85 m ha (NRSA, 2000); based on 1:50,000 scale mapping whereas, NBSS&LUP has reported soil degradation of 146.8 m ha in the country out of soil mapping on 1:250,000 scale.

The methodology adopted for harmonization of data sets consisted of collection of information available with NRSA, NBSSLUP, AISLUS and CAZRI, examining the definitions adopted by them, scope for harmonizing the classes in the legend of the maps and availability of maps (Ramakrishna et al. 2007). The nation-wide data are available only with NRSA and NBSSLUP. The data of AISLUS were covering only part of the country and hence not used in harmonization.

The comparison of legends between wastelands and degraded soil indicates that the common categories between wasteland maps and soil degradation maps are gullied and/ravinous lands, semi-stabilized to stabilized sand dunes, waterlogged & marshy lands and land affected by salinity/alkalinity. However, there are some exclusive categories such as land with/without scrub, shifting cultivation, degraded forest-scrub dominated, degraded pasture/grazing land, agriculture land inside notified forest, degraded land under plantations, steeply sloping area loss of top soil, terrain deformation, over blowing and loss of nutrients in soil degradation map.

After thorough deliberations on the data sets of wastelands and soil degradation, a legend comprising wasteland classes and soil degradation was prepared and the statistics were generated on degraded lands of India. The wasteland classes were compared with soil degradation classes to arrive at common classes and mutually exclusive classes. As per the harmonized efforts, the total degraded lands in the country are 105.96 m ha. The figure for soil degradation by water erosion (loss of top soil) is 20.52 m ha and 3.76 m ha for wind erosion (loss of top soil). The area under gully formation under water erosion is 8.47 m ha and under ravines is 1.9 m ha. Under wind erosion the aerial extent of over blowing is 1.89 m ha and 3.24 m ha under terrain deformation. The chemical degradation consists of salinization/alkalization and acidification (<4.5 pH) where the harmonized statistics are 6.73 m ha and 6.19 m ha, respectively. Under water logging two categories namely surface ponding (0.97 m ha) and sub-surface water logging (5.44 m ha) have been identified. The vegetal degradation with water erosion includes land with/without scrub, degraded forest - scrub dominated, agriculture land inside notified forest, degraded pasture/grazing land, degraded land under plantations and abandoned & current shifting cultivation areas of wasteland map prepared by NRSA. The area has been estimated to be 35.45 m ha. The other category includes mining and industrial waste, barren rocky/stony waste and snow covered/ice caps and their aerial extents are 0.2 m ha, 5.77 m ha and 5.43 m ha, respectively.

Classes of Wastelands and Correctives

Since wastelands are unproductive for different socio-economic and bio-physical reasons, different technical solutions will be needed. Broadly speaking, Venkateswarlu (2003) grouped the wastelands into:

- Uncultivable
- Cultivable
- Social
- Marginal

Some details are discussed below:

Uncultivable Wastelands

The first reason is lack of soil of any kind. This includes those areas of barren rocky outcrops and where the surface consists largely of fractured rock, coarse gravel or loose boulders. The Himalayan peaks, frozen arid valley of Ladakh and the hot arid deserts of north-west again come in this category. They can be improved only by planting sparse forest cover in select micro-sites or soil pockets.

Cultivable Wastelands

These areas have some soil and include large areas where the soil is excessively acidic, alkaline, saline or waterlogged either naturally or through previous mismanagement. Such areas may be turned productive by:

- selecting especially tolerant species and varieties or arable crops or trees,
- special soil treatments like deep ploughing, drainage etc, and
- chemical amendments like liming, gypsum or sulphur application.

Generally, such treatments (ii & iii) are costly and only high value crops are likely to give an economic return. Therefore, selection of tolerant trees may be the only economically viable option.

Social Wastelands

This is another category of wastelands that are cultivable. The soils would largely be good with climate that is not extreme. But various social and economic factors make these lands subject to excessive exploitation pressures that remove the productive capital as well as the interest or harvestable annual production.

Among these are, mainly the lands where ownership is either ambiguous, absent or is common. Evidently nobody has a controlling interest to manage it for long term production. On the other hand everybody has an interest in extracting as much as possible. Returning such lands to productivity will require social and economic adjustments that can come through people's participation.

IRMA, Anand had a detailed study on such 'social wastelands' through six case studies. They conclude that the most desirable answers to be:

- assign property rights on newly developed wastelands to individual poor families; with technical back stop largely from voluntary agencies;
- community involvement in wasteland development reducing the indispensability of powerful local leadership;
- reward individual showing quality efforts;
- encourage group consensus in decision-making and also to avoid any possible conflicts;
- let small groups be made responsible for small units of land;
- provide incentives for the rate of growth of trees maintained by these small groups; and
- see that all the participants have access to the gains;

Yet another aspect under social wastelands is the CPRs. In and around the settlements (villages), the economically disadvantaged group (small and marginal farmers and landless labourers) depend on CPRs for their livelihood and also day to day amenities. They also need similar treatment as above.

Marginal Wastelands

This is another large category where combinations of the foregoing causes are at work. These are areas where the soil is very shallow or is gravelly or where other physical or chemical factors make it infertile and unproductive. Often such lands are neglected, partly because their productivity is low at best. But another important reason is because they often are held by resource-poor farmers who cannot afford the investment required to make them productive. Yet they are forced by their situation to continue to try to scratch a base subsistence of food crops for them. Most of the assigned lands (*Patta* lands) fall under this category. Restoring such lands to better productivity also requires a combination of socio-economic and technical interventions. Government of Andhra Pradesh has come up with novel scheme of Comprehensive Land Development Program (CLDP) and tree-based farming system by Bharatiya Agro-Industries Foundation (BAIF).

Watershed Approach to Reclamation

Reclamation products would be more effective if implemented on a watershed mode. This is particularly the case in respect of addressing land constraints such as soil erosion, water logging, salinity, and wind erosion, which have strong spatial dimension in their manifestation. A watershed approach means a strong central planning, active participation of stakeholders and institutions involved and collective ownership. Farmers' participation should be ensured from the beginning and they need to be appraised of the short-and long-term benefits of the measures. Plans need to be drawn such that farmers can see some short-term benefits and the technologies are remunerative. People participate only when they get tangible benefits. The traditional customs and practices, user rights of common pool resources, sustenance of natural resource base have to be taken into account so that the new approaches to development meet the needs of different sections of the society. Most of the degraded lands in a topo-sequence are located in the ridge part of the watershed. These are the hotspots and source of surplus runoff and soil erosion. The success of greening lies in treating these spots and site improvement.

Microsite Improvement

Rehabilitation of degraded lands is very important to enhance the green cover in India. Trees play positive role in ameliorating ill effects of harsh environments of the dry areas. Though many trees are planted each year through various planting programs and the target is achieved, the survival and growth of planted trees remain very poor in these areas. This may be due to many factors, among which poor site is a major one. Microsite improvement consists of soil profile modification. Size of the pit depends on the type of plant and has to provide a good rooting medium for the plant to establish and grow subsequently.

Microsite improvement is done by digging pits at spacing and of size appropriate to the tree species, back filling it with a pit mixture consisting of original soil, FYM and tank silt (in light soils) or sand (in heavy soils) in 1/3 proportion each (by volume). Phosphorus and insecticide are also added to the pit mixture to improve root growth and control termites. The digging can be done either manually or using tractor operated post-hole diggers. In the areas where labour is in short supply or the soil and climatic conditions are not favorable for manual pitting tractor can be used. The coverage with tractor drawn augers is more and faster. Moreover, the work can be done in unfavorable weather like hot summer when the manual work is not possible. Studies under rain-fed conditions at CRIDA have shown considerable improvement in survival and initial growth of the perennials. In the non-rainy period these trees can be spot irrigated using micro tubes or the drips. The cost of microsite improvement is a prerequisite for tree-based interventions to convert demanded degraded lands to dense greenlands.

Micro-catchments

Micro-catchments are formed around the single plant or along rows of plants depending on the planting geometry and topography of land. These measures are adopted to shape the land surface to concentrate the rainwater around the base of the plant. For this, mini–catchments or half-moon configurations are created around each plant. These mini-catchments around the plant can be created in many ways, triangular, rectangular, fish bone, crescent, V-shaped, catch pits, etc., can be raised with an open end at upper side to concentrate the surface flow for higher infiltration into the root zone. Besides these, trench cum bund, staggered and contour trenches were found useful in improving the survival and growth of seedlings planted.

Participatory Approach to Rehabilitate Common Property Resources (CPRs) with Biodiesel Plantations

Energy security has assumed greater significance than ever as energy consumption, food production; improved livelihoods and environmental quality along with water availability are interrelated. Asian countries with dense population are more prone to energy crises than to their counterparts in the world. A strong nexus between overall development and energy consumption as well as source of energy exists. Developed country use more fossil fuel to meet their energy demand where as developing country use lower energy as well as higher proportion of energy from the renewable sources such as wood, coal, animal power, cow dung cakes, etc., (Karekezi S and Kithyoma W, 2006).

Any increase in food production calls for higher energy use in terms of irrigation and fertilizer, as further expansion of area under agriculture is limited. Countries like India have to maintain a delicate balance between food, fodder, water and energy security. All these are interrelated and need to be considered together. For example India has to produce 250 million tones of food to feed its ever-growing human population. Water demand for food as well as for industries, human needs, and environmental services is increasing. Under water limited situation by 2025 one third of the developing world would be facing physical scarcity of water (Seckler et al. 1998). Similarly, of 852 million poor people in the world, 221 million are in India and more number of poor reside in dry land rural areas. Edible oils as well as productive lands will have to be spared for food. Considering all these points use of degraded common property resources (CPRs) along with low-quality private lands with conservation and efficient use of rainwater strategies open up a new window of opportunities for growing non-edible oil trees for improving livelihoods of rural poor (Wani et al. 2006). The advantages of perennials are many as the greenery will protect the land from further degradation and generate employment in rural areas. The total number of species with oleaginous seed material mentioned from different sources varies from 100 to 300 and of them 63 belonging to 30 plant families holds promise. Two species namely *Jatrohpa curcas* and *Pongamia pinnata* are favored in India because of their contrasting plant characteristics and the species selected should match the site characteristics.

ICRISAT developed novel approach for rehabilitating degraded common property resources (revenue lands) using biodiesel plantation involving local landless communities. CPRs for establishing biodiesel plantations were identified through consortium approach involving officials from government functionaries, non-governmental organizations (NGOs), local governing bodies and community. Institutional arrangement was carved out in the identified locations for involving unorganized agricultural labors as a stakeholder in the model. The village agricultural labors are encouraged to bind themselves to form self help groups (SHGs) and inspired to work in the identified lands for establishing biodiesel plantations (Fig. 1). Thus formed SHGs benefit not only earning from the wages and the groups are fostered to nurture plantations by offering harvesting rights (usufruct rights) (Fig. 2) once the plantation starts yielding economic benefits. The arrangement makes wage earners to inculcate ownership in the model. The successful establishment of model not only rehabilitates the degraded lands into greening lands but also becomes source of livelihood for the landless people. ICRISAT has restored more than 500 ha of degraded lands with biodiesel plantations in Andhra Pradesh through the participatory model.

Fig. 1. Biodiesel plantation through collective action of SHGs in Velchal, Andhra Pradesh.

Fig. 2. Biodiesel user-fruct rights handed over by the District Magistrate, Ranga Reddy, Andhra Pradesh, India, to the SHG leaders

Integrating Indigenous Fodder Grasses with Biodiesel Plantations in Low-Quality Grazing Lands

ICRISAT and BAIF evolved model for restoring grazing lands with biodiesel plantations on CPRs in Rajasthan, India (Dixit et al. 2005). In many parts of semi-arid systems, livestock is the mainstay of livelihoods for the survival, where common grazing lands are used to support fodder requirements of the livestock population. Over time, common grazing lands are degraded and grasses grown are neither palatable nor sufficient to feed the livestock population. The village communities are sensitized for collective action, to contribute the labor for the development of the grazing land. Initially, the lands are restored with biodiesel crops for preventing soil erosion and subsequently sowing of grasses were taken up in between rows of plantations with soil and water conservation structures. Institutional mechanism was designed to safeguard the restored areas and harvest the fodder grasses from the land. The model created a sense of ownership among the community for the protection of natural resources and management. The model is highly suitable for establishing plantations on marginal soils aiming at integration of livestock for generation of sustainable livelihoods.

The Process

BAIF Institute of Rural Development, an NGO that is implementing the project, initially recognized the problem and engaged the community to discuss about what could be done to improve the situation. The people reciprocated positively and agreed to part with half of the common grazing area for rehabilitation. The village stakeholder community consisting of grazers, herders and farmers through *panchayat* (local village governing elected body), resolved to erect stone fence around the 45-ha grazing land and not allow any cattle to graze in that area. Thus the area was fortified with physical and social fencing. The stakeholders agreed to take up rehabilitation of the grazing land in half the area initially so that the other half was accessible to common grazing. Villagers contributed their labor to erect stone fencing, and construct soil and rainwater conservation structures to arrest runoff and increase infiltration. Over 200 staggered trenches, 290 percolation pits and 6 gully plugs were constructed across the grazing land. Once the *in-situ* rainwater harvesting structures were in place villagers planted useful grasses and saplings all over the area. The degradation was so severe that the mortality of the saplings was very high. The idea of putting up stone bench terraces, contour trenches and catch pits for in-situ moisture conservation was considered. This resulted in excellent soil and moisture conservation and aided establishment of vegetation. Despite consecutive droughts from 2000 to 2003, the area turned lush green in stark contrast with gray area across the fence (Fig. 3). The villagers cut the required grass freely from the area to feed their cattle and no free grazing is done. For the benefit of CPR villagers leave half of the quantity of grass cut by them for the society. The society auctions the collected grass to neighboring villagers and earns an income of US$ 1830 per annum.

There was a perceptible improvement in the density of vegetation in the protected grazing land in contrast to the unprotected land (Figure 4). The density of vegetation including grass has attracted many birds and animals to this part of the grazing land. Prominent among these are blue bulls. The effort of the villagers and the *panchayat* for over six years has brought out remarkable changes in the flora and fauna of this piece of land. The whole episode has brought out valuable learning for all those involved in the project and helped enhance the confidence level of the villagers. It was precisely at this juncture that the project staff thought of getting the whole process recorded and evaluated by the very people who were instrumental in the success of the project. Thus came the idea of getting the villagers to assess the biodiversity in the rehabilitated grazing land in contrast with land not rehabilitated.

The Objectives of this Exercise

- Let the community know the worth of the efforts put in by collective action.
- Create awareness in the community about the importance of community action in natural resource management.
- Create a sense of ownership among the community so that the conservation and management of natural resources by the community go beyond the project period.

Fig. 3. A villager showing the difference in vegetation on either side of the fence at Devjika Thana, Rajasthan.

Fig. 4. Rehabilitated CPR and Devjika Thana, Bundi in Rajasthan: The PBA team with a blue bull calf found in the same area.

- The number of species of useful grasses and fodder has increased tremendously. Besides the flora, even the fauna was rehabilitated in this area. This area is a safe haven for nilgai (a species of wild cows (blue bulls), adults and young ones. Rabbits, hares, jackals, foxes, mangooses and a host of bird species are found in this area. A biodiversity assessment was undertaken recently with the community participating actively in enumerating and listing the uses of the various herbs, shrubs and grasses that have been rehabilitated in this area.

Opportunity and Challenges of Common Land Development-
Seva Mandir`s Experiences

Seva Mandir, a NGO, involved in community development activities in Rajasthan since 1969. It focuses on enhancement of rural livelihoods through development of private wastelands; soil and water conservation activities and small lift irrigation schemes under the guidance of JFM and National Watershed as about 42% of the land is under forest. From 1986 to 2005, Seva Mandir afforested 13255 ha out of which 2509 ha is CPR land.

The problem of encroachment on commons cannot be dealt with by enacting a law against trespassing. To overcome it, Seva Mandir implemented GTZ supported project "Decolonizing the commons" – the provision of an "Environment Fund" which could be used to disburse incentives to the encroachers to handover the land back to the community.

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Trends in Negotiations and Outcomes

1. Facilitation by an outside agency: Presence of Seva Mandir in all cases has initiated the steps towards development of the commons and removal of encroachments, because of disempowerment of formal institutions such as *panchayats* to take any initiative on restoration of these lands, despite being their legal custodians.
2. Reasons for Encroachments: People are willing to buy even encroached pieces of land where the certainty of tenure is highly dubious. The encroachments in Shyampura, Turgarh, Madla all fall in the category of "bought" encroachments.
3. Extent of encroachments: Scattered encroachments are the major fact as in the cases of villages Turgarh and Shyampura, where the encroachers have encroached pockets of an entire forest block.
4. Implications of Encroachments: Ties between people in a village are not one-way but reciprocal and a dissonance in one sphere might translate into loss of support of the patron in other forums.
5. Eviction of Encroachments: The momentum generated on one issue can be transformed to other spheres of development. Building of informal institutions such as *gram vikas* committee, *samuh,* etc., gains support from this observation. It is easy to dislodge a small number of encroachers as in Gadla and Sankhla, recent encroachers than old ones.
6. Ambiguity in Land records, encroachers who have made the maximum investments on lands is not dissuaded under peer pressure to vacate the encroachments.
7. It is absolutely important to establish group norms for the management and usufruct sharing of the common assets developed, eg, *gram vikas* committee, by Seva Mandir.
8. Ambivalent state policies.

In this process, the poor gained the most. A sample survey conducted in 2005-06 on 16 sites covering poor 691 households (mostly tribals) revealed that each household received a monetary value of Rs.1392 (SISIN implementation report, Seva Mandir 2005-06). Apart from this, there have been enormous social and institutional gains. These relations have encouraged the emergence of stronger village level institutions with greater social cohesion (Bhise S.N. 2004, EERN 2002).

Policy Issues

- Access to treat the forestland falling under the watershed. Moreover, since the location of forests is on uplands, leaving forestland untreated would reduce the longevity of watershed treatment benefits downstream.
- Converting revenue land into village pasture can be made simple so that investments can be made to make revenue lands more productive.
- It would indeed be better if authority over village pastures were delegated to the concerned *gram sabha* rather than the *panchayat*.

Recommendations for Practitioners

- Rehabilitate wastelands or low-quality lands not fit for growing food crops with suitable SWC measures with suitable tree cover to decelerate land degradation.
- Use known source of planting material and promote self help groups for raising nursery.
- Identify nutritional constraints in lands targeted for such cultivations and undertake need-based nutritional amendments
- Adopt collective action mechanisms to ensure that livelihood of vulnerable groups and landless dependent on CPRs is not taken away.
- Provide usufruct rights to SHGs of landless/women to harvest benefits from rehabilitated CPRs to ensure improved livelihoods and sustainable management of CPRs.
- Most CPRs are encroached and it's a challenging task to evacuate the encroachments. Combination of social pressures, enabling policies and financial incentives could help in decolonizing the CPRs.

Investment Needs by Local/National Governments or Other Donors

- CPRs and low-quality lands owned by vulnerable group members in the society need public investment to minimize land degradation and provide livelihoods to the stakeholders.
- Greening wastelands through such initiatives need 700-1500 US$ per ha depending on locations and other factors.

Policy and Financial Incentives

- Policy support to access, develop and maintain CPRs is needed.
- Enabling policies to empower landless and vulnerable groups for collective action and facilitation by GOs and NGOs.

Conclusion

Wastelands can be developed with appropriate land and water management practices involving micro-site improvement and micro-catchments. Appropriate nutrient management options along with other agronomic measures can green the degraded CPRs and other low-quality lands through collective action. By allocating usufruct rights for the SHGs of vulnerable groups along with rehabilitation of degraded CPRs livelihoods can be improved and environment also could be protected. PRIs and the community-based organizations can ensure benefits to vulnerable members of the society. However, suitable mechanisms and policies should be worked out to target marginal areas for planting of need-based tree crops integrating with annuals.

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16. Participatory Monitoring and Evaluation of Watershed Development Projects: Issues for the Future

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Abstract

The watershed development programs aimed at promoting the overall economic development in rural areas through optimum utilization of in situ natural resources, to generate employment and to restore ecological balance. To achieve these objectives several issues form crucial to the policy makers. One such important issue is participatory monitoring and evaluation of watershed development projects. An attempt has been made in this paper to critically review various watershed development programs implemented in the country over years and to analyze various issues which are crucial to enhance peoples participation in watershed development activities. The stakeholders should be involved at different stages of selection of project activities, planning and implementation with the ultimate objective of sustainability. Institutionalizing participatory monitoring and evaluation (through setting up of Participatory Monitoring and Evaluation Cell) at watershed level is a vital one. Also, the local villagers should be given proper training in monitoring and evaluation aspects. As watershed development has become important today, these issues may be given priority for successful achievement of the developmental objectives.

Keywords: Watershed, impacts, participatory approach, monitoring, evaluation.

Introduction

Watershed development has been conceived basically as a strategy for protecting the livelihoods of the people inhabiting the fragile eco-systems experiencing soil erosion and moisture stress. The aim has been to ensure the availability of drinking water, fuel wood and fodder and raise income and employment for farmers and landless labourers through improvement in agricultural production and productivity (Rao, 2000).

The watershed development programs involving the entire community and natural resources influence (i) productivity and production of crops, changes in land use and cropping pattern, adoption of modern technologies, increase in milk production etc., (ii) attitude of the community towards project activities and their participation in different stages of the project, (iii) socio-economic conditions of the people such as income, employment, assets, health, education and energy use, (iv) impact on environment, (v) use of land, water, human and livestock resources, (vi) development of institutions for implementation of watershed development activities and (vii) ensuring sustainability of improvements. It is thus clear that watershed development is a key to sustainable production of food, fodder, fuel wood and the meaningfully addressing the social, economical and cultural conditions of the rural community.

Though the watershed development has considerable merit in economic, agricultural, environmental and socio-economic conditions of the people who belong to it, watershed development has not produced desired results in many parts of the country. The watershed intervention need hitherto in many situations have failed to make any discernible impact on adoption of technologies by the farmers even in the adjoining villages. There are several factors responsible for poor performance. They include poor socio-economic status of people, low literacy and conservatism, remote locations, socio-political conflicts, inadequate credit facilities, subsistence orientation, inadequate marketing facilities, absentee landlordism, subdivision and fragmentation of holdings, inadequate storage facilities, lack of proper infrastructure facilities and lack of legal mechanism (Singh and Mishra, 1999). In addition, there are several issues centered around watershed development include financial, technological, people participation, capacity building, institutional support, monitoring and evaluation and coordination.

Keeping these issues in view the present paper aimed to examine the various watershed development programs in India and critically analyze the issues in relation to participatory monitoring and evaluation of watershed development. This paper is based on the evaluation study on impact of DPAP and IWDP watershed development programs conducted in Coimbatore district of Tamil Nadu.

Importance of Participatory Watershed Management

Unlike other development programs, watershed development program is banking heavily on participatory approach. In fact watershed development program envisages an integrated and comprehensive plan of action for the rural areas. Therefore, people's participation at all levels of its implementation is very important. This is so because the watershed management approach requires that every piece of land located in watershed be treated with appropriate soil and water conservation measures and used according to its physical capability. For this to happen, it is necessary that every farmer having land in the watershed accepts and implements the recommended watershed development plan. If these factors are looked into in an efficient manner, the watershed development could be hastened in the country. As the issue of sustainable natural resource management becomes more and more crucial, it has also become clear that sustainability closely linked to the participation of the communities who are living in close association with these natural resources. The slowing down, arresting and reversing the degradation of the important natural resources like land and water will be possible only if it becomes a people's movement involving the rural community and all those who work with them and have any stake in their development. This requires sustained effort in two important areas: (i) to inform and educate the rural community, demonstrate to them the benefits of watershed development and that the project can be planned and implemented by the rural community with expert help from government and non-government sources and (ii) to critically analyse the various in relation to monitoring and evaluation of participatory watershed management.

Participatory watershed management is constrained by several factors that affect the effective planning and implementation of the program. The people's participation depends on attitude of the people, rural environment, attitude of the government functionaries, government approach, lack of capacities, lack of women's participation, formulation of local institutions, ignoring local technologies and cost sharing (Palanisami et al. 2002). Thus, a watershed development project to become successful, the various issues concerned should be addressed. Active participation of watershed community at every stage of watershed development program e.g. planning, implementation and maintenance is a must for effective development and sustenance of the watershed development activities.

Monitoring and Evaluation of Watershed Projects

Watershed management is a unique development approach in which watershed is used as a basic unit of planning and management of land, water and other resources. Monitoring the watershed development program entails checking if the objectives of the program are being met successfully. It may not always be possible to measure the results that have been achieved because they may be intangible or it may be too costly to measure them effectively. In such cases indications that success is being achieved will make good proxies. Such indicators, however, must be chosen carefully so that they are reliable substitutes to direct measurement and are easy to measure in terms of time and effort. The choice of indicators is determined by who the end-user is.

What Should be Monitored?

In monitoring watershed projects, it is more important to understand the aspects that are to be monitored. The following should be considered while performing monitoring and evaluation by the stakeholders: (i) physical development of the watershed structures, (ii) capacity of the different stakeholders, and (iii) institutions to manage the watershed resources.

Participatory Monitoring and Evaluation of Watershed Development Projects

Participatory monitoring and evaluation is an ongoing process of information identification, information gathering, information analysis and information feedback (Davis-Case, 1989). Monitoring must be participatory. This means that each stakeholder is involved in identifying the indicators and in measuring the benefits. Participation will ensure that those indicators will be chosen which are meaningful to the stakeholders. This implies that the review of the indicators should be undertaken jointly by the community, the implementing agency and the donor agency. Decisions to make any modifications in the project/program being implemented must also be taken jointly based on the review. The key elements of participatory monitoring and evaluation are: (i) participatory monitoring and evaluation is directed and conducted by the beneficiaries in order to systematically record and analyse the information which they have determined to be important, (ii) it is systematic and consistent over the life of the project, rather than a one-shop information gathering exercise. This means that participants must have decided at the beginning of the project what is to be monitored, and how and when it will be recorded and processed, (iii) it is flexible, in the sense that if what is being monitored is not giving useful information, there is room for adjustment and (iv) it is locally relevant. The terms of measurement and tools of measurement are chosen by the beneficiaries.

Participatory evaluation is project evaluation in which communities and/or beneficiaries take the lead. They are encouraged and supported to take responsibility and control in planning, carrying out and reporting the results of the evaluation. Outsiders support and facilitate their efforts. The logic behind this perspective is that what the community feels is the real cost and benefits of the project are of the highest concern.

A participatory evaluation does not necessarily mean that a final judgement is being made. Rather, these events work towards making ongoing adjustments in the lifespan of the project. What can emerge is encouraging changes or adjustments in activities and perspectives, and/or increases in clarity of purpose. One important aspect of participatory evaluation is that it can determine whether or not project objectives are being met while also revealing the relevance of those objectives. It can indicate the need to adapt, revise, or change the old objectives. The overall purpose of a participatory evaluation is to encourage projects to stop and reflect on what has happened in the past in order to make decisions about the future. By evaluating, people learn about the things that have worked well and the things that have not worked well. They begin to realize why things have or have not worked well. And through the process, it becomes more likely that corrective measures will be implemented because they are discovered and understood by the community. In a participatory evaluation, the objectives of the project, as well as the expected outputs can be examined and clarified. It may be that the objectives of the community have changed, or that the expected outputs were unrealistic. Changes and adjustments may need to be made in order to achieve the desired results.

Participatory evaluation can also be used to avert a potential crisis; they provide a forum for discussion and problem solving. The findings of a participatory evaluation can also be presented to decision makers outside the community, giving them access to the perceptions of the community, which may be difficult to obtain through other means.

Indicators of Participatory Monitoring and Evaluation

In participatory evaluation, both project staff and beneficiaries together discuss and assess the performance in order to understand how they have performed. What the problems are and what the future holds for them, etc. The project staff plays a mere guiding role to formulate appropriate questions and find answers.

There is no single indicator of successful watershed development, so the most feasible approach is to compare the performance of a variety of indicators. The various performance indicators also reflect the diversity of the project objectives. These include raising rain-fed agricultural productivity, recharging ground water for drinking and irrigation, raising productivity of non-arable lands, creating employment, promoting collective action and building or strengthening social institutions.

The indicators can be broadly classified into bio-physical and socio-economic. The bio-physical indicators may include hydrological (runoff and silt load, ground water level, duration of pumping for will to go dry and recuperation time), number of surface water storage structures, arable lands (area under different crops, irrigated/ unirrigated area, inputs used, crop yields, fruit yields), changes in vegetative cover in the watershed (forest/vegetation cover) and land use changes. The socio-economic indicators include human population, family income from different sources, revenue generated from common property resources, cattle population, milk, meat production, changes in housing facilities, source of fuel/energy for domestic uses, farm and house hold assets acquired, literacy level, infrastructural development, growth of social institutions/organisations. Economic analysis such as net present value, benefit cost ratio and internal rate of return are widely used to assess the impact at watershed level.

Box.1. Peoples' Participation: Experience from DPAP Watersheds in Coimbatore District of Tamil Nadu

Evaluation study of 15 DPAP watersheds conducted in Coimbatore district of Tamil Nadu indicates that overall community participation was found to be low with overall peoples' participation index (PPI) as 42 per cent. The PPI was found to be 55, 44 and 27 per cent respectively at planning, implementation and maintenance stages. This suggests medium, low and very low level of community participation at planning, implementation and maintenance stages of watershed development program. This could be attributed to the fact that those who are not benefited from the project directly might not have participated in implementation and maintenance.

The study also revealed that community members of watersheds have contributed in cash and kind towards the works on private lands. Overall contribution for works on private land was found to be 14.71 per cent. It varied from a low of 7 per cent for fodder plots to a maximum of 22 per cent for horticulture and farm pond. The other activities include contour bunding, land leveling, summer ploughing, vetiver plantation and horticulture plantation. However, contribution in terms of cash/or kind towards development of structures such as percolation ponds, check dams etc., was found to be nil. This lucidly shows that the community members show inclination towards improving private benefits rather than social benefits.

Box. 2. Peoples' Participation: Experience from IWDP Watersheds in Coimbatore District of Tamil Nadu.

Mid-term evaluation of 18 IWDP watersheds in Pongalur block, Coimbatore district, Tamil Nadu, was carried out by the Water Technology Centre, Tamil Nadu Agricultural University during 2002. A total number of 270 respondents across eighteen watersheds were interviewed and assessed the peoples' participation in various stages of watershed development activities. It is revealed from the analysis that peoples' participation index at planning stage was medium (52.69 per cent) followed by low level at implementation stage (39.28 per cent). This shows medium to low peoples' participation at both the stages of the project. It could have been more by involving more people at planning as well as at implementation stage to ensure better sustainability of the project.

Regarding women participation in the watershed association, it was observed that two watersheds were led by women presidents, while only one watershed had elected woman secretary out of 18 watersheds. It was found that none of the presidents or chairmen was from scheduled caste (Adi Dravidar) community. However, there are eight scheduled caste members in three watershed registered bodies. It was also found one *dhobi* and one *barber* community representation in one watershed as members of the registered body.

Source: K.Palanisami, S.Devarajan, M.Chellamuthu and D.Suresh Kumar, Mid-Term Evaluation of IWDP Watersheds in Pongalur Block Of Coimbatore District, 2002.

Issues for the Future

In spite of the significant impact in performance, the experience raises a number of important issues, which have significant bearing on improving performance, impact and the sustainability of watershed development program. They are (i) role of different stakeholders in monitoring and evaluation, (ii) empowerment of human resources through training, (iii) peoples' participation and sustainability and (iv) post project sustainability, and (v). participatory monitoring and evaluation.

(i) Role of Different Stakeholders in Monitoring and Evaluation: Having realized the importance and potential benefits of watershed development, major changes are taking place across country in the context of watershed development. They have increased government commitment, increased demand for transparency and accountability in the process of implementation and increased pressure towards clarity and transparency in decentralization of decision making. Under this situation, there arises two important issues, viz., (i) interrelationship between project implementing agencies (PIAs), community based organizations like watershed associations, watershed committees, self-help groups and user groups and PRIs and (ii) the role of these stakeholders in monitoring and evaluation at different stages of its implementation. Monitoring and evaluation by these actors in the watershed is vital to effectively implement the projects. Thus there is dire need for promoting co-operation, co-ordination, relationship between local organizations and their participation in monitoring and evaluation. This will help in a big way the smooth functioning of watershed development program.

(ii) Empowerment of Buman Resources through Training: Empowerment of human resources is an important component in watershed development program for effective planning, implementation, maintenance and monitoring and evaluation of watershed development projects. Different people have different roles and responsibilities in project implementation and there is a need to the villagers involved in watershed development program. Training enhances knowledge, skill, attitude and human relationships. Though, a number of measures have been taken for strengthening training at various levels, the experiences show that the training programs should aim at (i) strengthening those processes, skills and knowledge that help in the delivery of various watershed development activities, (ii) improving the quality and content of the subject matter and (iii) providing more number of relevant trainings involving more community participation. Therefore, it is essential to examine in depth the whole gamut of training towards capability building among the various clientele groups operating in watershed. There is also a need for setting up training institute both at national and state levels for human resource empowerment.

(iii) People's Participation and Sustainability: Watershed development programs aim not only to conserve the land and water resources but also to ensure optimum utilization of natural resources and production. To achieve these objectives, the sustainability of watershed development efforts should be pursued. The experience raises a number of important issues. One such important issue is institution building and leadership formation for ensuring effective participation of people on a sustained basis (Rao, 2000). Also peoples' participation and decentralization of program administration which account for the success achieved so far, is highly inadequate for sustaining this development, especially in areas where the program has proceeded too fast by fulfilling the targets for completion of works without waiting for the required institution building and leadership formation at the grass root level (Yughandhar, 1999). Hence, the issue that comes to the mind of policy makers is how to encourage local leadership formation. Though, it should be a voluntary, the emergence of good leadership will help achieving the sustainability in watershed development programs. The stakeholders should be involved at different stages of selection of project activities, planning and implementation with the ultimate objective of sustainability.

(iv). Post Project Sustainability: In several watersheds, the structures are not maintained due to lack of funds as well as lack of co-ordination among beneficiaries. Also because of the local (*panchayat*) elections, many of the presidents of the watershed association have not been reelected resulting in lack of co-ordination particularly during the post-project management. Hence, appropriate strategies are to be evolved to manage this situation where, the presence is very alarming in several locations.

(v). Participatory Monitoring and Evaluation: In spite of the wide implementation of the watershed development program over years across the country, policy makers advocate setting up proper institutional mechanism for monitoring and evaluation both at macro and micro levels. At macro level, central monitoring and evaluation cell exclusively for watershed development programs may be started. At micro level/watershed level, the participatory monitoring and evaluation unit should be thought. This will help local community to monitor and evaluate the implementation of watershed development program in the context of objectives and expected results of the program, social and economic impact and coverage of the program. This will further help in making appropriate decisions that affects its development and more knowledge about the impact of various treatment activities. Institutionalizing participatory monitoring and evaluation (through setting up of participatory monitoring and Evaluation Cell) at watershed level is a vital one. Also, the local villagers should be given proper training in monitoring and evaluation aspects.

Table.1. Policy Matrix

Issues	Role of Stakeholders			
	Rural households	Community based organizations	PIAs/WDT/ NGOs	Government (Central and State)
Role of different stakeholders in monitoring and evaluation	Co-operate with CBOs, PIA and other organization	Interaction and linkages with other organizations	Promote relation with other organisations	Create conducive atmosphere for promoting co-operation, co-ordination and interrelationship among organizations
Empowerment of human resources through training	Active participation in training	Active participation in training	Impart training on relevant subject matter, more training	Setting up training institute exclusively for watershed training
Peoples participation and sustainability	Passive recipients to active participants	Should function during post project period also	Acts as facilitator and provide technical support	Separate funds for post maintenance activities
Post project sustainability	Emergence of local leadership	Should function during post project period also	Provide support during post project period	Separate funds for post maintenance activities and institutional mechanism
Participatory monitoring and evaluation	Should actively involve in monitoring and evaluation	Should actively involve in monitoring and evaluation	Conduct of bench mark survey before implementation	Institutional mechanism both at macro and micro level

Conclusion

Today watershed development has become the main intervention for natural resource management. Watershed development programs not only protect and conserve the environment, but also contribute to livelihood security. With the large investment of financial resources in the watershed program, it is important that the program becomes successful. For achieving the best results, people should be sensitized, empowered and involved in the program. Local community leaders and stakeholders should necessarily be motivated about conjunctive use of water, prevention of soil erosion, etc., through various media. The stakeholders at different levels should be involved at various stages of project activities, planning and implementation with the ultimate objective of sustainability. In addition to the above, strengthening of community organizations within the watershed, implementation of the planned watershed management activities, encouraging linkages with other institutions and initiating groups towards formation of apex bodies will help motivate the people and make it a people movement.

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17. Remote Sensing, GIS and IT in Watershed Development Programs

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Abstract

Adaptation of high-tech tools in tandem with the various processes involved in the project implementation provides the right platform to achieve success in implementation. A case in point is Sujala watershed. The advantages offered by remote sensing and GIS have been effectively used by Sujala for watershed prioritization, resources inventory and mapping, generating water resources and land resources action plan, site selection for implementation, monitoring of implementation, impact assessment, post project evaluation, run-off estimation.

Keywords: Watershed, GIS, remote sensing, information technology, monitoring.

Introduction

Participatory watershed development program aims at harmonizing the use of soil and water resources in an area that drains to a common point and designing approaches to generate the necessary collective action among affected people. The green revolution that transformed agriculture in India had little impact on rain-fed agriculture in the arid and semi-arid tropical regions, where agriculture productivity is low, natural resources are degraded and people are poor. The rain-fed areas are associated with high degree of land degradation and suffer from number of constraints such as low and uncertain rainfall, poor soil fertility, sparse vegetation cover, low productivity, lack of infrastructure, etc. A vast majority of people inhabiting in these areas have no access to primary education, basic health care or even clean drinking water and sufficient food. With the integrated mission of economic development, equity and environmental soundness, the accent has been on evolving multi-pronged strategy of sustainable rapid growth, especially poorer sections of the society and regenerating the eroded natural resource base. In this context, the Government of India is committed to watershed development as a priority approach to improve the social and economic conditions of people living in resource-poor, rain-fed areas of the country. Watershed development is gradually evolving into a comprehensive program with simultaneous pursuit of biophysical and rural development objectives that promote rural livelihoods. It is acknowledged now, that watershed based approaches can lead to substantial improvements in rural livelihoods as it provides new opportunities for households to diversify their livelihood strategies and supports agricultural intensification process.

Remote sensing and GIS inputs play an important role in empowering communities to enrich themselves with knowledge to develop watersheds, improve their standard of living and build a sustainable future on their own. An innovative program of participatory watershed development called 'Sujala' is being implemented in Karnataka state, using an optimal blend of earth observation inputs, GIS, field observations and information technology for planning, monitoring and implementation.

Constraints

There are a few constraints in using the high-tech inputs in watershed development in India, viz., general awareness on the technology, training and capacity building, simplification of the final product before being made available to the users, very few in the country have expertise to use remote sensing, GIS and information technology, service providers at local level, etc. There is a need to look into some of the above constraints in making the technology more user-friendly and adoptable for similar projects. There is also a general feeling amongst user community that the technology is expensive and not cost effective, but very few realize that in India the technology is very economical and cost effective and hence highly affordable.

Strategy and Approaches

The strategies and approaches that are to be adopted in any watershed development program should be fully process driven. Depending on the various well defined processes the right kinds of technologies have to be selected and customized for implementation. The potential of space technology in generating the base line information on land and water resources and in monitoring the progress and status of watershed development program has been well substantiated from various studies carried out so far.

Satellite remote sensing and GIS are the core technologies adopted for resource mapping, database generation, analysis and information extraction for watershed planning, implementation and monitoring. Under Sujala project, high resolution satellite data with the high spatial resolution of 6 meter has been utilised to generate maps on 1:12,500 scale. The advantages offered by remote sensing and GIS have been effectively used by the project for:

- watershed prioritization;
- resources inventory and mapping;
- generating water resources and land resources action plan;
- site selection for implementation;
- monitoring of Implementation;
- impact assessment;
- post project evaluation;
- run-off estimation.

While RS and GIS technologies could be used as mentioned above, the customized IT bases solution could prove to be effective in baseline database creation, customized solution for watershed development action plan in local language, on-line web-based monitoring through MIS and tools for withdrawal process.

Procedures and Practices

A unique opportunity to carry out monitoring and evaluation by implementing various RS, GIS and Information Technology at various stages of the Sujala watershed development project in five districts of Karnataka has successfully demonstrated. Adaptation of high-tech tools in tandem with the various processes involved in the project implementation provides the right platform to achieve success in implementation.

- The first and foremost requirement is to establish a strong baseline/benchmark database for the project area by the M & E team as a primary data source. This could be done by judicious use of remote sensing and statistical sampling based household surveys with respect to key performance indicators of the project. Both these inputs could be organized under a simple to use information system that uses RDBMS as the database engine.
- Design, development and deployment of a simple-to-use MIS tool at field level to capture information on the progress of various processes, particularly social mobilization, formation of community based organization (CBO), training and capacity building, processes involved in action plan preparation, continuous monitoring of action plan implementation and withdrawal mechanism/ consolidation.
- Deployment of process monitoring units with a focus on measuring socio-economic conditions and natural resources development. Systematic execution of process monitoring through out the project lifetime with an optimum mix of statistical sampling schemes, like, stratified random sampling, purposive sampling and multi-temporal repeat strategy. Execution of process monitoring in tandem

with MIS inputs and time-frame based information dissemination at field level and project authorities.

- Remote Sensing and sample ground based data integrated resource maping and action plan preparation. Provide such resource map based information with integration of cadastral data for the communities to take field-level decisions and prepare scientifically sound action plans. Customisation of such an information system under a simple-to-use GIS would help in better planning and execution of action plans.
- Customization of simple GUI based action plan preparation package. This package would facilitate the communities to record their preference for action plan implementation in their fields, ie. private land treatment and also village level decision to adopt common land development. The customization to take care of local language and local context while designing the package for local use.
- Facilitate a GIS customization to capture the peoples' aspiration with respect to item 4 so that action plan maps are digitally prepared in the field with people-participation. Again, it is important to provide simple GUI and easy to use menus under the package.
- Judicious use of the above items in impact assessment at various stages of project implementation. Remote sensing data usage at various stages of plan implementation helps in tracking the ground-based implementation including final impact assessments. Earth observation data can further be used in post-project phase to study the sustainability of the project and CBOs performance after project withdrawal.

Case Studies/Success Stories

Sujala is a participatory watershed development program, being implemented by Government of Karnataka with World Bank assistance in five districts, viz., Kolar, Tumkur, Chitradurga, Dharwad and Haveri of Karnataka State. The major objective of the project is towards improving the productive potential of degraded watersheds in dryland areas and poverty alleviation of rural community. The project is spread across 77 sub-watersheds (SWS) covering an area of about 0.51 million hectares and benefiting about 400,000 households. Locale specific action plans for sustainable development of land and water resources are generated (Fig.1) on micro watershed basis by integrating thematic information from the resource maps, people's aspirations and socio-economic inputs with special emphasis on community needs, survey number wise.

The major components of M & E are concurrent monitoring involving tracking of processes, input/output monitoring, and discrete monitoring of the impact due to interventions.

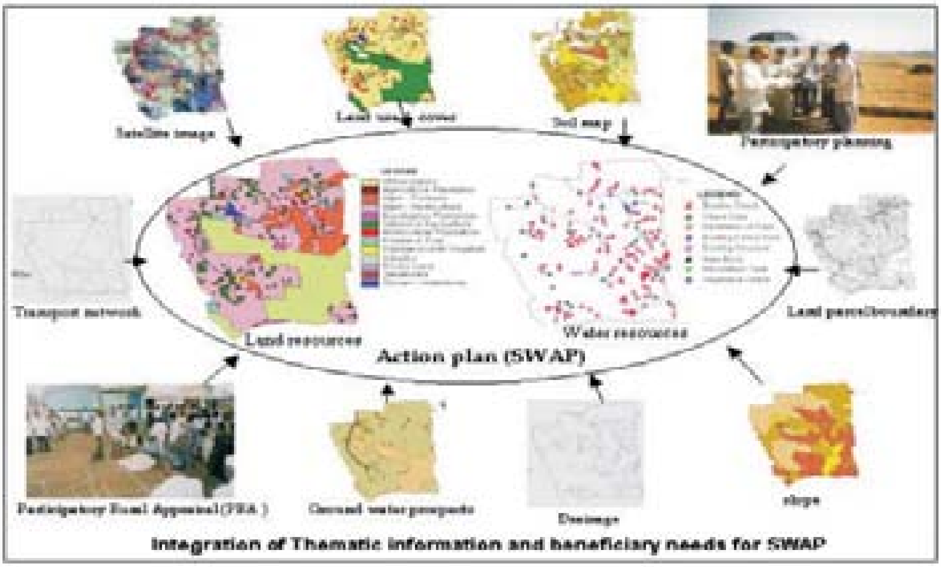

Figure 1. Schematic diagram representing EO data usage in action plan.

Input-Output Monitoring: Any project implementation would like to monitor the investments on a regular basis, which means that availability of a systematic reporting mechanism for assessing physical and financial status of the project on a near real-time basis. This kind of a input-output monitoring with respect to various processes, viz. entry point activities, social mobilization, training & capacity building, formation and functioning of CBOs, action plan preparation and tracking of plan implementation, etc., is facilitated through the MIS/GIS package viz., "Sujala Mahithi"(Fig.2).

The package is deployed across the project area and it helps in creating systematic database, allows user to query and analyze periodic field data and generate reports at different levels on any specific project indicator for on-line monitoring.

"Sukriya"– Sujala Kriyayojane, a bilingual software package designed, developed and customised for action plan preparation, not only enables quicker, uniform and systematic beneficiary-wise database creation but also provides scope for generating varieties of reports for analysis and assessment of the impact. It also categorises private and common land activities for further analysis. The package has significantly reduced the time taken for the participatory planning processes and Sujala Watershed Action Plan (SWAP) preparation. GIS-enabled solutions like 'SuKriya Nakshe' and 'Nakshe Vivara' have also been developed and deployed for use

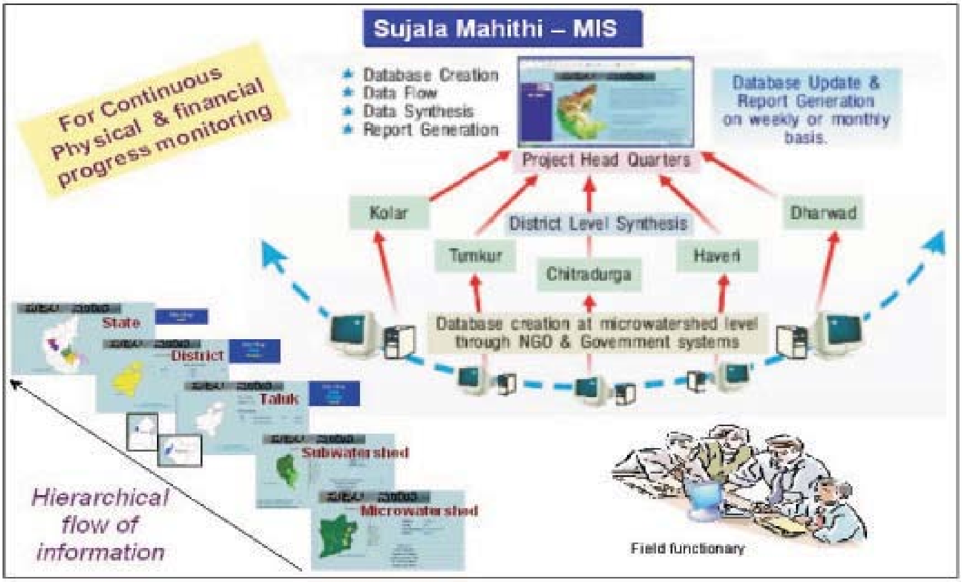

Figure 2. Information flow through Sujala Mahithi, MIS/GIS.

at grass root level. 'SuKriya Nakshe' allows for about 150 different types of activities to be depicted at micro-watershed level to prepare SWAP Map (ie, action plan maps in GIS enabled environment) on a *pick and drop* mode, for implementation and monitoring. 'Nakshe Vivara', a map viewer tool, facilitates the display of various resource maps like land use/cover, soil, land parcel, with necessary legends and also allows overlay of user defined layers with specific query facility (Fig 3).

Process Monitoring: Concurrent process monitoring is carried out to capture near real time information on the key processes, constraints/gaps, observations on specific quality parameters. This leads to successful ground implementation which reflects on community based decision-making powers and facilitates self-learning and corrective measures. Some of the key processes monitored under the project are: awareness & sensitization, participatory rural appraisal, entry point activity, formation of CBOs, capacity building, action plan preparation, environment & social screening, action plan implementation, income-generating activity, operation & maintenance, aspects related to sustainability, etc. (Fig. 4).

As a part of process monitoring, evaluation of the functioning and performance of CBOs like self-help groups (SHG), area groups (AG) and watershed executive committees (SWS-EC), NGOs, various training/capacity building programs and other project activities are carried out. Besides, specific thematic evaluations like women empowerment, equity, investment pattern, income-generating activities, livestock survey, etc., are also carried out on a regular basis, which has given rich dividends to the project and the community.

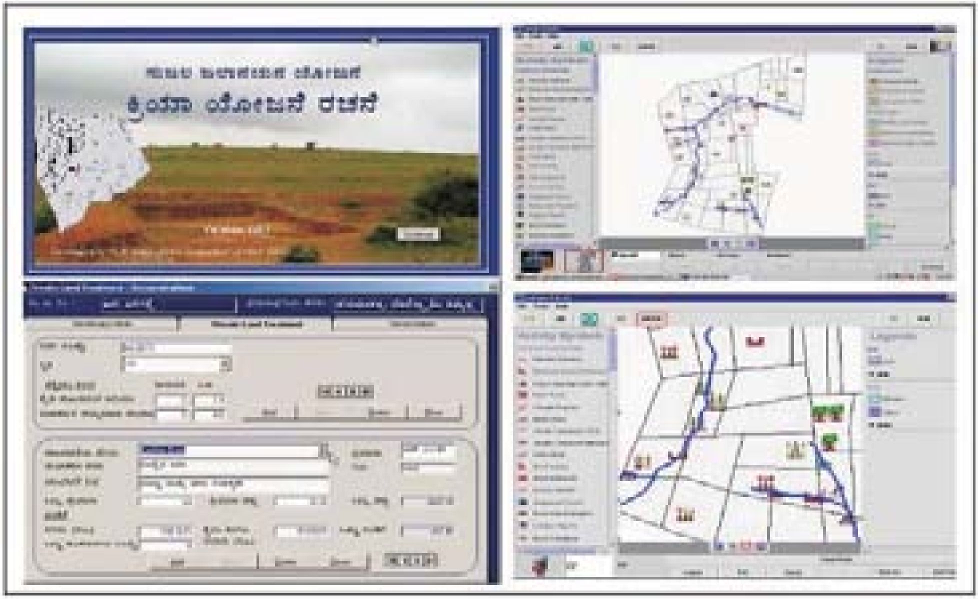

Figure 3. Sukriya, Nakshe & Vivara package customisation.

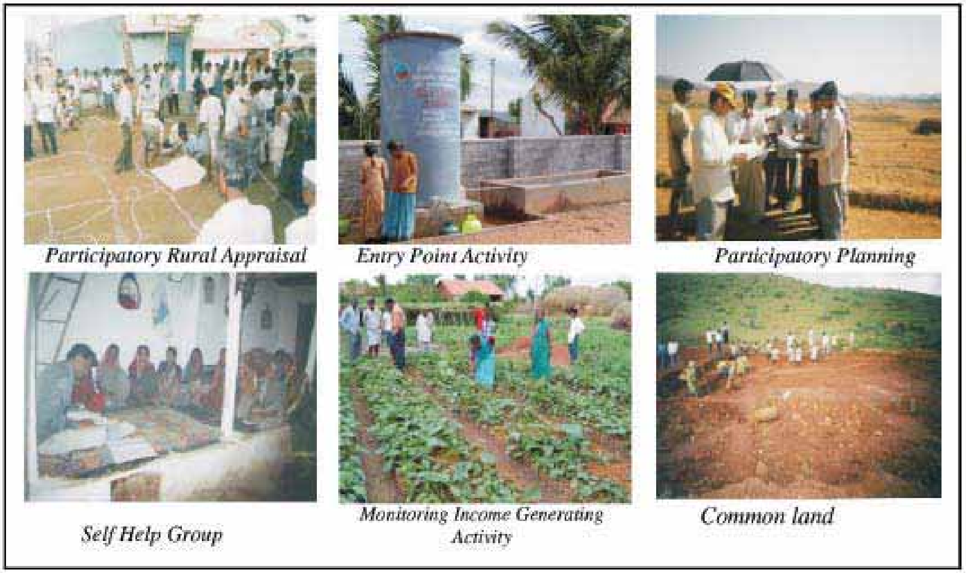

Figure. 4: Glimpses of various process monitoring activities.

Impact Assessments: High-resolution satellite data from RESOURCESAT-1 and CARTOSAT-1, acquired at frequent intervals, are effectively used to monitor the implementation of the land treatment activities and assessing the changes in land use/land cover, cropping pattern, biomass and reclamation of fallow/barren land, etc. (Fig. 5) The satellite images underlying below depicts the implementation of activities like bunding, farm ponds, afforestation, agro-horticulture at the farm level.

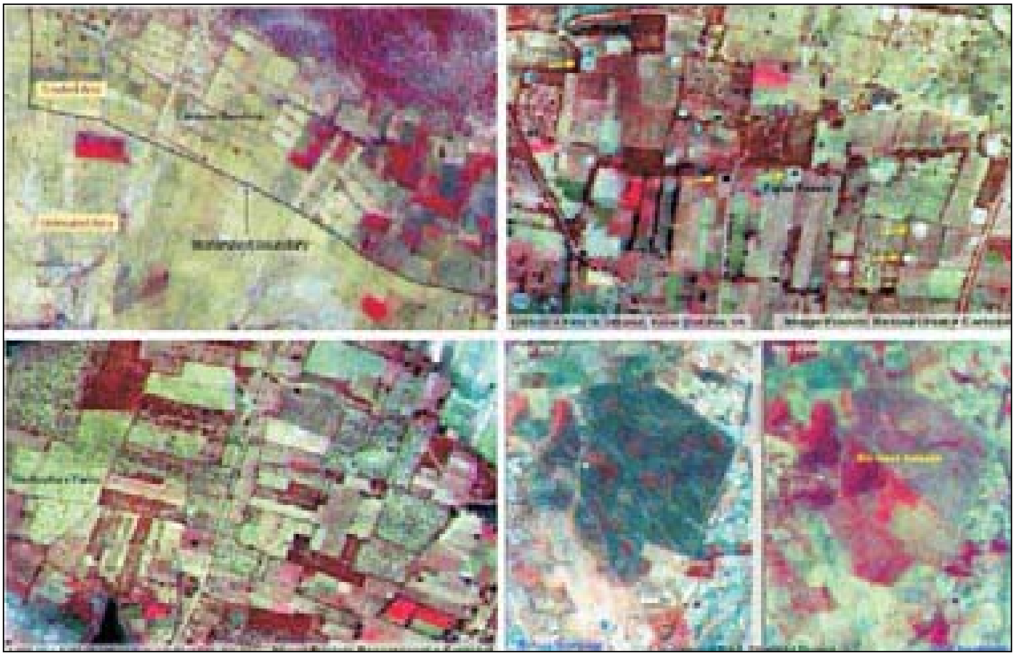

Figure 5. EO based monitoring of different watershed development activities (clockwise from top left: Monitoring of land treatment; Monitoring of form pond activity; Monitoring of afforestation and Monitoring of horticultural activities).

Through a combination of remote sensing data, GIS, process monitoring data and farmers/household surveys, impact assessments are carried out at pre-determined time intervals to establish the net contribution of the project to poverty alleviation, capacity building and natural resource regeneration. Impact is evaluated using a variety of qualitative and quantitative indicators before (baseline), during (midterm) and after project implementation (final). Impacts are also analyzed based on observations in the project and control areas. A comprehensive benchmark data has been created, by judicious combination of conventional and remote sensing data. This has been effectively utilized for process monitoring and impact assessment. One of the most crucial points to be noted in effectively carrying out such impact studies is establishment of strong baseline database, both from satellite remote sensing and field based observations with specific correlation analysis for future reference.

The application of cutting edge technology including remote sensing, GIS and computer based monitoring system in conjunction with ground observations has provided robust baseline and change data and wealth of information for in-depth analysis.

Recommendation for Practitioners

- The methods discussed above have been put into practice effectively under the World Bank-aided Sujala Watershed Development project, Watershed Development Department, Government of Karnataka. Following are the recommendations.
- ME & L has to be done by an external agency for unbiased project evaluation.
- The ME & L activities should have the concurrent monitoring component for effectiveness of the feedback mechanism and mid-course correction.
- ME & L should necessary have the components of process monitoring, MIS/IS based input-output monitoring (both are concurrent monitoring methods) and systematic impact assessments using satellite remote sensing and ground observations.
- It is essential that process monitoring is done by deploying the process monitoring units at the field.
- ME & L should always be an integral part of any watershed development program.
- Optimal blend of space technology, information technology and ground based data.
- All concurrent monitoring components under ME & L should follow participatory and facilitation process for effective implementation.

Investment Needs by Local Government

- As has been observed in the Parthasarathy committee report or any other report brought out and used by various government mechanism, it is necessary to have meaningful investment in ME & L implementation in any watershed development project. Is is essential that 2 – 4 % of the project implementation cost be kept for institutionalization of ME & L for all watershed development projects in the country.

Conclusion

- Earth observation inputs along with judicious mix of MIS, GIS and ground-based observations have helped in micro level plan preparation, concurrent progress/ process monitoring and impact assessment at various stages of project planning and implementation. The integrated approach of monitoring and evaluation with application of cutting edge technology has provided wealth of information to support in-depth analysis. Systematic feedbacks of the observations are linked to the monitoring of project development objectives and outcomes such as natural resource regeneration, productivity improvements and strong institutions leading to sustainability. EO inputs have provided the state-of-the-art information enhancements for tracking the project impacts and outcomes to answer questions about progress against broad development indicators and milestones. It has also enabled appropriate policy formulation, implementation of suitable strategies /action plans, assessing the impacts, resulting in mid course corrections and so on. It has also increased transparency and accountability in the project.

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18. Guidelines for Planning and Implementation of Watershed Development Program in India: A Review

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Abstract

With a view to checking soil erosion and controlling wastage of water, the Central and State governments launched soil and water conservation programs. After gaining experience with the soil and water conservation, the state shifted its policy focus from mere conservation to that of integrated land management with focus on conservation and management of land and water resources. The aim now was retention of water moisture, biomass production and enhancing incomes of the farmers and expanding their livelihood options. This amounted to a policy shift from soil and water conservation to watershed development, where the emphasis was on supporting livelihood system of the people residing in the degraded land zones. Since the emphasis now was on supporting the livelihood system of the people, it called for a shift from line department's top-down planning approach to participatory approach for watershed development. Also as there was a shift from engineering focus to livelihood development it attracted players other than the state such as NGOs and people's movements and more recently private entrepreneurs in planning and implementing the watershed development programs (Wani et al. 2006). A brief review of the history of watershed development program in the country shows how these shifts in the strategies and approaches were ushered in by the different guidelines for planning and implementing the programs.

Keywords: Watershed, guidelines, policies, institutions, sustainability.

Introduction

Over the decades, the concerned authorities in India have been drawing up a series of guidelines from time to time – each time revising them to suit the changing situation and to make them more flexible, specific to regional variations and to the demands of new developments. There are also different sets of guidelines evolved by the donor agencies and the NGOs based on their own understanding of the ground situation and norms of planning and implementation of the watershed development projects. This paper[1] critically reviews all these guidelines and assesses how far the guidelines evolved from time to time kept pace with the above parameters[2].

Constraints

The watershed development guidelines appear to have two basic elements:

- One, the set of guidelines dealing with the process mechanism for planning and implementation of the projects. The tasks involved are: identification of the watershed, preparing the proposal and getting it approved/sanctioned, planning for the grounding of the project, implementing the project and management of the assets created.
- Second, the set of guidelines relate to the organisations, where the stakeholders assemble for decision-making and the institutions/rules that bind the stakeholders in all their operations.

Each of the two sets of guidelines is examined in relation to a normative reference point, which is supposed to give optimum results of watershed project management. The normative reference point is derived from the micro level planning theory in general and project management theory in particular. This paper attempts to draw upon the critique of watershed projects done by the academics by operationalising the propositions implied in the theory of micro level planning and the theory of project management. One constraint of this method is that such a reference point may fall short of an ideal point. However, it is used here as an approximation.

Strategies and Approaches

Initially the focus of agriculture policy was on provisioning of yield-increasing inputs like irrigation, improved seeds and fertilisers. However, when it was realised that the scope for increasing yields through this means, especially by using river water which is limited, the state policy shifted its focus to soil and water conservation. For, it was realised that though India had vast area, much of the land available was degraded and because of this, it was not suitable for cultivation. Also, whatever land was cultivable had the problem of soil erosion. Therefore, with a view to checking

1. This paper is drawn from a larger report prepared by the same team on the same subject.
2 Study team: Dr KV Raju (Professor and Head, Centre for Ecological Economics and Natural Resources, Institute for Social and Economic Change, Bangalore), Prof. Abdul Aziz (former member, Karnataka State Planning Board and Professor, ISEC), Dr SS Meenakshisundaram (former Secretary, Ministry of RDPR, Govt of India and Development Commissioner, Govt of Karnataka and now Visiting Professor, NIAS, Bangalore), Dr. Madhushree Sekhar, (Associate Faculty, CEENR, ISEC).

soil erosion and controlling wastage of water, the Central and State governments launched soil and water conservation programs. After gaining experience with the soil and water conservation, the state shifted its policy focus from mere conservation to that of integrated land management with focus on conservation and management of land and water resources. The aim now was retention of water moisture, biomass production and enhancing incomes of the farmers and expanding their livelihood options. This amounted to a policy shift from soil and water conservation to watershed development, where the emphasis was on supporting livelihood system of the people residing in the degraded land zones. Since the emphasis now was on supporting the livelihood system of the people, it called for a shift from line department's top-down planning approach to participatory approach for watershed development. Also a shift from engineering focus to livelihood development attracted players other than the state such as NGOs and people's movements and more recently private entrepreneurs in planning and implementing the watershed development programs (Wani et al. 2006).

A brief review of the history of watershed development program in the country shows these shifts in the strategies and approaches that were ushered in by the different guidelines for planning and implementing the programs.

Interest in soil conservation and application of dryland farming techniques is said to date back to 1930s when the individual farmers tended to adopt these measures (A.Vaidyanathan, July 8-15, 2006). Only in recent years, when it came to be realised that improvements in soil and moisture conservation have to be planned on an area basis that a series of programs were grounded in the country by the Government of India. The watershed development program belongs to this category and takes a lead in treating the degraded lands using the low cost and locally evolved technologies like soil and moisture conservation, afforestation, etc. Such an effort is supposed to promote sustainable farming, utilise the non-arable land through afforestation, horticulture and pasture development and restore ecological balance.

The programs evolved and the projects designed for using the watershed development approach are the Drought Prone Area Development (DPAP), the Desert Development Program (DDP), River Valley Project (RVP), and National Watershed Development Project for Rainfed Areas (NWDPRA), and the Integrated Watershed Development Program (IWDP). These projects, being primarily engineering-oriented ones, largely focussed on water harvesting through construction of percolation tanks, contour bunds, gully control structures, contour trenches, etc., and came under state governments' soil and water conservation projects. There were also some projects launched by the NGOs like MYRADA, WOTR, BAIF, AKRSP, Seva Mandir, BAIF, FES, etc., and people's movements like projects by Pani Panchayat and Anna Hazare's Adarsha Gaon Yojana efforts whose focus was on socio-economic development of the resource-poor sections. That apart, we have the donor agency sponsored projects by the DFID, GTZ, KFW, World Bank and DANIDA. As a result, there has been a multi-agency participation in the watershed development program in India.

These programs launched at different points of time needed to be integrated with a view to optimising the results. Hence, the concept of integrated watershed development was advocated. Even so, the several programs targeted to improve the degraded and wastelands continued to be implemented in a fragmented and piece meal fashion. Besides, all these programs initially aimed at improving land productivity in the difficult terrain. Subsequently, with the establishment of the Department of Land Resources (DOLR), the focus shifted to enhancement of the viability and quality of rural livelihood systems. In recognition of this fact, the Government of India tended to issue guidelines and has been revising them from time to time.

- The Hanumantha Rao Committee (1994) had already recommended a set of operational guidelines for implementing the watershed development programs. As a follow-up, guidelines for watershed development were framed by the DOLR and applied to all the above programs from April 1995.
- The Ministry of Agriculture (MoA) launched in 1990-91 the National Watershed Development Project for Rain-fed Areas (NWDPRA) Program.
- The common approach for watershed development jointly formulated by MoA and MoRD, resulted in the drafting of new guidelines for implementing the NWDPRA, which came into effect in November 2000. These guidelines provide for decentralization of procedures, flexibility in choice of technology and provisions for active involvement of the watershed community in planning, execution and evaluation of the program.
- With lapse of some time, a need was felt to revise the guidelines to introduce some amount of flexibility to suit the varying local needs and conditions and to making them "contemporary, transparent and easy to follow". As a follow-up, the new guidelines for watershed development were framed in 2001 which are now program specific, and contain flexibility and give specific role to various institutions, greater role to women, SHGs, PRIs and so on.
- To further simplify the procedures and to involve the PRIs more meaningfully and actively in planning, implementing and managing rural development projects including the watershed development projects, the DOLR formulated and issued what have come to be called "the Hariyali Guidelines 2003".
- Subsequently, in February 2005 the DOLR constituted a technical committee under the chairmanship of S Parthasarathy, better known as "From Hariyalli to Neeranchal Committee", which submitted its report in January 2006. The committee has suggested a shift in focus "away from a purely engineering and

structural focus to a deeper concern with livelihood issues". The Neeranchal Committee suggestions, tries to build on the Hariyali guidelines and addresses the issue of their applicability to differential state situations.

- Following the announcement of the Union Finance Minister in his budget speech of 1999-2000 about the creation of a watershed development fund (WDF) with NABARD to unify multiple watershed development programs into a single national initiative, such a fund was created in NABARD with a contribution of Rs.100 crores each from NABARD and Government of India.
- The Government of India appointed a committee under the chairmanship of Shri Eswaran with a view, among others, to assess the training requirements for capacity building at grassroot level and to recommend modules of training of different functionaries engaged in watershed development.

Procedures and Practices

It should be admitted that when the watershed development program was initiated on a big scale by the State, guidelines already existed that were laid down and followed by the NGOs whenever they took up some programs in a small way. There was therefore a base available for the State to build on it when it went on to issue guidelines for the benefit of its bureaucracy. It would not be wrong to say that such a base was taken advantage of by the Hanumantha Rao Committee whose recommendations became a basis of the 1995 government guidelines. A second point to be noted is that the guidelines evolved after 1995 are meant to be those that are improvements over/revisions of the ones laid down in the immediate past taking into account the requirements of the changing times and the inputs from academic and practising experts on the subject. In this sense, there should be a link between the past and the present and from the present to the future. Therefore, a review of the government guidelines ought to be done from these angles to trace the procedures and practices introduced for watershed development and situate them in this perspective.

- The objectives of the watershed development program were for the first time clearly spelt out by the revised guidelines of 2001. Developing the waste/degraded lands, promoting overall development, restoring ecological balance, improving the socio-economic conditions of the resource poor and encouraging village community for sustained community action are the objectives mentioned by the 2001 guidelines.
- It is the revised 2001 guidelines, which provided detailed criteria for selection of watershed area and villages. It is stated that the watershed may have an area of 500 ha, that such area must have acute shortage of drinking water, have a large proportion of SC and ST population, preponderance of degraded land

and common lands, and that the area where actual wages are lower and where people's participation is assured through contribution of cash and kind. These criteria were reiterated by the Hariyali guidelines. The Neeranchal study while reiterating all the above selection criteria added low gross irrigated area, high incidence of poverty, positive history of women and community actions and the proposed watershed to be contiguous to another watershed.

- The 1995 guidelines explicitly refer to the need for community mobilisation by constituting SHGs and UGs with help from the WDT. The guidelines did not seem to have recognised the possibility of disputes arising during or after the project implementation over land and other assets. As such, no important guidelines were provided for dispute resolution except suggesting that the *grama sabha* should resolve differences if any, between different SHGs/UGs or among members of these groups (Hariyali).
- The 2001 revised guidelines for the first time suggested that the Participatory Rural Appraisal (PRA) should be carried out before a plan for watershed development project is prepared. Following this, the *gram panchayat* (GP) should prepare the action plan. The Hariyali thus gave a bigger role to PRIs in the planning and implementation of the watershed development programs. Thus the revised guidelines of 2001, Hariyali and Neeranchal study, recognised the need for holistic development of natural resources and people, and suggested that there should be a convergence of all the programs of MORD such as JGSY, SGSY, rural drinking water, etc, and the programs of other ministries like health, education and agriculture.
- The 1995 guidelines had missed out on the issue of targeting benefits to different sections of the community. The revised guidelines also made no effort at discussing this issue except to end-up by saying that it is the responsibility of the PIA to look into the question of targeting benefits. Besides, the project duration specified varies from one set of guidelines to the other. Thus, the duration conceived under the 1995 guidelines is four years; the Neeranchal study talks about an eight-year duration with three phases. People's contribution suggested by the guidelines varies from 5 per cent to 10 per cent of the cost of the project. The cost norms of the project are fixed by the guidelines. The various items of expenditure allowed are watershed development activities which account for nearly 80 per cent of the total, community organisation, training and administrative overheads. The extent of expenditure permitted varies from one set of guidelines to the other.

The government guidelines, though comprehensive, had one problem. They were not adequately equity oriented in the sense that the outcomes of the watershed development were not fully poor-friendly and weaker section-oriented, at least in the initial stages, with several biases against the poor (Mascarenhas, 1998), such as:

- Investment biases: Disproportionately more was spent on private lands usually located in the more productive lower lands in the watershed and usually owned by the relatively rich.
- Technological biases: (a) over-emphasis on water harvesting structures likely to be useful to better-off farmers in lower slopes; (b) under-emphasis on soil and moisture harvesting measures in the upper reaches; and (c) disregard of indigenous approaches to soil and water conservation.
- Capital formation biases: Opportunities for savings and credit, creation of assets, infrastructure, human capital like leadership skills and social capital were biased towards wealthier areas and individuals to the utter neglect of the needs of the weaker sections.

The guidelines formulated by the NGOs and donor agencies largely addressed this issue (SL Seth S, Damgaard and L Larsen 1998). In fact, the guidelines formulated by them were largely guided by the equity consideration[1].

In terms of the institutional mechanisms for implementing the watershed programs, the practice in the early projects was more characterized by a line department approach, in which WDM was under the overall administrative control of respective departments. In this, techno-centric and target oriented approaches were followed by involving one or two departments of the government without much coordination among each other[2]. This approach, it is argued, suffered from numerous problems, such as:

a. lack of co-ordination between line departments in implementation;
b. stereotyped approach and tackling of problems in an isolated manner;
c. looking at project activities as mere additions to the departmental targets;
d. lack of innovative strategies; and
e. lack of flexibility.

Hence, different strategies for appropriate institutional structures were formulated for the purpose.

(i) The importance of coordination between departments, and of the integration of skills and technologies, led to the adoption of more unified programs. The DPAP and DDP adopted a watershed approach in 1987, as did the NWDPRA. The National Wastelands Development Board also implemented their programs on a watershed basis since 1989. Nevertheless, whilst coordination between line departments was perhaps more effective, the various programs had their distinct approach, technical components, guidelines, norms and funding patterns;

(ii) Local participation continued to be minimal, but it was not that concerns of devolution/participation were entirely missing. However, in the earlier model, the method of ensuring this participation was not spelt out. Further, by people's participation, the approach mostly implied the participation of NGOs, and that too in a limited role of supplements rather than as alternatives;

(iii) Whilst the donors had been experimenting with participatory methodologies since the 1980s, 'participatory watershed management' was only effectively 'institutionalised' in government policy in 1993. The emphasis was based on the rationale that institutions have to precede any physical work for the watershed work to be sustainable. In order to ensure this participation it was accepted that the government would have to decentralize management and implementation, both to local committees and to local PIAs.

The institutional landscape for watershed programs in India can be summarized as follows.

(i) An elaborate organizational structure to implement and monitor, watershed project was suggested under the watershed guidelines. In most of the states, such bodies have been constituted at state, division, district, and watershed level.

(ii) The MoA, MoRD and the MoEF along with their respective line departments in the States are the three main government ministries in charge of watershed protection and development. Each program focuses on different aspects and activities within the ministries criteria for developing the watersheds–

- The MoA deals with issues like: erosion-prone agricultural lands, optimising production in rain-fed areas and reclaiming degraded lands. The Department of Agriculture and Cooperation (DAC) and the Department of Agricultural Research and Education (DARE) of MoA are involved in all aspects of watershed development, supported by two autonomous bodies: the Indian Council for Agricultural Research (ICAR), and National Institute for Agricultural Extension and Management (MANAGE).
- The MoRD is involved in implementing watershed projects in the non-forest wastelands and poverty alleviation programs with important components of soil and water conservation. The key department in MoRD is the Department of Land Resources, particularly the Wastelands Development Division. There are two other departments, the Department of Drinking Water Supply and Department of Rural Development, which are also involved in WSD activities. Two organizations support the MoRD: the National Institute of Rural Development (NIRD) and the Council for Advancement of People's Action and Rural Technology (CAPART). The former provides advice on policy matters about watersheds, through the Centre for Natural Resources Management (CRES), whilst CAPART deals with the

voluntary sector. CAPART also has a division that sanctions watershed projects to NGOs and voluntary organizations.

- The MoEF is another ministry dealing with forest and wasteland issues, promoting afforestation and the development of degraded forests within an integrated watershed approach.

(iii) Legislation promoting state adaptation of the programs and the involvement of outside parties and autonomous agencies has lead to a myriad of WSD programs and involvement of multiple institutions at the state and district level. At the district level, the district rural development agency (DRDA) or *zilla parishad* (ZP—district level council) have overall responsibility for program implementation in the district. They appoint a watershed development advisory committee to advice on issues such as the selection of villages, training, and monitoring. Project implementation agencies (PIAs) are selected by the DRDA/ZP and are responsible for appointing a watershed development team (WDT) of four members representing disciplines such as agriculture, engineering, life sciences and social work. The WDT works with the communities in planning and implementing the watershed program. Each WDT is expected to handle 10 micro watersheds. The watershed association (WA) represents all members of the community who are directly or indirectly dependent on the watershed area. The WA appoints a watershed committee (WC) consisting of representatives of user groups, self-help groups, the *gram panchayat* and the WDT

The provisions pertaining to these institutional mechanisms for developing and implementing watershed programs, are outlined in the different watershed guidelines.

The Department of Wastelands Development and the Ministry of Rural Development in 1994, set out a strategy to decentralize watershed management, and set up partnerships between government line departments, NGOs and newly formed local resource and user groups. The 1995 Watershed Guidelines were thus an important initiative towards institutionally and ecologically sustainable enhancement of rural livelihoods. The Revised Guidelines of 2001 sought gainful and transparent utilization of public funds for watershed development, with a view to promoting the overall economic development and improving the socio-economic condition of the resource poor and the disadvantaged sections of the people inhabiting the project areas. The Hariyali guidelines shifted the focus on how to simply institutional procedures and involve the PRIs more meaningfully in planning, implementation and management of economic development activities in rural areas. To infuse a greater degree of flexibility into the watershed development process in view of the large variation in local conditions, needs, and the social structure, the Neeranchal Watershed Development guidelines were formulated.

Studies show that the organizations identified and formed under externally funded watershed projects (the case of KAWAD in Karnataka and IWDP Hills II in Uttaranchal) and government watershed programs (DDP, DPAP, NWDPRA and IWDP) implemented by the line departments have been mandated to undertake certain functions to achieve development outcomes (Rajasekhar, et al. 2003). At the state level, the primary functional assignment of organizations is to implement the watershed development works within the framework of the watershed guidelines/ project guidelines and agreements with the sponsoring agencies. Among their other mandated functions, the state level organisations undertake the functions of coordination and monitoring. Financing, staffing and information sharing is also a function of the state level organisations in some of the externally funded watershed programs. The function of service provisions is normally undertaken by the village level organisations. Conflict resolution is another function that has not been assigned to the state level organisation, whereas staffing has been assigned to the state level organisations.

A matter of concern regarding the institutional provisions outlined in the watershed guidelines is that while the need to promote people's participation in the process of watershed management is well stressed, how to institutionalize this participation has not been satisfactorily resolved. Whether the leadership for organizing peoples' institution should be in the hands of competent NGOs or should it be left to the elected government/PRIs has been a matter of intense debate. On the other hand, participatory institutions like the SHGs and watershed institutions must also be necessarily promoted, as they are the grassroots level organizations specially meant for protecting the interests of the stakeholders. As of now, two distinct institutional models exist in the field of people's participation in WSDPs in India.

(i) The first is the Karnataka Watershed Development Society model in Bellary district of Karnataka, which has the *zilla panchayat* (ZP) as the implementing agency. The weakness in this strategy is that there is no place for the watershed associations (area groups) at the micro-watershed level of 100 hectares. As a result, the watershed association at the 500-hectare level transfers funds directly to individual beneficiaries for private land treatment and livelihood enterprises. The committee also directly implements works on common lands.

(ii) The second model is Sujala, the WSDP supported by the World Bank, which provides a place to the micro-watershed associations at the 100-hectare level. This model recognizes the key role the area groups play in watershed development. The only weakness is that the area groups are treated more as contractors than as stakeholders.

Another area of importance regarding procedures and practices for carrying out watershed development programs pertains to the monitoring practices for effective and efficient project implementation. Different programs implemented in India during the last two decades indicate that:

(i) Any approach to monitor will have to be necessarily guided by the terms governing its implementation. For instance, the objectives and the methodology of implementation for the world bank-aided watershed projects in some States of India are quite different from those of the National Watershed Development Program for Rain-fed Agriculture (NWDPRA). On the other hand, conservation of land and water resources by adopting soil and water conservation measures got the highest priority under NWDPRA. The Sujala Watershed Project implemented in the state of Karnataka, with the assistance of the World Bank had its own priorities. An ideal monitoring system should include: (a) input-output monitoring, which is indispensable in any project monitoring; (b) process monitoring, as almost all the WSDPs equally emphasize the processes as against the outcomes; and (c) impact monitoring to assess the success and impact of the program vis-a-vis its stated objectives. While (a) and (b) will have to be concurrent and go hand-in-hand with the project implementation, (c) can be periodical, the periodicity being determined by the projected time span of the outcomes.

Recommendations for Practitioners

A comprehensive model needs to be designed to assess the impact of watershed development in a given region. The impact indicators that need to be evaluated at the watershed level, the state level and the national level can be summarised as follows:

Farm level indicators	State level indicators	National level indictors
• Area under irrigation • Crop intensity • Productivity (food, fodder & fuels) • Employment • Household food security • Risk management • Profit/cost reduction • Seasonal migration • Conservation of natural resources	• Agricultural production • Food security • Poverty reduction • Employment potential • Inter-sectoral linkages • Gender and equity issues • Social capital development	• Production • Price levels • Employment generation • Poverty reduction • Sustainability of natural resources

We need to go beyond the government agencies to get the WSDPs monitored. Remote sensing technology is a scientific tool that could be coupled with monitoring, to help identify sites with greater potential for externalities in watershed development as well as aiding in project planning and design. A number of donor funded WSDPs are already using this technology as an integral part of their monitoring systems.

There is a need for greater focus on inter-agency cooperation, coordination, and integration important to facilitate program implementation and monitoring. Moreover, although much emphasis is given on processes and mechanisms of implementation, not much emphasis is given for enhancing agricultural productivity. This insufficient focus is often at the root of most environmental management problems in the country including difficulties with compliance and enforcement. A careful examination of the two institutional models outlined above and a comparative study of institutions in different watershed programs (Sreedevi et al. 2007; Vadivelu, 2007), indicates that the 'Bellary Model' of involving the ZP could be replicated together with the 'Sujala model' of including the watershed associations (area groups) at the micro-watershed level. These two institutions together with the SHGs can form an institutional framework that appears most appropriate for implementation and management of the watershed programs. To sum up, for effective implementation of watershed projects we need to consciously promote partnerships. They can be public-private-community or public-*panchayat*-community.

Thus, the future guidelines should keep in mind the following concerns.

(i) As far as possible villages with low rainfall and low proportion of irrigation should be selected for watershed development keeping in view the equity concern. Areas with more poverty or low GDP as well as where natural resources are threatened should receive priority. Moreover, villages/watersheds should be selected in clusters to achieve higher impact and most importantly where community demands the program rather than supply driven.

(ii) In spite of strong presence of community organisations like SHGs, the process of planning as tended to bypass these institutions. This is disturbing because the success and sustainability of the watershed development are acknowledged to be very much dependent on participation of community organisations. Therefore, the future guidelines ought to be very clear in stating that wherever SHGs are present they should take-up the task of mobilising people and where such organisations are not present or weak (when they are present) NGOs can initiate SHGs.

(iii) The planning process has been ad hoc and not participatory. This is because the PIAs were under pressure to submit their proposal within the time limit laid down to take-up the project work and had little time to go through the consultation process. Also the plan process was largely influenced by the ideology of PIAs. The lesson to be learnt from this is that the PIAs should be given sufficient time to submit their proposal such that they have time to go through the consultation process. Training for PIA (NGO or otherwise) should be made mandatory.

(iv) Multiple problems such as delay in sanction of funds, release and use of funds, etc., are observed with regard to fund disbursement. Future guidelines have to be very clear about the need for prompt sanction and release of funds.

(v) Once the project is completed, its sustainability will depend on how readily the stakeholders take over and manage the assets. In this connection the problem noted is that constructing rainwater-harvesting structures in the tank catchments would lead to some trade offs arising from reduced inflow of water into irrigation tanks because of which people may lose faith in the watershed development program. The future guidelines should take care of the adverse impact of constructing rainwater-harvesting structures in the catchments of the tanks.

(vi) It is essential that some kind of a balance needs to be maintained between the line department personnel and the watershed department personnel. In addition, considering the fact that there is some amount of reluctance on the part of the line department personnel to interact with people there is need to arrange for some training to them before they are actually put on the project work.

(vii) The available literature presents a mixed bag of what has happened to the equity question. The future guidelines should emphasise on imparting skills of social organisation to the government staff and orienting them to interacting with the people.

(viii) Regarding the institutional mechanisms, *gram panchayats* do not evince much interest in involving themselves in the watershed works. The solution is first of all to plan the watershed program such that its area coincides with that of the *panchayat* concerned by taking cluster approach and ensuring representation of PRI members in WCs. The state Departments of Rural Development and Panchayati Raj ought to play a pro-active role in this regard.

Investment Needs by Locals/Government

Recognising that the WSD programs have been implemented in a fragmented manner by different departments without any well-designed plans prepared on watershed basis by involving the inhabitants, the 1994 Technical Committee on watershed development under the chairmanship of Prof. Hanumantha Rao recommended that the sanctioning of works should be on the basis of the action plans prepared on watershed basis. It called for introduction of participatory modes of implementation, through involvement of beneficiaries of the programs and NGOs. Around this time, the Constitution of India was amended bringing in the PRIs as local governments to manage natural resources in rural India.

In this design of the institutional arrangements best suited for WSDPs, public-private partnership has been an un-explored phenomenon in India, in so far as it relates to the involvement of private enterprises. The technical committee on WSDPs in India constituted in 2006 by the Ministry of Rural Development, Government of India, has however put forward some suggestions in this regard to the Government of India for their consideration. These include encouraging corporate sector to contribute generously to the national/state funds and to the watershed development funds at the micro-watershed level, by providing 100 % tax exemption to such donations and involving the corporate sector in technical assistance, capacity building and training besides implementation of benchmark initiatives in collaboration with science and technology institutions. In the committee's perception the strength of the corporate sector would lie in developing marketing systems, providing agricultural extension and other value added services through IT-enabled activities, energy resource development and management and some commercial initiatives in terms of developing agricultural plantations, which would also return some benefits to the agricultural community in terms of buy back guarantees, information enriched services, etc.

Policy and Financial Incentives

Program implementation has been mainly approached from a community perspective by looking at the conditions that determine collective action for implementing the program. There is a relationship between the spread of the resource used as a community resource (in terms of its area/coverage) and the pattern of usage among the users that can influence the community's willingness to and participate in the strategies to develop and manage the watershed. Communities capacity for collective action in implementing watershed development programs will be strengthened according to the density of social networks and inter-personal interactions, as well as the organizing practices existing within them; the local level leadership's capacity for responsive interactions both within and outside the community, and the educational achievement of the community.

Conclusion

We conclude by examining to what extent the watershed development guidelines are consistent with the objectives of the watershed development program.

(i) It may be noted that watershed program was launched with the objective of conserving soil, rainwater, and vegetation. This limited objective culminated with the authorities evolving an engineering approach in so far as the implementation of the program was primarily in the nature of construction of check dams, percolation structures and so on. Accordingly, the guidelines had focused largely on how to go about selecting the watershed, building structures, duration of project implementation, funding pattern, asset maintenance for sustaining the life of the project and so on. There should be convergence of all other non-land based programs of the Government of India. The problem in this system is the absence of adequate and appropriate guidelines as to how such a convergence can be achieved at the ground level. Neither the state machinery nor the NGO-donor agencies have ever attempted this exercise.

(ii) Secondly, what would happen to the project when the PIA makes an exit from the watershed area is another issue that deserves attention. For the sustainability of the project, thereafter two conditions need to be met: one, a locally acceptable mechanism of watershed development fund for project maintenance ought to be evolved; and two, the manner of ensuring equity and sustainability of the benefits of the assets created ought to be spelt out.

(iii) Lastly, the working group on natural resource management during the Eleventh Five Year Plan adds new objectives by insisting on the program to deal additionally with drinking water, development of livelihoods, enhancement of productivity, proper management of developed natural resources, equity for resource poor families, empowerment of women and ensuring of project sustainability. It is time to draw up a new set of guidelines incorporating the concerns recorded by the working group. Also, in order that the new set of guidelines become more comprehensive, the concerns and gaps identified by in this chapter need to be incorporated.

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19. Institutional Reforms under Participatory Watershed Program

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Abstract

The expectations from, and scope of, the watershed program is going through a major change. Development of natural resources and generation of employment potential are no longer the primary objectives. Gender and equity are assuming much greater significance since large amount of public funds are used under the above program. Development of livelihoods (based on land, water, livestock, perennial biomass, etc) is assuming as much of significance and also considered quite critical to facilitate growth processes during post project period. Management of natural resource is now considered more important as compared to development of natural resource carried out earlier.

Keywords: Watershed, institutional reforms, participatory, natural resource, community based-organization.

Introduction

Since more than one decade participatory approach has been adopted under watershed program for sustainable development of natural resources. This has brought community based organizations in the center stage of development as bulk of the developmental fund goes directly into their accounts. The organizational set-up at other levels (ie, project, district, state and nation) is now expected to perform facilitation role as compared to implementation role performed earlier under the top-down approach.

Critical review of the ongoing watershed program has shown that participatory approach has still not been institutionalized on a large scale. Post project sustainability continues to be a serious concern in majority of watershed projects where participatory processes are not adopted to a satisfactory level. Delivery mechanism is a critical weak link under the above program, which includes institutional set up at community level as well as higher levels. A few successful experiences are however available under NGO managed projects as well as bilateral projects (under watershed program) where institutional reforms have been made at different levels to institutionalize participatory approach as per details given below.

Organizational Reforms at Community Level

By and large four types of CBOs are presently organized under the mainstream watershed program. This includes (i) self help groups, (ii) user groups, (iii) watershed committee, and (iv) watershed association. Broadly speaking SHGs (particularly those which have been organized before starting the watershed project) have been functioning satisfactorily. These groups have shown higher level of sustainability even beyond the project period. The remaining three types of CBOs (ie, user groups, watershed committee and watershed association) have initially performed well to a limited extent but could not remain functional after the project period. Lack of sustainability of many of the physical structures is attributed essentially to the unsustainability of above CBOs during post project period.

The expectations from, and scope of, the watershed program is going through a major change. Development of natural resources and generation of employment potential are no longer the primary objectives. Gender and equity are assuming much greater significance since large amount of public funds are used under the above program. Development of livelihoods (based on land, water, livestock, perennial biomass, etc) is assuming much significance and also considered quite critical to facilitate growth processes during post project period. Management of natural resource is now considered more important as compared to development of natural resource carried out earlier. Hence institutional set up at community level needs to be modified under the changing scenario. This involves enhancing the sustainability of existing CBOs as well as integrating new CBOs in order to meet the emerging needs.

Enhancing the Sustainability of Existing CBOs

Self Help Groups (SHGs): At present majority of SHGs include women members and only a limited number of families of the village are represented in these groups. Systematic ranking of SHGs (with regard to maturity) is also not carried out in most of the cases. The role of SHGs under the existing watershed program is limited. In view of this, the following critical aspects may be considered for improving the functioning and sustainability of SHGs.

- Organization of not only women SHGs, but also men SHGs.
- Development of proper book writers at village level.
- Periodic ranking of SHGs regarding their maturity.
- Allocation of greater roles for SHGs under watershed program.

User Groups (UGs): These groups are being organized for carrying out specific activities regarding development and management of natural resources in private as well as common land. While considerable interest has been shown by user groups during execution of above works, subsequent management of developed natural resources has not received the due attention of the above groups. With the result majority of structures/measures particularly those belonging to common property resource have become non-functional. This is largely due to non-functioning of user groups after construction of above structures/measures. Based upon successful experiences under innovative projects the following specific steps may take to improve sustainability of UGs.

- Facilitate UGs to either become SHGs (in case its members are homogenous) or join different SHGs (if its members are heterogeneous).
- Encourage SHGs to become UGs particularly with respect to biomass use in common land, fisheries in common tank, etc.
- Improve the stake of UGs through the followings:
    - Adoption of demand-driven approach in planning of CPR.
    - Collection of a part of the contribution from actual users in advance (before preparing design and estimate) – KAWAD, MANAGE.
    - Formal allocation of user rights (as a part of the planning process).
- Working out modalities for repair, maintenance and protection of CPRs (during the planning phase).
- Adequate investment on capacity building of UGs as being done in case of SHGs.

Watershed Committee (WC): The above committee is to perform a central role for participatory development of watershed through proper involvement of various stakeholders. Management of fund is also its main responsibility since direct funding to the community has been adopted as a major instrument of peoples' participation and empowerment.

Under the ongoing program watershed committee (WC) has indeed played a crucial role. By and large, it has functioned properly during the project period. However, it became virtually non-functional during post project period inspite of having significant amount of common fund collected as contribution from the community. Further, this committee could not focus on livelihood development component, particularly in situations where revolving fund was to be used.

Recently the following initiatives have been taken under watershed program for addressing the above problems.

- Replacing the WC with *gram panchayat*, as it is a constitutional body so that the question of post project sustainability of the committee may not arise. This initiative was taken during 2002 by MoRD through Hariyali guidelines.
- Replacing the WC with federation of women SHGs from beginning of the project. This initiative was taken essentially for enhancement of democratic decentralization in decision making process, empowerment of women, proper management of common fund, etc. This initiative was taken by Government of Andhra Pradesh under the bilateral project (APRLP) during 2003.
- Constituting a conventional type of WC during initial period under the project but replacing it with a federation of SHGs towards later part of the project. This federation consists of representatives from not only women SHGs but also men SHGs. This initiatve was taken under two bilateral projects in Karnataka namely DANWADEP and KAWAD.
- Constituting a conventional type of watershed committee during the project period with representatives from SHGs as well as UGs. At the end of the project period, this committee was converted into a federation of UGs for carrying out management of common property resources developed under the project. This initiative has been taken by MYRADA in Kadiri *mandal* of Andhra Pradesh.

Keeping in view the successful experiences with innovative organizations, the following recommendations are made to improve the overall functioning of WC:

- Initially enroll the membership of existing WC by having representatives from not only women SHGs, but also men SHGs as well as from not only men UGs but also women UGs.
- Towards end of the project, sub-divide the above committee into two types of federations ie, federation of SHGs (of women and men) for management of revolving fund, and federation of UGs (of men and women) for management of CPR.
- In situations where funds are to be released to GP (eg. under Hariyali guidelines); functional integration may be institutionalized between GP and federation of SHGs (of women and men) at village level in such a way that GP may initially receive funds under the project but it may later on transfer it to federation of SHG for execution of works and development of livelihoods.

Watershed Association*:* Watershed association is expected to function as a decision-making body and WC as its executive body. Under the mainstream watershed program, WA was not able to perform the above function due to various reasons including large size of membership; inherent conflict among members, difficulty in participation due to distant location of certain habitations, etc. Based upon successful experiences, the following suggestions are made.

- Organization of small size sub-association (for each local blocks of land) in addition to the original WA for the entire micro-watershed. This should be done particularly in cases where all participants are residing in one large village.
- Organization of habitation based associations (in addition to the original watershed association) particularly in cases where participants are spread over more than one habitation. This initiative has been taken by NGOs in Chittoor district of Andhra Pradesh.
- Organization of majority of members of the association into different SHGs so that they could develop harmony among themselves, articulate their views properly, carry out adequate preparation in smaller groups before coming for the meeting of WA, etc. This initiative was taken by MYRADA in PIDOW Watershed in Gulbargah district, Karnataka.

Organization of New CBOs

Broadly speaking two types of new groups namely (i) Area groups and (ii) Common Interest Groups as well as two types of new management bodies namely (i) federation of SHGs and (iii) federation of UGs are to be organized under the emerging watershed program. A brief description of above groups and management bodies is given below.

Common Interest Groups (CIGs): This is a generic name to include groups in which members have common interest around a particular economic activity. This may include livelihood groups, commodity groups, labour groups, etc. It is expected that all members in a particular group would be dealing with the same type of economic enterprise, even though they may be heterogonous with respect to socio-economic status. Preliminary experience showed that sustainability of CIGs would be enhanced if its members emerge out of different SHGs. In such cases CIGs may be involved mainly for carrying out technological transactions, procurement of inputs, marketing of produce, sorting out management related issues, etc. However, financial transactions on above aspects may be carried out by the members in their respective SHGs

These groups may eventually adopt community-managed production and marketing system with respect to specific commodities and enterprises. As the functioning of the above groups improves, they may be registered under Producers Company Act. Wherever needed community-based entrepreneurs may also be encouraged for carrying out specific jobs in a professional manner.

Area groups: It is now well recognized that the current size of watershed association (for an area of 500 ha) is too large for functioning in a coherent manner. Organizing small size area groups (for about 100 ha each) would be useful in facilitating participative democracy in place of representative democracy (which is inadvertently happening through WC due to inefficient functioning of WA).

The following two new management bodies may be considered under watershed program in order to meet the emerging needs.

- **Federation of SHGs:** This body consists of members from not only women SHGs but also men SHGs. To begin with, it may be organized at village level for sustainable development of livelihoods through the use of revolving fund. It may be formed wherever more than 50 percent of the families in a village are represented in one or other SHGs. Towards end of the project this body would also manage the common fund available with the WC. Additional federation may however be organized of women SHGs, belonging to resource families so that their empowerment processes is not adversely affected
- **Federation of UGs:** This body consists of members from not only men UGs but also women UGs associated with common property resources. It may be organized wherever 8-10 UGs are functioning. This is needed where size of CPR is large and where there are multiple user groups in each CPR so that it can help in conflict resolution, protection of natural resources, etc.

Organizational Reforms at Other Levels for Performing Facilitation Role

Under the participatory approach, major responsibilities for planning and implementation of watershed program rest with CBOs. The organizations at higher levels are expected to facilitate the above process through the following specific responsibilities (i) organization of community, (ii) capacity building at different levels (iii) concurrent monitoring and evaluation, (iv) concurrent policy support, (v) flexible administration and (vi) follow up support during post project period.

Organization of Community

As discussed earlier a member of groups and management bodies are to be organized at the community level under the changing scenario in the next generation watershed program. Developmental functions could be performed by the above bodies if adequate efforts are made to organize them into a sustainable institutional set-up. Hence there is one of the most crucial functions to be performed by the project implementation agency (PIA). Field experience has shown that the following guiding principles may be adopted for organizing the community into a sustainable institutional set-up.

- Beginning may be made with organization of adult members of all the participating families in the village into women SHGs and men SHGs.
- Afterwards other groups as well as management bodies may be organized by drawing members out of above SHGs.
- Sequencing of above CBOs may be carried out in such a way that they are organized as and when the need arises. The following specific sequence may however be considered as a general guideline:

Step – I: – SHGs (of women as well as men)
– UGs (of men as well as women)
– Development of book writers and para workers
Step – II: – Area groups and Watershed Association
– Watershed Committee
Step – III: – CIGs (of one livelihood at a time)
Step - IV: – Federation of SHGs
– Federation of UGs
Step – V: – Community-managed resource center

Special care may be taken to see that organization of WC is not hastened. It may be constituted only after organizing sufficient number of SHGs and UGs and also after preparation of first year action plan for development of individual oriented natural resources (through SHGs) and of community-oriented natural resources (through UGs). The WC may be organized (after this stage) for consolidation of above action plans and also for taking follow-up actions related to approval of plan, release of funds, implementation of approved works, etc.

Community organization is a slow process hence greater lead time is required for achieving the above objective. Also financial management principles are to be modified because ratio between administrative expenses and physical work expenses would be much higher for the institutional building phase as compared to the main developmental phase.

Organization of community requires not only greater lead time but also specific skill and attitude to evolve sustainable institutional set up. By and large NGOs have shown better abilities to do the above job. In view of this the following two specific approaches may be adopted keeping in view the successful experiences in innovative projects.

- Separation of institution building phase from the main implementation phase (which may require about two years) and allowing this phase to be managed by NGOs as PIAs. Afterwards the subsequent developmental phase may be managed even by governmental organizations as PIAs. This is based upon successful experience with WOTR and NABARD in Maharashtra.

- Outsourcing of community organization responsibility to experienced NGOs even in situations whereas governmental organizations are the PIAs (this is based upon successful experience under the bilateral program namely DANWADEP in Karnataka).

Capacity Building

This is to be carried out for stakeholders at community level as well as all other levels indicated earlier. Field experience under bilateral projects in Andhra Pradesh (APRLP) and Orissa (WORLP) have shown that following two provisions need to be created in order to achieve the district level.

- Creation of dedicated resource centers at different levels namely *mandal*/block; district and state exclusively for building the capacity of stakeholders within the respective jurisdiction. These resource centres are to be nurtured by experienced NGOs having sufficient experience with participatory watershed management.
- Organizing a consortium of resource organizations for capacity building. This consortium may consist of representatives from governmental as well as non-governmental organizations having practical experience on different aspects related to participatory watershed management. It may be managed by a small secretariat to be located either with the concerned government department or with an experienced NGO.

The capacity building support at *mandal*/block may be provided by a pool of resource persons (PRPs) from various organizations working in the concerned area. This suggestion is based upon the ongoing experience under the bilateral project (APRLP) in Andhra Pradesh as well as WORLP in Orissa.

Concurrent Monitoring and Evaluation

This is one of the weakest links under the mainstream watershed program. Much of the attention is paid towards monitoring of physical and financial progress without due emphasis on participatory processes, gender, sustainability, etc. Wherever processes are monitored, the information is rarely used in the decision -making process for improving the management of the project. External monitoring and evaluation on current basis is rarely done under the mainstream watershed program. Based upon successful experiences the following two specific initiatives may be considered.

- External monitoring and evaluation of the project on concurrent basis (every six months or so), through a panel of experienced resource persons (this is the generally practices under bilateral projects).
- Internal review of participatory processes on regular basis through a combination of external and internal resource persons (this is based upon initial field experience under APRLP in Andhra Pradesh).

Concurrent Policy Support

The mainstream watershed program is spread over a vast area in the country with high degree of heterogeneity and complexity. A common national guideline can not serve the purpose under all situations. The following two initiatives have shown successful results.

- Preparation of state specific process guidelines to build upon its unique strengths and opportunities.
- Constitution of empowered committee at state level for taking periodic decisions pertaining to policy matters based upon concurrent feedback, etc. These committees have been constituted and successfully functioning under bilateral project (namely DANWADEP) in Karnataka, Madhya Pradesh and Orissa.

Flexible Administrative Set-up

Situation under watershed program varies considerably between different states, districts and even watersheds. It is therefore crucial to have flexible administrative set-up to respond to these variations as per the merit of the case. This calls for a major reform in the institutional set-up at state and district level.

- Establishment of a dedicated as well as autonomous organization (through registration under Society Act). This reform has already been adopted in some states namely Madhya Pradesh, Orissa, Tamil Nadu, etc., where a separate watershed mission is established at state level. The autonomous organizations at district level have been existing since long time in majority of DDP, DAAP district in the country.
- Establishment of a separate program management unit (PMU) at state and district level based upon number of the successful experience in a bilateral watershed project. This unit takes care of additional workload related to management of the project and to be established only for the project period.

Follow Up Support during Post Project Period

One of the main reasons behind low levels of post project unsustainability under watershed program is the abrupt discontinuation of support system by PIA after completion of project. The following two successful initiatives have emerged to address the above issue.

- Addition of a separate consolidation phase for two years (after completion of main implementation phase) so that post project sustainability related issues could receive focused attention. This is based upon successful experience with bilateral project (DANIDA) in Karnataka, Madhya Pradesh and Orissa.
- Organization of a community managed resource center with cluster of villages to provide need-based support on 'charge' basis. This is based upon successful experience by MYRADA in establishing a series of such centers.

Keeping the above experiences in view, the following institutional framework has been suggested at different levels.

National Level Institution

- National Watershed Management Agency (NWMA) to be registered under Society Act.
- Project Support Unit (PSU) for the project period.
- Empowered review committee for concurrent policy support.

State Level Institution

- State Watershed Management Agency (SWMA) to be registered under Society Act.
- Project support unit (PSU) for the project period.
- Panel of resource persons for external monitoring and evaluation of project.
- Consortium of resource organizations for external monitoring and evaluation of project and capacity building of state and district level stakeholders .
- Empowered review committee for concurrent policy support.

District Level Institution

- District watershed management agency (DWMA) to be registered under Society Act.
- Project management units (PMUs) for each set of watershed projects.
- District livelihoods resource centre (DLRC) for capacity building of project level stakeholders.

Project Level Institution

- Empowered review committee for concurrent administrative support.
- Project facilitation agency (PFA) with flexibility in hiring of need-based resource persons from phase to phase.
- Cluster level resource centre (CLRC) with each cluster of villages/projects for providing handholding support to community based stakeholders.
- Pool of resource persons (PRPs) at project/cluster of project level.

20. Agriculture and Allied Micro-enterprise for Livelihood Opportunities

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Abstract

Micro-enterprises are the keys to generate employment opportunities as well as income earning avenues to both landless, women and landholding people. Therefore, the poverty alleviation in semi-arid regions requires a greater understanding of the interactions of agriculture and allied enterprises and their implications for the household economy. This paper synthesizes the available evidence on agriculture and allied enterprises in watershed development areas and how policy should address the issue to balance between agriculture and micro-enterprises promoted by watershed development programs.

Keywords: Micro-enterprise, agriculture, watersheds, livelihoods.

Introduction

Agriculture and allied activities support livelihoods of nearly 70 per cent of India's rural population (Hiremath 2007). In recent years, land-based livelihoods of small and marginal farmers are increasingly becoming unsustainable, since their land has not been able to support the family's food requirements and fodder for their cattle. As a result, rural households are forced to look at alternative means for supplementing their livelihoods. In this context, natural resource-based micro-enterprises have emerged as alternative livelihood opportunities in rural areas. Varying socio-economic and environmental trends including declining crop prices, swelling labour forces, migration and urbanization increased the demand for alternative employment and off-farm livelihood opportunities. Due to lack of skill development, formal employment ceased to keep pace with the demand for employment. In this context, watershed development strategy facilitated small landholders, landless and women groups to benefit from small scale allied activities.

Watershed development is the strategy for sustainable growth in the vast rain-fed regions since 1980s to enhance agricultural production, conservation of natural resources and raising rural livelihood system. Although soil and water conservation was initially the primary objective of watershed program that saw large public investment since inception, later its focus shifted to principles of equity and enhancing rural livelihood opportunities and more recently to sustainable development since mid nineties (Wani et al. 2002). As the focus of watershed development shifted, the landholders (small and large farmers), landless, women and youth groups were brought to ensure the success of the program. Traditionally, watersheds have been viewed as hydrological units to conserve soil and water, and a compartmental approach has been adopted. However, through the integrated watershed management approach all natural resources in the watershed are managed efficiently and effectively so that the rural livelihoods can be improved substantially through convergence of various activities (Sreedevi, 2003).

Micro-enterprises are worth giving attention to for several reasons. Firstly, in some areas these make a significant contribution to household income, employment and economic production. Secondly, they have a potentially key role to play in supplying resilient and flexible services. Thirdly, compared to land-based agriculture, they tend to generate relatively good income and hence provide resilience to household economic conditions. Finally, being relatively less technology oriented, these activities support a proportionately larger section of the unskilled labour force and produce larger number of livelihoods per unit of output. Micro-enterprises are the keys to generate employment opportunities as well as income earning avenues to both landless, women and landholding people. Therefore, the poverty alleviation in semi-arid regions requires a greater understanding of the interactions of agriculture and allied enterprises and their implications for the household economy.

This paper synthesizes the available evidence on agriculture and allied enterprises in watershed development areas and how policy should address the issue to balance between agriculture and micro-enterprises promoted by watershed development programs.

Constraints

Although, micro-enterprises are operates locally and have low entry and exit barriers, it suffers from major constraints.

- Flow of funds (credit availability) is a major constraint for their effective operation.
- Shortage of capital.
- Lack of necessary skills in the chosen activity.
- Competition from larger units.
- Lack of marketing facilities and effective pricing for goods.

Along with credit, poor people need various other services/input viz. training for skill development, information, insurance and market linkages which would minimize risk and enable them to generate income for their survival. Providing poor people with credit for micro-enterprise can help them work their own way out of poverty.

Strategy and Approaches

Information on micro-enterprise based livelihoods was drawn from a wide range of published and unpublished sources, including field research by members of GT-Agroecosystems at ICRISAT. Although there is now rich debate and discussion on various aspects of livelihoods, there is no evidence on overall synthesis of micro-enterprises, which are dependent on natural resource. This paper brings information together to create composite picture of changes in rural livelihoods and enhanced livelihood opportunities.

Micro-enterprises, Markets and Technology

Small-scale entrepreneurship through watershed development plays a significant role in poor people's lives and is one of the keys to lifting people out of poverty. Some of the activities are the backbone on which the rural society survives in most arid and semi-arid regions. Watershed development primarily aiming sustainable management of natural resources contributing for overall agriculture development and livelihood promotion in rural areas. Initial poverty eradication efforts in India concentrated on supply of agricultural technologies, inputs and services that were often 'production' orientated. However, they were largely inappropriate to the needs of the poor and the benefits were mostly captured by the wealthy. Later, the approach changed towards 'capacity-building' in sector organizations to equip people and organizations with the skills and resources to do a better job. The concept of livelihoods and livelihoods analysis emerged in the mid nineties - closely associated with poverty reduction strategies. This approach was useful to identify and prioritize the needs of the community in enhancing their livelihoods.

Market Structure

Although micro-enterprises operate in very informal, unregulated environments, the fortunes of most of these activities are connected by supply chains through production channels and the influence of competition, to mainstream commercial markets. These interrelationships increasingly link allied enterprise activities performance to the behavior of other actors in economic networks. Most times production activities of allied enterprises are supported by local markets to fulfill local demand. However, monopoly does not arise as diverse actors are involved in the production processes. Thus, most often, micro-enterprise activity serves as a strong social capital, within the community, builds strong social network.

The Role of Technological Change

In a world influenced by rapid technological developments, the capacity to cope with, generate and manage change seems like key factors in determining the livelihood strategies of poor people involved in agriculture allied enterprise. In the livelihood analysis, technology assumes greater significance as having at least four interrelated constituents viz. technique (machines and equipment), knowledge (know-how and skills), organization (systems, procedures, practices and support structures), and product (design, specification) (Scott, 1996; Pauli, 1999).

Agriculture and allied enterprise activities enhance rural livelihood system through locally available technological backstop. In principle, poor people stand to gain from technological change – generating easier access to information, higher productivity, lower inputs costs, less wastage and better environmental management. However, the pace and volatility of change can be a problem, particularly when allied activities are left behind the agriculture development or forced to take greater risks in order to keep pace with increasing vulnerability. As a result, the livelihood outcomes that allied enterprise owners practice, is likely to be increasingly determined by these activities capacity to generate and manage technological change. In the long run, an effective analysis of the factors that influence technological change in and around agriculture and allied enterprises is important for understanding the livelihood strategies and options for poor people who work in these activities.

An approach in understanding the livelihood opportunities is presented in Figure 1. This approach explicitly link watershed development with rural livelihoods and effectively poverty alleviation. Rural livelihood system is dependent on input and output chains which are centered on utilization of natural resources. The input chain is mainly providing support to achieve higher growth and larger income flows to different category of people who are depending on these activities. These are the keys to value addition to their income activities that are dependent on market and technology.

For example, village seed bank, vermicomposting, nursery raising and bio-fertilizer enterprises are providing enough opportunity to the value addition in the household economy. The allied agricultural activities are gaining importance as the proportion of income coming from agriculture fell and households became increasingly dependent on other sources of income (Deb et al. 2002).

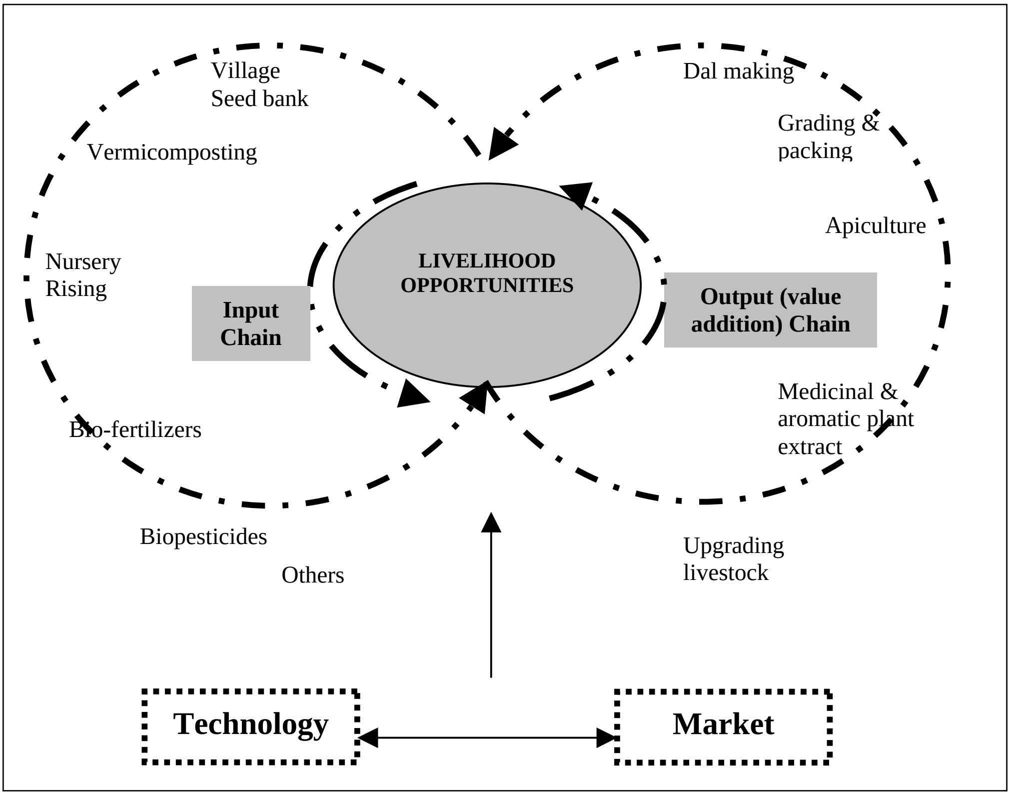

Figure 1. Input - output chain in livelihood promotion.

The watershed development provides better training and development to farming communities in micro-enterprises forms a better way to reduce migration to urban areas for seeking employment during off-farm season. Selection of micro-enterprises can be based on the locally available resources and technical backstopping for training the farmers. The selection of micro-enterprises can also help women and landless people to promote their livelihoods and to improve the economic condition by using locally available resources. Several micro-enterprises activities provide an opportunity to diversify their livelihood activities and to improve the crop productivity by increasing soil fertility through ecological methods of farming (Wani et al. 2002). These activities avail market facilities at the nearest places to sell their products. Hence, agriculture and allied activities provide greater opportunity to strengthen rural livelihoods.

Income-Generating Micro-enterprises

The innovative farmer participatory approach for integrated watershed management implemented through a consortium of research organizations, development agencies and NGOs envisages a strategy of convergence of the activities in watersheds. In this paper, experiences from APRLP-ICRISAT, ADB funded and other projects are used to describe success stories of growing micro-enterprise activities in rural watersheds (Wani et al. 2002).

Medicinal and Aromatic Plant Extracts: Medicinal and aromatic plants possess the ability to grow in poor soils and under low rainfall and moisture conditions, thereby assisting in the natural regeneration of these crops. These crops improve specialized skills; encourage contacts with niche markets; adds to crop diversification; and provides employment opportunities (Rangarao, 2009). Value addition to medicinal and aromatic plants product is one of the objectives of crop diversification. Processing of aromatic plants by extraction of oil is value addition to lemongrass, palmarosa, vetiver, and *Eucalyptus citriodora* (Reddy et al. 2008).

Figure 2. Distillation of lemongrass in Padmatipally, Nalgonda.

Apiculture: The harvesting of honey from the forest has been in practice since long and huge profits from this enterprise promoted rearing bees in the farms. In the recent past rural communities while diversifying their agricultural practices, have adopted this practice gradually. Production of honey from farmlands can be a secondary activity for farmers as it requires less time as compared with other activities and can be carried out by women in a house. On an estimate, about 80 per cent of honey is used directly in medicines and 10 per cent is used in Ayurvedic and pharmaceutical production (GoI, 2006). Studies found that apiculture is an excellent, esthetic livelihood generating endangered hobby. It has a potential market with environmental responsibility and worldwide medicinal and nutritional recognition. Apiculture requires less investment and easy-to-learn (Rangarao, 2009). It also helps in pollination of crops and increase seed setting in many crops.

Figure 3. Apiculture.

Figure 4. Upgrading livestock.

Upgrading and Rearing Livestock: watershed program is an important intervention in dryland areas to improve crop as well as livestock productivity. Small ruminants like, sheep or goats are the best source of regular cash income throughout the year for rural poor without much investment. They form a major component in a tree-crop-livestock diversification/integration paradigm. As integrated crop-dairy farming system is a viable and profitable proposition to the farmers, upgrading livestock is essential.

Village Seed Bank: Village seed bank system was introduced as part of income-generating activities in many watersheds. These seed banks are providing self-sufficiency and self reliant for farming communities since they experience the drudgery of seed companies in terms of spurious seeds supply. Therefore, seed banks emerged as a worthy social capital in rural areas.

Figure 5. Village seed bank system.

Vermiculture: Vermiculture became a prominent micro-enterprise for rural landless and women groups, as it requires low investment. Vermiculture is environment friendly as it converts disposal of organic wastes generated in farms as well as in household front as productive plant nutrient. These residues contain valuable plant nutrient and can be effectively used for increasing the agricultural productivity. Earthworms convert the residues into valuable source of plant nutrients by feeding on the organic material and excreting out valuable organic manure. Earthworms are one of the major soil macro-invertebrates. The role of earthworms in the soil is to improve soil fertility and soil health. Vermicompost increases water-holding capacity of the soil, promotes crop growth, helps produce more, and improves food and fodder quality (Nagavallemma et al. 2004).

Figure 6. Vermicomposting by women SHGs in Mentapally, Mahbubnagar.

***Dal* Making:** Dal making is a best micro-enterprise to avoid middlemen and get maximum market price for the product. Dal-making is also a value addition to the product through which farmers can benefit the most. This micro-enterprise is brings women self-help groups together and builds strong social network among rural communities (Figure 7). Apart from value addition to the product, farmers also get nutrient-rich fodder to feed animal (ICRISAT, 2004).

Poultry-based Activities: Agro wastes (eg, from maize cultivation) can be diverted for poultry feed along with other supplemental food. Rearing of improved breed like broilers can increase the returns and improve the livelihood options.

Horticulture and Forestry-based Activities: Teak planting, pomegranate cultivation and custard apple cultivation along the bunds and marginal lands will provide profit to the farmers.

Nursery Raising: Nursery raising forms a means of livelihood for large number of people (Figure 8). Nursery raising as the means for developing livelihood and income-generating opportunities for the local communities. It also provides capacity building and skills upgrading for members of the communities. Nursery raising generates cash income, means for poverty alleviation, opportunity for women and aged people to contribute to income generation and flexible working hours.

Figure: 7. Low cost dal mill in watershed villages.

Figure 8: Nursery raising.

Case Studies

Vermicomposting: A Bio-enterprise for Sustainable Agriculture

The ICRISAT led consortium initiated the concept of vermiculture enterprise for rural women to improve soil fertility and crop productivity through eco-friendly methods of farming and train the women SHGs in vermiculture technology and assist them to set up viable vermiculture enterprise at the household level (Figure. 9). These alternate sources of nutrients supply sizeable quantities of nutrients, reducing the need for huge quantities of costly fertilizer. A proper combination of nutrient management options together with soil and water management practices will result in improved productivity and also the productivity can be sustained without any harm to natural resources. On-site training was also provided and women SHGs were empowered to undertake vermicomposting. As a result, women SHG members are involved in vermicomposting enterprise as a strategy to cope with insecurity prevailed in household economy. Numbers of watershed projects following livelihood approach have adopted vermicomposting through SHGs which avoids pitfall of neglect of vermicompost pits in individual approach during the absence of individuals.

Figure 9. Women involved in vermicomposting activity.

Box 1: Adarsha Watershed, Kothapally

Ms. Lakshmamma and four other women have set up a vermicomposting enterprise in a common place under one roof. Having begun with a population of 2000 earthworms of three epigeic species, they regularly harvest around 400 kg of vermicompost every month collectively. Their work in making vermicompost is shared collectively and the unique marketing strategy involves meeting potential customers. Sometimes, they even get customers from distant places. They earn a net income of around Rs. 500 each month. By becoming an earning member of the family, they are involved in the decision-making process in the family. This has also raised their status in the society (extracted from Nagavallemma et al. 2004).

Box 2: APRLP Watershed

Ms. Padmamma living in Sripuram of Mahbubnagar district in Andhra Pradesh leads a routine life. She joined the women's SHG at the beginning of the APRLP project. Though reluctant during the initial stage, she started taking active part in the weekly meetings and showed interest in the discussions about raising income through small activities like adopting the vermicompost scheme. This scheme was introduced to enable crop productivity in the fields and enable the farmers to get more per hectare yield. Ms Padmamma is able to get higher yield from different crops such as maize and vegetables with the application of vermicompost in her own field. She now proudly displays the vermiculture beds to any visitor who comes to meet her (extracted from Nagavallemma et al. 2004).

Village Seed Banks: An Initiative for Self-reliance and Self-sufficiency

With the advent of hybrid technology, the farmers are required to replenish seeds every season from external sources to harness higher productivity. However, due to increased demand for seeds, it is difficult for organized seed sector to meet farmer's demand considering number of crops and varieties cultivated. Thus, unscrupulous elements in the seed industry are active in supplying spurious seeds to farmers, causing heavy losses to the farmers and the economy.

Therefore, many attempts are on to practice village seed bank to meet self-sufficiency in production and distribution of quality seeds for the crops where improved cultivars are high yielding and stress tolerant. Watershed development through collective community participation enables the community to revive the age-old concept of self-sufficiency through developing village seed bank. There are successful community initiatives across watershed development programs.

ADB-Funded Lalatora Watershed

Lakshmi Self help group is a thrift group with eleven women members. The group started procuring seeds of improved chickpea varieties (ICCC 37, ICCV 10, ICCV 2 and KAK 2) supplied by ICRISAT under the ADB project from 2000 (Figure 10). The group first identifies the farmers who have sown the improved chickpea varieties. Upon harvest of the crop, the group approaches the identified farmers and offers to buy

Figure 10. Discussion with project scientists.

their produce at a premium of Rs 1.00 to 2.00 kg^{-1} over the prevailing market price. In the first year, the group bought 300 kg seeds of improved chickpea varieties from farmers who had grown these varieties using breeder's seeds provided through the project. With the technical guidance of the project staff, the women graded the seeds and treated them with thiram 2.5 g kg^{-1} of seed (Figure 11). The group incurred approximately Rs 20 per 100 kg seeds. The seeds were then stored in the government warehouse located about 15 km away from the village at a cost of Rs 20 per bag. Besides, they also had to pay Rs 10 per bag for transportation.

The group procured 400 kg seeds of improved chickpea varieties during 2001 and earned a net profit of Rs 1940 by selling the same in post-rainy season 2002. The SHG procured 800 kg chickpea seeds in post-rainy season 2002. As the volume of seed procurement is growing year after year, the SHG is considering increasing their monthly contribution from Rs 10 to Rs 50 at least for few months in a year to generate additional capital. At present, the group savings are to the tune of Rs 5600 and have received financial assistance of Rs 11,260 from the project as revolving fund for buying the seeds.

The seed reliability, quality and availability at the farmer's doorsteps are the major factors, which are influencing farmers to buy chickpea seeds from the group at a premium price. It is indeed interesting to note the prevailing notion is that the SHG

Figure 11. Trained women grade and treat seeds.

would sell the seeds at a lower price than that quoted in the market. In fact, the SHG is earning this premium for the goodwill they have in their community. Selling seed and standing by its quality is indeed an asset and a worthy social capital. Having gained confidence in dealing with chickpea seed, the SHG is considering procuring breeder's seeds of improved varieties of soybean, sorghum and coriander in the coming years. Besides, the group is also enthusiastic about taking other income-generating activities like dairy. On the reaction of the male members of the families to the seed procurement initiative, the women members reveal that they are getting a good deal of cooperation from them. Besides, they are encouraged to contribute higher amount of subscription to the thrift fund. The women feel more confident and acknowledge that the seed bank has brought new enthusiasm to the SHG and empowered the women. They thankfully acknowledged the contribution of the project to the SHG revolving fund (Table 1). The SHG members are willing to learn new technologies related to seed production and quality. Further, they opined that the seeds sold by the SHG are much superior in quality compared to what they used to buy from the market. The seeds, they said, has good germination (over 90%) and give high yield. Considering the success of the Lakshmi SHG, other thrift groups also showed keen interest in adopting the concept of "seed bank" as an income -generating activity.

Table 1. Seed bank activity in ADB-funded Lalatora watershed development project.

Particulars	2000	2001	2002	2003	2004
Participating SHGs (no.)	4	2	3	3	2
Seed procured (kg)	1200	800	2210	2213	1618
Project loan (Rs)	19740	10920	37620	34008	21364
Group savings (Rs)	1860	2000	3000	3000	2000
Seed buying price (Rs 100 kg^{-1})	1800	1615	1700	1600	1600
Seed selling price (Rs 100 kg^{-1})	2100	2100	1900	1860	1800
Amount earned by SHGs from seed sale (Rs)	25200	16800	41990	34408	29124
Net profit to SHGs (Rs)	3600	3880	4180	3942	3036

Source: Dixit et al. 2005.

Pigeonpea *Dal* Making

In Mahbubnagar and Kurnool districts pigeonpea is grown on substantial area. The improved variety of pigeonpea has produced good yield and farmers sold it at Rs. 14 kg^{-1} in the market and for their own consumption they have purchased *dal* at Rs 24 kg^{-1}. By adopting the principle of adding value to the produce before leaving the watershed to ensure that maximum proportion of market product price goes to the

Figure 12. Dal making by women self-help group in Karivemula.

farmers and not the middlemen, *dal* making proposition was discussed with the PIAs and farmers. Farmers in Mentapally were the first to come forward and formed the SHG and established the *dal* mill on a pilot basis (Figure. 12). Till now they have converted 600 kg of pigeonpea into dal and added Rs 5400 value to their produce. They have worked out the charges to be paid to the SHG, which are lesser than the commercial mills and have recorded 90% dal recovery. In addition to the value addition, farmers have got the nutrient-rich pigeonpea hulls to be used as animal feed (ICRISAT, 2004).

Livestock Rearing and Upgrading

The cattle breeding center set up in 2003 at Adarsha watershed, Kothapally, has evoked good response from the farmers. This center also runs mobile artificial insemination centers with portable equipment does the artificial insemination for buffaloes and cows. The cattle breeding also provide gainful self-employment to the rural youths who are unskilled to apply high science tools. Small and marginal farmers with a couple of crossbred cows, increased milk production through artificial insemination, are coming out of poverty.

Until November 2009, this center has done 2592 artificial insemination for cows and buffaloes out of which 1297 are pregnant and 524 calfs were born (Table 2). Each farmer has to pay Rs. 40 per animal for artificial insemination for their cows or buffaloes. This money will be deposited in a bank account. The youths were trained to undertake this activity in surrounding villages.

Table 2. Artificial insemination done at Cattle Breeding Center, Kothapally during August 2003 to November 2009

Cattle	No. of cattle inseminated	Pregnancy examined	Pregnant animals	No. of calf born		
				Male	Female	Total
Cow	490	388	243	51	52	103
Buffaloes	2102	1737	1054	205	216	421
Total	2592	2125	1297	256	268	524

The cattle rearing activity after installing artificial insemination center as part of watershed activity has boosted milk production in the village. According to villagers, after the implementation of watershed development program in the village, the cattle rearing activity has gone up due to year-round availability of fodder for cattle. Also artificial insemination center set up in the village provided farmers to go for crossbred cows and buffaloes for higher milk yielding. Before the project implementation animals were giving just one to two litres a day. But all that is changing now because of fodder availability and artificial insemination. The milk yield has now gone upto 15 liters a day per animal. The milk yield at present ranges from 2 to 15 litres per animal per day depending on the type of animal. Because of watershed intervention, farmers grow *Napier bajra, Cencrus Ciliaris* and wild green gram as fodder crops for animals which help to increase the milk productivity.

The market availability at the village is one of the major factors for undertaking livestock activity in the village. During the year 2007-08 Reliance Group set up a milk collection center in the village and the milk collection per day is nearly 400 litres. Before Reliance milk collection center was set up in the village, farmers used to sell their milk for private milk collectors for low price without any incentive. Reliance Group is paying Rs. 20-31 per liter based on fat content. However, there are three private people collecting nearly 250 litres milk per day and paying maximum Rs. 18 per litre. Due to increase in milk yield and easy access to market for milk, farmers are investing on animals to multiply their incomes. One of the best things about the program is its multiplier effect and after five years of establishing artificial insemination center, the cattle wealth in the village has increased manifold.

Agriculture and Micro-enterprises: A Growing Partnership?

The above case studies provide ample evidence for a growing partnership between agriculture and allied enterprises. Figure 1 shows the range of available options and indicates increasing opportunities for livelihood enhancement. The figure offers a choice of 'career paths' through the different levels of livelihood security. In support, market and technology play a major role in making use of available opportunities.

The village seed bank, for example, provides an alternative to centralized production and distribution of improved seeds and help farmers to become self-reliant. The necessary stable technical backstopping and empowerment of the community members demonstrated the viability of village seed banks. The village seed bank not only ensure good quality seeds for enhancing productivity but also in generating income for the community members, resulting in improved livelihoods. The problem of spurious seeds supply and associated losses can be overcome by applying locally available seed system.

Similarly, vermiculture enterprise at the household level for rural women helps to improve soil fertility and crop productivity through eco-friendly methods of farming. The above case study demonstrated that vermicomposting is a viable option to increase the productivity and assists to improve environmental quality through absorbing organic wastes generated in farms and domestic front. Therefore, vermiculture enterprise serves as multipurpose criteria to sustainable rural development.

The above mentioned micro-enterprises are in close association with agriculture development either as an input or value addition to the products. Since these enterprises are based on locally available technology and resources, appropriate market linkage should be provided to facilitate rural entrepreneurs who are engaged in these activities. Therefore, agriculture and allied enterprises should go together to make difference in rural livelihood system.

Recommendations for Practitioners

Micro-enterprises are informal, low costs, local business hubs for livelihood security of poor marginalized section of the society. The further promotion of these allied enterprises lies in the interest of decision makers and practitioners. Thus, following specific points to be taken care while formulating policies to promote micro-enterprises.

- Easy availability of rural finance for their effective operation and smooth running.
- Providing appropriate training to improve necessary skills in their chosen activity.
- Facilitating effective support system to overcome uncertain and unorganized marketing system for products.
- Policies should concentrate on effective pricing for goods and services generated by micro-enterprises.
- Necessary arrangements need to be created to provide sufficient revolving fund as project contribution to SHGs to overcome financial crisis.
- Adequate capacity building training programs need to be arranged to improve the skills of landless and women groups and to provide necessary information about new technologies, marketing avenues and techniques.

Conclusion

It has been demonstrated from the above case studies that the relationship between agriculture, natural resources and micro-enterprises are interrelated. It is therefore, important to be able to understand exactly what is likely to occur in particular contexts. Given the increased witness on the role of micro-enterprise in promoting rural livelihoods and the associated increase in the proportion of household income derived from these activities, this merits some serious study; a need that has also been emphasized by researcher (Sreedevi, 2003; Dixit et al. 2005; Nagavallamma et al. 2004; Rangarao, 2009).

In this context, attention needs to be paid to the broader context in which changes are taking place. The economy is going through a transition in which agriculture and industry are changing rapidly in response to globalization, environmental limits, stresses and population pressure. A stronger push is also being experienced in many areas with land fragmentation, drought, groundwater scarcity and falling agricultural commodity prices. In view of this, it is very likely therefore that the increase in productivity and income from agriculture may not be sufficient to handle the situation. Therefore, probably the most important implication for policy is to recognize that agriculture and allied enterprises continue to provide a safeguard to rural livelihood system.

Agricultural allied enterprises should be viewed as an alternative to mainstream non-farm employment opportunities and although not the perfect way of providing employment to the poor in rain-fed farming. Therefore, there is an urgent need to understand how watershed development can become a part of efforts to support most diverse livelihood portfolios where a win-win situation can be created through improving the resource base which creates a more conducive environment for undertaking micro-enterprise activities, leading to an overall increase in standard of living, employment, poverty reduction and building resilience of the community to cope with the impacts of drought.

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21. Innovations in Capacity Building Efforts in the Context of Watershed Development Projects in India

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Abstract

The paper narrates the processes and essential features of various capacity building experiences in the country in general and in Andhra Pradesh in particular. These experiments related to capacity building processes initiated within large scale mainstream development projects and within civil society sector. Several innovative features on various components of the various watershed projects like NABARD supported project, DANIDA's Watershed Development Program have been highlighted.

Keywords: Watershed, capacity building, innovations, training, partnerships.

Introduction

From Training to Capacity Building – A Conceptual Advancement or a Practical Reality?

The role of training in development projects needs no emphasis. Through training, one gets an opportunity to learn about newer aspects of development process and benefit from training inputs. Over a period of time, the meaning and scope of "training" in development sector changed. Training is replaced by "capacity building" in various debates and discourses around development processes. Training is considered to be an "event", while capacity building is interpreted as much larger process that "enables" the project partners to perform their roles and goes much beyond training programs. "Capacity building" is considered to be more holistic, which includes several components such as creating enabling policy support and operational norms; development of skills, attitudes and knowledge base; experiential learning; communication and so on. Various experiences contributed to this process of evolution of conceptual clarity on the terms like "training" and "capacity building". This paper looks at the innovations in capacity building processes in the context of watershed development projects in the country in general and in Andhra Pradesh specifically.

Enabling Policy Provisions – an Opportunity for Making the Rhetoric a Reality

Though training is recognized as important input into the process of development, development projects seldom provided support for training components. This support includes financial provisions, institutional arrangements, professional human resource support and monitoring support. Designs, objectives and scope of several rural development schemes/projects were also narrowly focused and understood. In such situations, the need for training programs was also not so clearly articulated. Even if the training need was identified, related inputs largely remained either sporadic or completely absent in several development projects. Training support was perceived and designed as a "separate and independent" project, which may or may not have any relationship and/or contribution to other development projects. TRISEM, a scheme aimed at developing skills of rural communities for self employment, which was being implemented by DRDA is a good example of such approach. One gets a sense that importance given to training programs largely remained as "rhetoric".

With this background, watershed development projects and the guidelines (GoI, 1994) could be considered as "revolutionary" as they provided specific budgetary support to training programs and community organization (5% of total budget each) as part of the project itself. In India, one could consider that this is the first time a government project had an in-built budgetary provision for training and community organization. This "reality" helped in creating an importance and priority to the agenda of training, which otherwise is generally ignored. This policy provision helped in generating various types of experiences related to training, also made several advancements conceptually and institutionally. This support also established creative and innovative models across the country. One of the important contributions of these experiences is to "differentiate the training programs from capacity building support". This paper presents the experiences related to capacity building processes in the context of watershed development projects in Andhra Pradesh. A brief narration of related experiences in the country is also presented. The paper is organized into three sections.

Section 1:

- A brief narration of good experiences on capacity building processes in watershed development projects in India

Section 2:

- A brief narration of good experiences on capacity building processes in watershed development projects in Andhra Pradesh

Section 3:

- A critical reflection of experiences – enabling and concerns for up-scaling

Section 1: A Brief Narration of Good Experiences on Capacity Building Processes in Watershed Development Projects in India

Interestingly, there are several good experiences in the context of watershed development projects in the country even before 1994. One could argue that these models/experiences also influenced the guidelines of watershed development projects in the country. Some of these good experiences in the country facilitated by civil society organizations (AKRSPI; Relagam Siddhi; MYRADA; WOTR; Others) were carefully studied before finalizing the guidelines. One important feature of these experiences is a strong input and support provided to training, capacity building and institution development. This observation was converted into a policy provision by providing a specific budget item for capacity building (training and community organization) as part of the project. Some experiences, which are initiated during last ten years, are relatively new. These experiments related to capacity building processes are initiated within large scale mainstream development projects and within civil society sector. A brief account of such influencing experiences is presented here.

NABARD-Supported Projects

NABARD, Indo German Watershed Development Projects and WOTR implemented several watershed development projects in Maharashtra. These projects have several innovative features on various components of the project. A large number of smaller NGOs functioned as project implementing agencies. Self selection process was adopted for selecting villages. Each village has to establish their interest and commitment towards watershed development project by voluntarily donating manual labor (*Shram daan*) and undertake some physical work collectively, even before the projects are formally sanctioned. After this qualifying *Shram daan*, a small portion of the village area would be taken up for "demonstrating" the watershed project approach. This phase is called "capacity building phase". The focus of this phase is on "experiential learning (learning by doing)" by communities related to various aspects of watershed development projects (planning; implementation; monitoring and so on). Once this phase is "crossed", the main implementation phase begins. Since several NGOs are part this process, the need for capacity building support was very significant. The capacity building process was not just limited to implementing agencies and but also to communities. The interesting part of this approach is – experiential learning by communities. This approach required considerable efforts, support and focus on capacity building agenda. WOTR functioned as resource organization for a large number of NGOs and community based organizations. The capacity building inputs were related to various project phases of the watershed development projects. WOTR developed various modules and standardized these capacity building inputs. Apart from organizing classroom/ field-based training programs, WOTR also undertook several project management related functions such as assessments, monitoring and reviews and funding. This integrated approach strengthened the project implementation process in capacity building and management aspects.

Experiences from DANIDA's Watershed Development Program (DANWADEP)

DANWADEP supported governments of MP, Karnataka and Orissa for implementing watershed development projects. These projects began even before the participatory guidelines of GoI (1994). DANWADEP had a special focus on capacity building inputs and experimented with various approaches in these three states. Some of these approaches and project designs also gave good lessons in terms of capacity building strategies. Since DANWADEP worked with ministries; line departments; NGOs and communities, the capacity building strategies aimed at stakeholders at all levels. The capacity building strategies were integrated with project management. Formation of coordination committees at state/district levels was one of the important instruments to ensuring smooth implementation of project and also designing capacity building strategies. The effective function of these committees ensured that project management decisions taken and capacity building related strategies are evolved from time to time. A clear strategy for capacity building was designed which focused on improving productivity, people's participation, improving know-how, improving sustainability and project management. Project partners at various levels were specially targeted based on the roles and tasks performed by each partner. This project evolved several "instruments" to ensure that overall support system is

Guiding Principle for Capacity Building Strategy - DANWADEP

- Partnership
- Access to information
- Participation
- Subsidiary
- Flexibility
- Extended time scale–system's perspective Is a process

Source: NL Narasimha Reddy and P Narender Babu-Experiences of DANWADEP: Changing Frontiers of Capacity-Building in Watershed Programs (2005) – Development Assistance Committee (DAC) of the Project evolved for the project, which looked at project management and capacity building needs. Developing partnerships with resource organizations across the country (MANAGE; WOTR; MYRADA), partnerships with NGOs and a specific role for them in the project, intervention-based action research, evolving consolidation phase of the project, capacity building of stakeholders at various levels; experts being hired from other line departments/universities on deputation - are some of the key innovations of the project in terms of capacity building. Such practices are not generally adopted in a main stream projects. One of the important contributions of this project is "consolidation phase", which is not still part of watershed projects and its policy. Watershed development projects are generally dominated by planning and implementation of activities. The communities are largely engaged with these activities and it is very difficult for the project facilitators and communities to build the capacities of CBOS for management of watershed assets/resources/finances. DANWADEP made a special emphasis on creating this phase in the project and built capacities of the CBOs/implementing agencies to address the concerns of the project after implementation phase.

Formal Space for Support Voluntary Organizations – Guidelines of CAPART

Though several guidelines of watershed development projects recognized the need for training/community organization, there is an inherent understanding that project implementing agencies (PIAs) could provide this input to communities. These guidelines largely ignored the capacity building needs of PIAs. It is assumed that these agencies would "automatically" have required capacities for implementing watershed projects. Since several NGOs are not really capable of facilitating watershed development projects, the need for supporting such NGO implementing agencies was latently present. Guidelines of CAPART (1997) supported watershed development projects identified this need and provided institutional space for support voluntary organizations (SVOs). The role of these SVOs is to strengthen the NGO PIAs which implement watershed development projects. The "strengthening" of NGOs largely includes the following functions – orientation of NGO functionaries; building skills of the teams in performing various tasks of the project; demonstration of various events/tasks in real life conditions; hand holding the NGOs while they execute various tasks of the project, monitoring/evaluation of project; facilitating critical reflection of project teams and so on. This "formal" space for SVO has generated a new set of experiences in watershed development projects in capacity building agenda. CAPART supported various resource organizations are People's Science Institute (Dehardun); Samaj Pragati Sahayog (MP); Development Support Center (Gujarat), AFARM (Pune) and others in the country. Since these organizations have considerable experience and expertise in natural resource management projects and performed various functions (project implementation; training, production and dissemination of communication material, project management functions such as visioning, planning, monitoring and evaluation, advocacy, research and networking), they could bring certain level of "visibility' to the concept of support organizations. These organizations tried to bring this concept into mainstream watershed development projects (supported by MoRD/MoAgri, GoI) also, but met with limited success.

Community Managed Resource Centers

MYRADA, an NGO working in Karnataka, AP, Tamil Nadu has a long experience in establishing various community-based institutions for micro finances and watershed development projects. Over a period of time, MYRADA decided to withdraw from some of its field areas, where there is a sound institutional base of communities. However, MYRADA realized the need for a support system that helps and supports the development process by providing various development support services. Without this support system, the development process could dissipate. To fill this gap, MYDARA initiated the process of establishing community managed resource centers (CMRC) since 2002. MYRADA established center for institutional development and organizational reforms (CIDOR), which provides required support to CMRC. The CMRCs provide a variety of services to associated CBOs and get paid for these services. This arrangement is expected to consolidate the project activities and offer continued support services to the institutions. Several SHGs, their apex bodies and others take various services from these CMRCs. Now there is about four to five years of experience of such CMRC in various parts of MYRADA's field areas. MYRADA is slowly withdrawing from these areas and CMRCs are filling the gap. This institutional arrangement goes much beyond normal thinking that "training and capacity building inputs are required only during project period". The lessons and issues related to viability of such community managed support systems are certainly advancing the theory and practice of capacity building related practices.

Committees for Strengthening Training and Partnerships

State government of Gujarat established several state level committees for strengthening watershed development projects in the state. State level committee for training is one of them. This committee formulated several polices/procedures at state level to strengthen the training component of watershed development projects. One of the important features that emerged from this process was "partnership" between government and NGO resource organizations. Three resource organizations – NM Sadguru Foundation, Development Support Center and Sardar Patel Institute of Public Administration (SPIPA) were recognized as state level nodal agencies for offering training services to all PIA/WDT in the state.

Each resource organization was allocated a particular number of districts, in which watershed development projects are being implemented. The resource organizations were asked to organize series of training programs for secondary stakeholders (PIA/WDT/DRDA/Others) on various aspects of the watershed projects. Unit costs were developed and other linkages are formally established to facilitate this process. The three resource organizations also worked together to share resource and modules. This arrangement was operational for a long period of time in the state. (1997 to 2007). However, the function of the committee is not so regular.

Section 2: A Brief Narration of Good Experiences on Capacity Building Processes in Watershed Development Projects in Andhra Pradesh

Setting in Andhra Pradesh

During mid-90s, GoAP had already initiated the process of developing participatory platforms for several development projects such as water users associations (for management of irrigation infrastructure); forest protection committees (for managing forest cover); self help groups (mainly of women, for economic empowerment). The watershed project guidelines by Central government were also in tune with the on-going approaches of the State government. The State government provided adequate attention and made enough attempts to access watershed development projects from central government. The senior government officers of the Government of Andhra Pradesh (GoAP) proactively got the highest number of watershed projects in the state. By 1998-99, the watershed projects got the recognition as an important intervention in the state. Apart from GoI, GoAP accessed funds from other sources such as NABARD (RIDF) for implementing watershed projects in the state.

During this process, GoAP realized that the scale of the project is too huge to handle. The core concerns of the participatory watershed projects were getting neglected. The capacities of implementing agencies (both government and non government) were questioned. The capacity building provisions of the guidelines was poorly interpreted and wrongly practiced. The participatory processes were largely converted into massive rituals. Technology domination and standardization dictated the action plans and execution. Partnerships between GO and NGO implementing agencies created several tensions. It was difficult to work with each other as the quality of NGOs was not uniform and sensitivity of GO officers was not adequate in all places. There were several issues that created considerable tension and misunderstanding among partners (administrative hassles; delays in fund releases; corruption and so on).

The administrative leadership of the watershed development projects was sensitive to these emerging issues and was keen on improving supporting systems of the project. The priority was certainly on capacity building. During this period, GoAP also started implementing AP Rural Livelihoods Project (APRLP) with the support of DFID I. This project has a special emphasis on capacity building support also. This support from DFID I helped to facilitate several innovative arrangements in the capacity building sector.

Experiments in Institutional Arrangements for Effective Delivery of Capacity Building Services

A large scale development project like watershed development projects requires a systematic delivery mechanism for capacity building purposes. There are several innovations and experiments related to this theme in Andhra Pradesh in watershed development context. A brief account of these arrangements and experiments is presented here. A timeline of evolution of these institutional arrangements is presented in the Box. No1.

Box 1. Experiments in CB Delivery in AP.

Evolution of Institutional Arrangements for CB Purposes in AP	Time Line
Pilots as Learning Laboratories	Early 2000
Working Group for Capacity Building	2001-2003
District Capacity Building Centers in APRLP Districts	2001-2007
CB Network –RR District	2001 to 2003
Networks of PIAs in Nalgonda (Network Based Watershed Project Management)	2002-2004
Pool of Resource Persons	2000 – Continuing
Watershed Based Livelihoods Promotion – An Approach Facilitated by ICRISAT	2003 -2006
Livelihoods Resource Centers	2004 – Continuing
Consortium of Resource Organizations	

Pilots as Learning Laboratories

Learning from doing is considered to be one of the best methods of building capacities. Project Support Unit of APRLP initiated several pilots in watershed development projects with the support of established and experienced NGOs. Each pilot focused on a particular theme and generated field level experiences. These experiences/pilots acted as demonstrations plots for learning purpose in subsequent stages, by other implementing agencies.

District Capacity Building Centers (DCBC)

DCBCs are established with professionally qualified teams in each of APRLP districts. The mandate of these centers was to provide fillip to capacity building agenda and professional delivery. These teams facilitated the evolution of training calendars, delivery of training programs and monitoring of the training programs. These centers also provided technical and managerial support to the project from time to time. The contribution of DCBCs was to sensitize the project authorities at district level on the importance of professional support to capacity building agenda.

Working Group for Capacity Building

During the initial phases of APRLP, a state level working group was established with members from Commissionerate or Rural Development (CRD); AP Academy of Rural Development (APARD); MANAGE, a national level resource agency, and WASSAN, a national level support organization engaged with watershed development projects. This working group met regularly and provided necessary strategic direction to the capacity building agenda from time to time. The member agencies in the working group also took some responsibilities of providing capacity building services to the secondary stakeholders on newer components of watershed development projects such as productivity enhancement, livelihoods concepts and so on. The group also responded to the "demands" of the project in terms of capacity building agenda. This group was anchored by CRD.

Network-based Capacity Building Support

WASSAN, a national level support organization facilitated various "models" for capacity building delivery systems. Networking of resources – organizations/person/material is a common theme running across all these models. The scale of project required decentralized approach and networking of the resources was an important approach. In this approach, there are mainly three "experiments".

Network of PIAs in Nalgonda

Two networks of NGOs namely, Deccan Development NGO Network and Sphoorthy Network in Nalgonda district were engaged with watershed development projects as PIAs. WASSAN was associated with these networks as a support organization. WASSAN facilitated the evolution of systems and procedures for addressing the capacity building needs of the communities. Action plans for capacity building were developed for the project villages. The capacities of network members were augmented in such a way that they are able to function as resource persons. Members of a particular organization acted as resource persons to another organization and vise versa. The human resources of the network were pooled to serve the common agenda of the network. The capacity building budget available in the network were utilized in a systematic manner. WASSAN regularly facilitated planning and review meetings; organized training of training programs and supported the network in developing close collaboration with district/state level project authorities.

Capacity Building Network RR District

Since several NGO PIAs were busy with implementation related tasks most of the time, they were not able to provide necessary input related to capacity building of primary stakeholders. Considering this reality, WASSAN facilitated a network of resource persons in RR District called CB Network – RR District. This network consisted of several individuals and representatives of NGOs/line departments, who could "give" time to capacity building agenda. WASSAN took the responsibility of providing necessary support to this CB Network. This support included – organizing planning and review meetings; training of trainers programs; developing formal relationships and MoU between network and District Water Management Agency and CRD. The administrative and financial arrangements were evolved through various planning and review meetings. The funds available for training purpose were channeled to CB Network and PIAs (NGO and GO PIAs). WASSAN developed standard modules for various themes and linked the capacity building events with the learning needs of the project.

Pool of Resource Persons

There was always a scarcity of resource material, person and organizations in such a dynamic large scale development projects. Considering this need, WASSAN initiated a process through which interested individuals are identified and their capacities were built in such a way that they could function as resource persons. The services of members of this pool of resource persons were accessed by any district/PIA/project depending on their need. This was a loosely-nit-network of individuals. In some situations, the district level pool of resource persons functioned more effectively.

Watershed based Livelihoods Promotion– An Approach Facilitated by ICRISAT

ICRISAT and APRLP developed a partnership to experiment and demonstrate newer approaches for improving productivity and livelihoods. Capacity building of partners at community level and PIA/district level was one of the important inputs of this approach. A consortium of NGO, ICRISAT, agriculture universities, KVKs. CRIDA and district level government departments was constituted. This consortium adopted few watersheds villages in APRLP districts and made these villages into "a nucleus villages" for neighboring villages. Several newer experiments (seed, pest management, soil fertility and other practices) were introduced in these villages. Regular field events were organized to convert the observations from field into lessons for replication in neighboring villages. This support to the villages and PIA/ district offices had contributed significantly to experiences of capacity building agenda.

Livelihoods Resource Centers

The need for providing institutionalized and decentralized capacity building services to the primary stakeholders finally took the shape of Livelihoods Resource Centers (LRC) in the state. The lessons learned from previous experiences were consolidated to design the concept of LRCs in the state. CLRCs are established at cluster level (55 Nos) and DLRCs are established at district level (17 Nos). The CLRCs provide capacity building services to primary stakeholders and DLRCs provide capacity building services to secondary stakeholders. Each CLRC caters to about 70 to 100 projects in the district. Adequate human resources are deployed at LRC level in the form of a course director and assistant course director/computer operator. Each LRC has a pool of resource persons, who provide capacity building inputs. The LRCs are equipped with module, resource material and so on. Administrative and financial systems are designed and operationalized to professionally run the LRCs. Training calendars are developed in consultation with various stakeholders. Capacities building related budgets available under watershed development projects/other projects are utilized for meeting the operational costs of the LRCs. The staff/ administrative costs of LRCs are met from the other sources.

Consortium of Resource Organizations

A Consortium of Resource Organizations was established to strengthen the capacity building agenda of watershed development projects. This consortium consists of members from academic/research institutions (ICRISAT/CRIDA/agriculture universities); NGO Resource Organizations (WASSAN, BAIF, APMAS, MYRADA, WOTR and others) and line departments. This consortium provided two types of inputs to the capacity building agenda – strategic direction to capacity building agenda; professional support services for improving the capacity building delivery. Several members of consortium developed modules/resource material on various themes. Similarly, some members of Consortium (APMAS, CARE and WASSAN) also functioned as "professional support agencies" to strengthen LRCs in various districts. WASSAN provided secretarial services to consortium during the initial phases. Later on APARD and PMU, CRD took over this responsibility.

Section 3: A Critical Reflection of Experiences – Enabling Factors and Concerns for Up Scaling

One could also argue that the above experiences as part of evolution of policy or practice. If this is a natural process, these developments could have occurred everywhere in the country. But it is obvious that such experiences did not take place in all parts of the country, but only in limited places/states of the country. Thus the above mentioned experiences of Andhra Pradesh and other projects/states deserve a special place in development discourse. So it is very important to conduct a critical reflection of the above experiences to "place" them in right perspective. This section goes beyond the "narration of experiences" and brings in various dimensions of the above experiences. The enabling and disabling factors behind a particular development/ experience are presented here, as part of this critical reflection.

Triggers of Change

The budgetary provision for training and community organization is part of guidelines. However, as one could see, the experiences and processes related to capacity building agenda are different in different parts of the country and during different time periods. There are also several "highs and lows" in the process. These variations and "non-uniformity" in approaches and successes indicate that there are certain "local" factors which might be the cause of these variations. These local factors could be termed as "triggers of change". An attempt is made here to distill these triggers of change from the above experiences in the capacity building arrangements. Understanding of these triggers is an important aspect theorizing the practice, in development sector. Though these triggers are largely from Andhra Pradesh experiences, lessons are derived from other experiences also.

Role of Donors

The proactive nature of donors is an important contributing factor behind the above good experiences. The donors such as NABARD, DANIDA and DFID I not only made capacity building agenda a priority in no uncertain terms, but also facilitated the evolution of various institutional forms and processes to ensure that the priority gets translated into reality. Provision of budgets for capacity building purpose (developing resource persons, material and human resources), constitution of high level committees that could take decisions and steer the agenda are some of the instruments, they adopted to ensure that innovative experiences are generated in large scale development projects. Flexibility in funding arrangements to support project support units, engage in partnerships with resource organizations and supporting pilots is a relative advantage that these arrangements have. All these donors helped in designing an alternative arrangement for receiving and granting funds to enable various innovative processes. Obviously these alternative arrangements have greater levels of flexibility when compared to any department. Apart from this arrangement, they also facilitated the constitution of various forums for decision making such as working groups and empowered committees. The resource agencies were given greater responsibility of project management, apart from providing capacity building services. Donors also regularly monitored the project developments including capacity building related mile stones. This visible priority to capacity building agenda obviously created good experiences.

Role of Project Authorities

A proactive and visionary project leadership was a backbone of the experiences in the state. Project leadership at state and district level has a vision for capacity building and systematically worked on institutional arrangements and partnerships. The policy support from central government projects and bilateral projects was creatively "re-articulated" and "contextualized" in the state. Project authorities interpreted the guidelines and policy provisions creatively in the favor of communities and participatory processes oriented learning process. Administrative instruments were designed to strengthen delivery of capacity building services. The project administration constantly interacted with civil society organizations and got inputs from them from time to time. The project administration did not hesitate to develop partnerships with resource organizations to strengthen capacity building support systems. The additional funding support received from bilateral projects came handy to the project authorities to innovate and experiment. However, there are also examples in which project authorities established newer models (CB network in RR district; network of PIAs in Nalgonda) even without external funding support and within the available funding support of GoI/state government. Such experiences only indicate that creative ability of project authorities is the ultimate limitation in establishing newer models, but not the availability of additional funding support.

Enabling Policy Framework and Administrative Arrangements

In Andhra Pradesh, the watershed guidelines issued by GoI were reinterpreted from time to time as per the local needs and experiences. This leadership of GoAP in creating locally relevant policy support certainly provided a fertile ground for innovating and experimenting various approaches for project management including capacity building. Apart from the guidelines, the state and district governments established various institutional and administrative arrangements for "pushing" the agenda from policy to action. Forming working groups, secretariats, consortium, planning and review meetings are part of this process in Andhra Pradesh. Similar process is also observed in case of Gujarat and DANIDA supported projects, where working groups/committees are constituted to provide leadership to the capacity building agenda. The project management certainly included the monitoring of capacity building related developments and milestones. Apart from using flexible funding support from bilateral projects effectively, the state government also exercised its "discretion" to maximize the benefits of centrally sponsored schemes. Several of such instruments, procedures and processes gave "teeth" to otherwise dormant policy. This experience clearly indicates the commitment of project management in operationalizing the policy provisions by creating various administrative instruments and developing partnerships.

Vision and Motivation of NGOs

Several of the above experiences got their roots in civil society organizations. Several resource organizations experimented on the above themes and established workable models. The policy provisions of watershed development projects had benefited from these models and adopted them as part of the policy/administrative framework. These NGOs also proactively collaborated with the state governments to share their experiences and lessons. This proactive nature of NGOs/CSO to partner with state governments is an important contributing factor in the above process. Various alternatives in provision of capacity building services are evolved by these NGO resource organizations within their own projects and large scale development projects. These NGO resource organizations have a long experience of working with mainstream projects at various levels – policy advocacy; project implementation and project management services. They also got adequate funding support from other donors, which made them as a strong partner in collaborating with government and establish the merit of their experiences/ point of view. These NGO resource organizations also realized the need for working with large scale development projects to mainstream their experiences. The collaboration between these NGO resource organizations and state governments were a mutually benefiting engagement. State governments also found that partnerships with these NGO resource organizations is a meaningful process and contributing to the over all development process with a specific focus on capacity building systems.

Belief in Partnerships

The newer themes such as productivity enhancement and livelihoods require a new approach in capacity building process also. Partnerships between international research institutions such as ICRISAT/consortia and state governments gave an opportunity for all the partners to experiment on innovative extension models in the context of watershed development projects. These models have considerable impact on the capacities of local institutions and facilitator groups. That expertise and capabilities need to be "pooled" together to achieve a common objective is a main lesson from these partnership models.

Concerns for Up Scaling

While the above enabling factors played a critical role in establishing the models and demonstrating the feasibility of an idea, there are also a set of disabling factors which strongly acted as counter weights to minimize the benefits of the advantages of the above approaches. The above experiences could "deal" with the following disabling factors to some extent. However, these factors could dampen the potential of the lessons learned, particularly while up scaling these practices. If these disabling factors/concerns are not addressed, it is likely that these lessons largely remain unused.

Continuity and Change - Institutionalization or Individualization

In large scale development projects, the priorities and related processes continuously change. The administrative procedures and systems do not get institutionalized to the extent they have to be. The administrative procedures and systems still depend on "individuals", who are at the helm of affairs, at a particular point of time. As senior government officers change frequently, the quality of guidance; support and commitment vary and results also vary accordingly. The belief in partnerships, role of civil society organizations and priority to capacity building agenda in real terms changes from person to person. These can have considerable impact on the process of institutionalization. All the above experiences have suffered and/or benefited from these uncertain institutional processes in the large scale development processes. The real solution to this issue is still elusive.

Wavering Priority to Capacity Building Agenda in Policy Formulation

The policy provisions of Government of India and bilateral/other donors have a strong influence on the importance of capacity building agenda. The policy provisions of GoI/donors still look at capacity building in a narrow perspective. The funding support is largely limited to "conducting" training programs. This support also was reduced over a period of time, while the above experiences indicate the need for greater support to the agenda. The mainstream policy still does not benefit from the above experiences which clearly proved the need for strong institutional arrangements for professional and qualitative delivery of capacity building services at various levels. This wavering priority has its negative impact on the operational mechanisms of capacity building processes at state/district/local levels.

Quality of Capacity Building Services in Up Scaled Model

There is always a scarcity of good quality resource persons, material and modules. There is a need for constantly investing on developing the pool of resource persons from time to time, for various purposes. The role of resource persons is still limited to largely "organizing" training programs. The larger understanding of capacity building (that capacity building is large than training) is still not yet operationalized in several livelihood resource center. It is important to realize that up scaling of capacity building delivery mechanism would also face similar fate as the mainstream projects in terms of quality. Added to this, the changing priorities of district administration also confuse the actual performance of the functionaries of the livelihoods resource centers.

Emergence of Support Voluntary Organizations

The above experiences clearly indicate the emergence of support organizations as a critical input to the above process. However, the policy still does not formally recognize these institutions. In the absence of such recognition, the project management might have limited opportunities to develop partnerships with potential resource organizations. Similarly, the donors also have to recognize the need, role and contribution of such support voluntary organizations and find out ways and means of strengthening such organizations in various parts of the country. In the absence of such "external" support system, the large scale development projects could have limited effectiveness in project management and capacity building related inputs.

Debates on Viability of Institutions

One critical aspect on the above experiences is the cost involved in supporting institutional arrangements for strengthening the capacity building service delivery. Without appropriate institutional arrangements, capacity building delivery would not be effective. The question is whether the costs involved in establishing and running the institutional arrangements are really meaningful. The above experiences clearly indicated the need for external financial support (of varying levels) in establishing the institutional arrangements for effective delivery of capacity building services. This external support was largely used for meeting the cost of human resources and administrative arrangements. Obviously these costs could not be met from the watershed project budgets. Given these experiences (where external support played a critical role), the debate is on the viability of such institutional arrangements, which could not be fit into the project funds. There is also an argument that these institutional arrangements are not viable. Given the relevance of the above experiences, this paper argues that the viability of institutional arrangements related to capacity building agenda needs a fresh look. Since the effective utilization of capacity building funds requires an additional input (in terms of human resources and institutional arrangements), the policy makers should make an "additional" financial and administrative provision as part of the policy itself to care of such arrangements. This additional support is required even in case of project management (human resources, planning, review and monitoring related functions, technical support systems) of watershed development projects at national/state/district level. There is an increasing realization that “additional and dedicated” support systems are required for effective and qualitative implementation of watershed development projects at national/state/district levels. These additional and dedicated support systems need/should not be part of watershed project budgets. Given this realization, the capacity building support system also should be perceived as part of this “additional and dedicated” support system. This understanding makes the entire debate on the viability of capacity building institutional arrangements redundant, as these systems are very much part of additional and dedicated project management.

Conclusion

The paper narrates the processes and essential features of various capacity building experiences in the country in general and in Andhra Pradesh in particular. The lessons learned from these above experiences are systematically analyzed through a critical reflection. Enabling and disabling factors of these experiences are also described as part of this critical reflection process. The need for re-looking at policy support to strengthen the institutional arrangements for capacity building purpose was high lighted by engaging with critical issues of the above experiences.

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About ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 644 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT is supported by the Consultative Group on International Agricultural Research (CGIAR).

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