12 Integrated Farm Management Practices and Upscaling the Impact for Increased Productivity of Rainfed Systems

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Introduction

Most countries in the world depend primarily on rainfed agriculture for their food grains. Despite large strides made in improving productivity and environmental conditions in many developing countries, more than 850 million poor people in Africa and Asia still face poverty, hunger, food insecurity and malnutrition, where rainfed agriculture is the main agricultural activity. Although the importance of rainfed agriculture varies regionally, it produces most food for poor communities in developing countries (Rockström *et al*., 2007; also see Chapter 1, this volume). These problems are exacerbated by adverse biophysical growing conditions and the poor socio-economic infrastructure in many areas in the semi-arid tropics (SAT). The SAT is home to 38% of the developing countries' poor, 75% of whom live in rural areas. Over 45% of the world's hungry and more than 70% of its malnourished children live in the SAT.

The challenges of outscaling in investments and policies

In a recent Comprehensive Assessment of Water for Food and Water for Life, a detailed review of managing water in rainfed agriculture listed the challenges of outscaling in investments and policies (Rockström *et al*., 2007). Investments in agricultural research in savannah agroecosystems in the past have generated highly disappointing results (Seckler and Amarasinghe, 2004). A reason for this is the lack of focus on water resource management in rainfed agriculture. Instead, the focus at farm level since the late 1950s has mainly been on crop research and soil conservation and partly on *in-situ* water conservation (maximizing rainfall infiltration), through various strategies of terracing, bunding and ridging. Management of water resources has been conducted on a larger scale oriented towards blue water flows in irrigated agriculture. It is only in the past 10–15 years that science and technology development has focused more strongly on water management in rainfed agriculture (on water harvesting and supplemental irrigation in rainfed systems), and on tillage research focused in more explicit terms on water conservation (conservation tillage systems) at the farm scale (Rockström *et al*., 2007).

Failure of outscaling innovation – indigenous and external

Upgrading rainfed agriculture requires that technologies (indigenous or improved) are strongly adapted to local biophysical and sociocultural conditions accompanied by institutional and behavioural changes (Harris *et al.*, 1991; van Duivenbooden *et al.*, 2000). As experienced by several researchers, it is quite difficult to assess the impact of various natural resource management (NRM) interventions simply by adopting normal econometric methods used for assessing the impact of commodity-based interventions (Shiferaw *et al.*, 2004).

Well-established evidence points to the important role of social and ecological crises in the adoption of new thinking and system transformation. Adoption of conservation agriculture in several parts of the world was driven by crises, e.g. in the USA as a response to the Dust Bowl in the 1930s, in part of Latin America as a response to an agrarian yield crisis, and in Zambia as a response to droughts. Increased emphasis on watershed management in India is largely to cope with droughts in drought-prone areas, i.e. drylands in India after severe droughts in the early 1980s. Established but incomplete evidence from the Sahel suggests that recent widespread adoption of soil and water management practices in Niger and Burkina Faso forms part of a response to crises related to land degradation and possibly climate change.

Moreover, investments in rainfed agriculture pose serious challenges as large numbers of households are small with marginal farmers. Furthermore, most rainfed areas have poor infrastructure facilities as large investments have been laid out in high-potential irrigated areas for a long time. Integrated watershed management approaches have shown the potential for scaling-out benefits, ensuring community participation largely due to tangible economic benefits as well as capacity development through knowledge sharing (Wani *et al.*, 2000; 2003d).

In rainfed areas the challenges are many, along with the widespread limitations of the capacity of local institutions engaged in agricultural development and extension to promote management of rainwater. This is a knowledge-intensive extension effort, which suffers from limited information of the options available, social and economic constraints to adoption, lack of enabling environments and backup services, poor market linkages, weak infrastructure and low means to pay.

Previous focus on blue water has generated weak policies for water investments in rainfed agriculture

The Comprehensive Assessment of Water for Food and Water for Life has recommended discarding the artificial divide between irrigated and dryland agriculture as there is a continuum from fully rainfed to fully irrigated agriculture (Molden *et al.*, 2007). However, traditionally the obsolete distinction between rainfed and irrigated agriculture translates to a wider approach to water resource management, focusing on management of rainfall. A result of the historic blue water (run-off) focus in agricultural policy is a history of weak water governance and policies for rainfed agricultural development. Water resource management for agriculture is normally governed under ministries for water affairs, and focuses entirely on developing and allocating water for large-scale irrigation, drinking water and hydropower. This has resulted in a downstream focus, with upper catchment areas, where rainfed agriculture predominantly is practised, being seen primarily as run-off- or blue-water-generating zones. Ministries of agriculture have focused on the ‘dry’ parts of agricultural development, and the tendency in the past was to give highest priority to erosion control rather than water management in general. Thus, although proven knowledge for better management of rainwater exists, investments in turning this knowledge into innovations in governance, policy, institutions, practices and technologies to support the smallholder farmers have been very limited.

Lately, increasing attention is being paid to management of green water (soil moisture) resources to upgrade rainfed agriculture. In the last few years, there has been an increased priority to develop policies and to build capacity in favour of investments in water management in rainfed agriculture. In several countries, central and state governments have emphasized management of rainfed agriculture under various programmes. Important efforts have, for example, been made under the watershed development programmes in India. Originally, these programmes were implemented by different ministries such as the Ministry of Agriculture, the Ministry of Rural Development, and the Ministry of Forestry and Environment, causing difficulties for integrated water management. Recently, steps were taken to unify the programme according to the 'Hariyali Guidelines' (Wani *et al.*, 2006b). In 2005, the National Commission on Farmers adopted a holistic integrated watershed management approach, with focus on rainwater harvesting and improving soil health for sustainable development of drought-prone rainfed areas (Government of India, 2005). In India, the government has established the National Rainfed Area Authority (NRAA) and it has brought out common guidelines for watershed development (Government of India, 2008). Recently the Ministry of Agriculture and the Ministry of Rural Development, who implement a large number of watershed programmes, initiated a Comprehensive Assessment of impacts of watershed programmes in India to identify strengths and weaknesses for enhancing impacts (Wani *et al.*, 2008a).

There is thus growing evidence of the importance of water investments in rainfed agriculture. Governance and management is gradually re-directed in certain regions of the world towards water management for upgrading rainfed agriculture as a key strategy for reducing poverty and increasing agricultural production. It is further increasingly clear that water management for rainfed agriculture requires a landscape perspective, and involves cross-scale interactions from farm household scale to watershed scale.

New Efforts Required to Promote Innovation and Adaptive Adoption

Upgrading rainfed agriculture involves integrated approaches to social and ecological management. A challenge facing low-productive rainfed agriculture is the need for innovations in management of water, which requires the introduction of novel technologies and management practices, e.g. water harvesting and conservation agriculture (Rockström *et al.*, 2007). A key for successful adoption and outscaling is the combination of innovation and adaptation. Adaptive co-management between local communities and knowledge-providing agents, e.g. researchers, where knowledge sharing and transformation is carried out in an iterative process, is a promising approach for successful adoption. Participatory approaches, farmer field schools and action research methods are but a few important tools for adaptive co-management.

Integrated approaches required to upgrade rainfed agriculture

An integrated approach to rainwater management is necessary, where the links are addressed between investments and risk reduction, between land, water and crop, and between rainwater management and multiple livelihood strategies. Strategies to enable upgrading including technologies and management are generally known; however, the missing links for scaling-up and scaling-out are institutions and social and economic processes which can link to suitable policies.

Important success from integrated approaches has been experienced in Asia, e.g. the integrated watershed management approach in India, where local ownership is combined with tangible economic benefits for individual rural households (Wani *et al.*, 2003d). The experience in India highlights the limitation of a compartmental approach, where the benefits from increased productivity were not realized to the desired extent, equity issues were not addressed and, moreover, community participation was not achieved, resulting in neglect of the various water-harvesting structures in the watersheds (Joshi *et al.*, 2005).

An integrated approach to land, water and crop management is required on-farm while meeting watershed and basin development strategies to increase yields in rainfed agriculture. Bright spots and successes are not directly transferable to other socio-ecological conditions but require adaptation and co-management. Benefits from rainwater in supporting all forms of biomass growth, e.g. for cultivated crops, pasture for livestock, non-cultivated food-plants, fuel and construction wood, indicate that rainwater plays an important role in determining overall resilience of rural communities practising rainfed farming systems. Thus, an integrated approach which takes into account all these aspects of water use is needed when investing specifically in upgrading rainfed agriculture.

Community watershed as a growth engine for development of dryland areas

The recent Comprehensive Assessment of watershed programmes in India undertaken by the consortium led by ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) has recommended an urgent action to improve water management and the opportunity to double the productivity of dryland small farms in rainfed areas (Wani *et al*., 2008a). The Comprehensive Assessment of watersheds has identified the community watershed as a growth engine for development of dryland areas.

The government has moved the watershed agenda forward in various ways: (i) with constitutional amendment to enforce more responsibility on *panchayati raj* departments for rural development; (ii) by refining watershed guidelines as lessons have been absorbed; (iii) by converging the drought-prone-area programmes with rural employment guarantee and watershed programmes around unified watershed guidelines; and (iv) most recently by unifying the guidelines and establishment of the NRAA. Further, the Planning Commission has taken cognizance of the recommendations of various task force groups. There are studies of public–private sector partnerships in watershed execution. The Government of Andhra Pradesh, which accounts for 40% of the total of watersheds in the country under implementation, has adjusted watershed budgetary allocations up to 27% for livelihood activities for women and vulnerable groups; and the Government of Madhya Pradesh appointed non-governmental organizations (NGOs) as watershed-implementing agencies throughout the state. Since 2003, several countries have approached India for assistance in piloting watershed work.

The Common Features of the Watershed Development Model

Government agencies, development thinkers, donors, researchers and NGOs have gradually learnt from each other (though some are ahead of the field and others deficient in some aspect or other, principally in people participation or in the science), but generally nowadays the better models have some or all of the following features in common (Wani *et al*., 2008c):

- Participation of villagers as individuals, as groups or as a whole, increasing their confidence, enabling their empowerment and their ability to plan for the future and for self-determination.
- Capturing the power of group action in the village, between villages and from federations, e.g. capturing economies of scale by collective marketing.
- The construction of basic infrastructure with contributions in cash or labour from the community.
- Better farming techniques, notably the improved management of soil and water, diversifying the farming system and integrating the joint management of communal areas and forest.
- The involvement of the landless, often in providing services.
- Arrangements for the provision of basic services and infrastructure.
- The establishment of village institutions and links with the outside world.
- Improved relationships between men and women.
- Employment and income generation by enterprise development in predominantly but not exclusively agricultural-related activities.

And sometimes:

- The fusion of research and development (R&D) by capturing the extraordinary power of participatory technology development, including varietal selection with direct links to germplasm collections.
- Complete avoidance of corruption so that trust is built and all the benefits pass to the community.
- Reduction in distressed migration.

Recent additions to the watershed model

- The pragmatic use of scientific knowledge as the entry point rather than money, complete dole-out by ensuring tangible economic benefit from low-cost interventions that generate rapid and substantial returns at low level of risk. Among these are novel interventions

focusing on seeds of improved cultivars, integrated pest management (IPM), micronutrients, and soil conservation and water table recharge structures.
- A broad-based approach to income generation, involving the private sector associated with scientific advances and markets: for instance, in the remediation of micronutrient deficiencies; in the marketing of medicinal and aromatic plants; with premium payments paid by industrial processors for aflatoxin-free maize and groundnut; with high-sugar sorghum, and selected crops such as *Jatropha* and *Pongamia* sold to industry for ethanol and biodiesel production; with the production for sale of commercial seed, hybrid varieties and biopesticides.
- Using new science methodologies to improve performance such as remote sensing for monitoring and feedback to farmers, yield gap analysis and rapid assessment of the fertility status of the watershed.
- Building productive partnerships and alliances in a consortium for research and technical backstopping, with the members brought together from the planning stage.
- A concern to create resilience in the watershed and its community to climate change and to events of post-programme intervention.

Where best applied, the model has led to profound farming-system changes, improved food self-sufficiency, expanded employment and commerce, and enhanced incomes. Where indifferently executed the approach has led to very little impact, as we shall see in what follows. There is indeed something here analogous to the 'yield gap' exhibited between research station and farmers' yields. Much of the difference can be captured by implementing agencies 'catching up' with best practice. The more recent linking of natural resource science with the private sector markets and with people's broader livelihoods in consultation with them is transforming the dynamic and success rate of development efforts (Wani *et al*., 2008c).

Broad overall conclusions about watershed performance and impact

The importance of rainfed agriculture in India has been underscored by several recent studies. The watershed approach is a paradigm that works in all rainfed circumstances, has delivered important benefits and impacts, and needs to be implemented on a large scale. But watershed impact covers a spectrum from 'no better than ad hoc development schemes' to impressive improvements of the natural resource endowment and of agricultural production, and a transformation of the socio-economy.

The difference in result between indifferent and best watershed practice is analogous to the 'yield gap' in crop production. In part, this is because the watershed approach has been rapidly evolving and the Comprehensive Assessment has been looking at a field in which the goal posts have repeatedly been moved. In part, it is due to deficiencies in execution.

To consolidate and build upon the foundation already laid and universally gain the impact that is possible, the government should undertake some difficult tasks, most notably introducing a new 'mind set' or different form of approach that accepts the following (Wani *et al*., 2008c):

- Watershed development is not just a means to increase production or to conserve soil and water but an opportunity for the fully integrated and sustained development of human and natural resources.
- The approach is valid across various rainfall regimes over vast tracts of India and can contribute in large measure to the simultaneous achievement of the government's production, environmental and social goals.
- Sustainability and better social impact and equity are very important issues with pro-poor interventions not as a spin-off or afterthought but planned and integrated with the whole.
- There are vast opportunities to reduce costs and increase output by improving the appropriateness and extent of technology.
- There is obvious value in converging government schemes in the interest of impact and sustainability, rather than a spread of activity; this is particularly important in the case of water and schemes aimed to reach the poor.

Watersheds should be seen as a business model. This calls for a shift in approach from subsidized activities to knowledge-based entry points and from subsistence to gaining tangible economic benefits for the population of the watershed at large. This is being done by productivity enhancement, diversification to high-value enterprises, income-generating activities, market links, public–private partnerships, micro-entrepreneurship and a broad-based community involvement.

Moving forward requires that a lack of capacity to effectively implement programmes is addressed. Implementing agencies need to expand and broaden their capacities and skills, while communities need to strengthen their institutions and their skills. This will require a longer implementation period of 7–8 years, with more time spent in preparation and in post-intervention support. It also requires additional funds and more flexibility in using budgets and the engagement of specialist service providers (Wani *et al.*, 2008c).

One of the weakest aspects lies in the generation and dissemination of technology. A big improvement is needed in making appropriate technology and information accessible to the watershed community. The remedy lies in devising technology for the drier and wetter parts of the rainfed area, more participatory development research and in forming consortia, and employing agencies to provide specialist technical backstopping.

There is a crucial need to improve monitoring and evaluation and the feedback of the information obtained to constantly improve performance. Only a few key indicators need to be monitored in all watersheds. At one or two representative watersheds in each district, a broad range of technical and socio-economic parameters should be measured to provide a scientific benchmark and a better economic valuation of impact than is currently possible (Wani *et al.*, 2008a,c).

Operationalizing the community watershed as a growth engine

Community watershed development programmes are used as growth engines for sustainable development of rainfed areas (Wani *et al.*, 2003a, 2006b, 2008b; Chapter 14, this volume). However, the major challenge is scaling-up to large areas, as successful watersheds remain few and unreplicated (Kerr *et al.*, 2002; Joshi *et al.*, 2005). Recently ICRISAT has developed and evaluated an integrated consortium approach for sustainable development of community watersheds with technical backstopping and convergence (Wani *et al.*, 2002, 2003a). Most farming problems require integrated solutions, with genetic, management-related, and socio-economic components. In essence, plant breeders, social scientists and NRM scientists must integrate their work with that of private and public sector change agents to develop flexible cropping systems that can respond to rapid changes in market opportunities and climatic conditions. The systems approach looks at various components of the rural economy – traditional food grains, new potential cash crops, livestock and fodder production, as well as socio-economic factors such as alternative sources of employment and income. The Integrated Genetic and Natural Resource Management (IGNRM) approach is participatory, with farmers closely involved in technology development, testing and dissemination. The adoption of this new paradigm in rainfed agriculture has shown that with proper management of natural resources the systems productivity can be enhanced and poverty can be reduced without causing further degradation of the natural resource base (Rockström *et al.*, 2007; Wani *et al.*, 2008b). The scaling-up of these innovations with technical support from the ICRISAT-led consortium has been attempted in Andhra Pradesh, India through Andhra Pradesh Rural Livelihoods Programme (APRLP) supported by the Department for International Development (DFID), UK; in Karnataka (India), Sujala watershed programme supported by the World Bank; in three districts of Madhya Pradesh and Rajasthan with support from the Sir Dorabji Tata Trust (SDTT), Mumbai, India; and four countries in Asia (India, Thailand, Vietnam and China) with the support of the Asian Development Bank (ADB), Philippines.

For realizing the goal of sustaining rural livelihoods and effective utilization of existing resources, a convergence (tendency to meet at a point) of activities mode was chosen. Adoption of convergence in APRLP is to improve rural livelihoods, which implies that all activities under APRLP should bring in betterment in rural livelihoods (APRLP, 2006b, 2007). For maximizing the efforts so as to meet strategic and practical livelihood concerns of the poor, small and marginal farmers, and women, the convergence system forms the strategy of APRLP. The APRLP has chosen the watershed as a logical unit for efficient management of natural resources collectively, and simultaneously thereby sustaining rural livelihoods, where the focus is on the scope and priorities for development of rural people.

The watershed as an entry point

For improving rural livelihoods, the watershed forms a logical unit for efficient management of natural resources, thereby sustaining rural livelihoods. A hydrological watershed is a delineated area from which the run-off drains through a particular point in the drainage system. Since soil and vegetation can also be conveniently and efficiently managed in this unit, the watershed is considered the ideal unit for managing the vital resources of soil, water and vegetation. Watershed management is 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 livestock in a sustainable manner (Wani *et al.*, 2002, 2003a, 2005).

Integrated watershed management approach

The conventional watershed approach attempts to optimize the use of precipitation through improved soil, water, nutrient and crop management but lacks the strategy for efficient use of the conserved natural resources. In an agricultural watershed approach, management of water and land is most important. People and livestock being an integral part of the watershed, traditional watershed programmes alone, which are structure driven, cannot offer solutions to improve rural livelihoods. Although the watershed serves as an entry point, a paradigm shift is needed from these traditionally structure-driven watershed programmes to a holistic systems approach to alleviate poverty through increased agricultural productivity by environment-friendly resource management practices (Wani *et al.*, 2008b).

The watershed as an entry point should lead to exploring multiple livelihood interventions (Wani *et al.*, 2006a,b, 2007, 2008b). The overall objective of the whole approach being poverty elimination through sustainable development, the new community watershed management model fits into the framework as a tool to assist in sustainable rural livelihoods. For the development of rainfed-agriculture-based livelihoods, the community watershed model conceptually provides an envelope through which many of the steps for sustaining agriculture and agriculture-related activities can be implemented. The task is to intensify complex agricultural production systems while preventing damage to natural resources and biodiversity and to improve the welfare of the farmers through value addition and market linkages. Watershed management is 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 the people and livestock in a sustainable manner.

ICRISAT's consortium model for community watershed management as shown in Fig. 12.1 espouses the principles of collective action, convergence, cooperation and capacity building (four Cs) with technical backstopping by a consortium of institutions to address the issues of equity, efficiency, economics and environment (four Es) (Wani *et al.*, 2006a).

The new integrated community watershed model provides technological options for management of run-off water harvesting, *in-situ* conservation of rainwater for groundwater recharging and supplemental irrigation, appropriate nutrient and soil management practices, waterway system, crop production technology, and appropriate farming systems with income-generating micro-enterprises for improving livelihoods while protecting the environment. The current model of watershed management, as adopted by the ICRISAT watershed consortium team, involves environment-friendly options and the use of new science tools, along with the concept of the consortium approach and emphasis on empowering farmers through capacity building. The model includes the consortium approach and adopts the concept of convergence in every activity in the watershed (Wani *et al.*, 2002, 2006a,b; Sreedevi *et al.*, 2004).

The Adarsha watershed (in Kothapally, Ranga Reddy district in Andhra Pradesh, India),

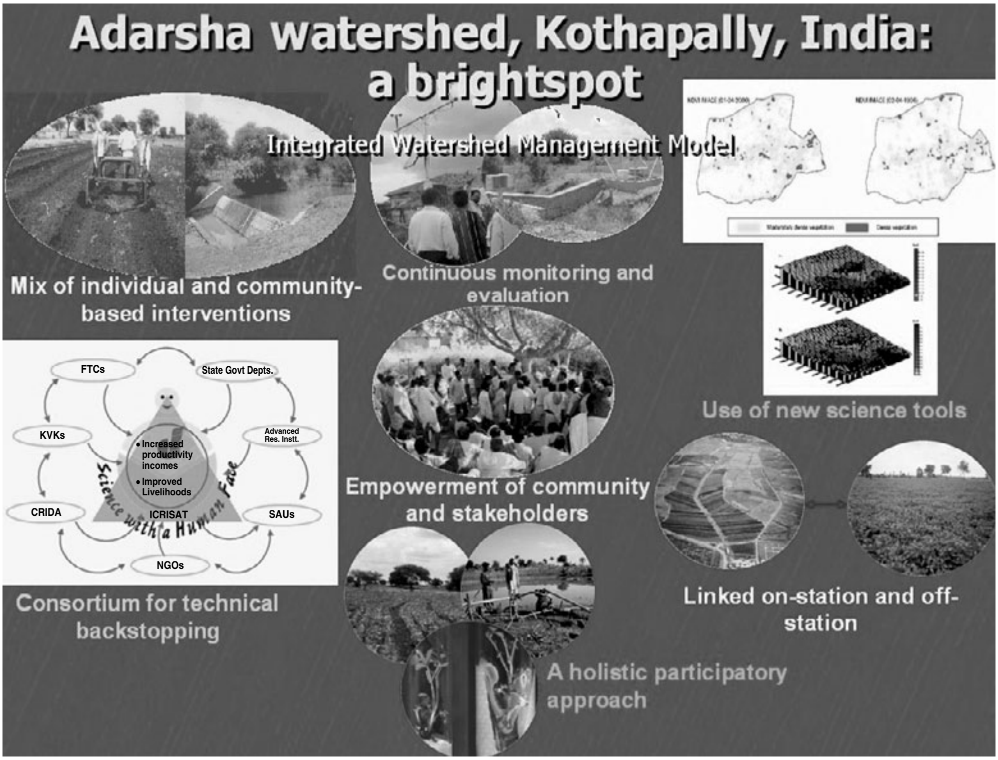

Fig. 12.1. Innovative farmers' participatory consortium.

led by the ICRISAT consortium, has clearly demonstrated increased crop productivity from rainfed systems through an integrated watershed management approach. APRLP's working mode to improve the rural livelihoods through the watershed approach has adopted the Adarsha watershed as an example of a more holistic vision that brings the concept of sustainability and eco-regionality and focuses on increased productivity and profitability of complex farming systems at the smallholder level.

Convergence in the watershed

Convergence in the watershed has evolved with the community watershed management model, which apart from the IGNRM strategy encompasses several other entities. By adopting a holistic watershed management approach, the community watershed is used as an entry point to converge and to explicitly link watershed development with rural livelihoods and effective poverty eradication and in the process identify policy interventions at micro-, meso-, and macro-levels (Fig. 12.2). Convergence can take place at different levels. Convergence at the village level requires facilitation of processes that bring about synergy in all the watershed-related activities. Scope for issues related to suitable processes for change in micro-practices, macro-policies, convergence, and information and management systems also formed part of the APRLP mandate. Socio-economic institutional and policy needs to increase adoption of improved options by the rural people are adapted in the convergence approach. The complex agricultural production systems were intensified while preventing damage to natural resources and biodiversity and improving the welfare of the farmers and landless rural poor. The activities in integrated watershed management approach where convergence mode works included:

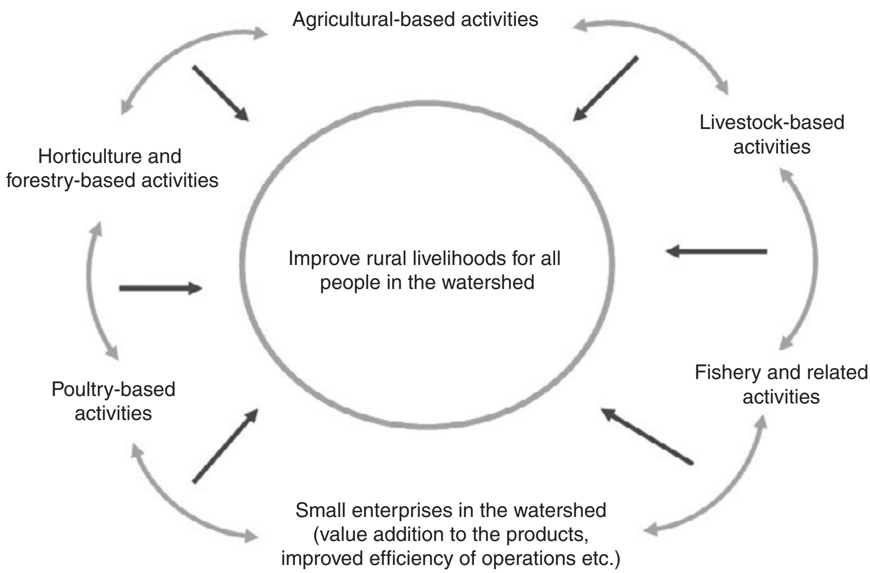

Fig. 12.2. Convergence in community watershed.

- Rainwater conservation and harvesting.
- Productivity enhancement.
- Soil conservation.
- Watershed development.
- Establishing village seedbanks through self-help groups (SHGs).
- Availability of quality seeds to farmers at reasonable rates.
- Processing for value addition (seed material, poultry feed, animal feed, grading and marketability, quality compost preparation).
- Livestock-based livelihood activities through improvement of breed, health and feed quality.
- Poultry rearing for egg and meat production and local hatching to provide chicks.
- Vermicomposting with cow dung, fodder waste and weeds, providing quality compost locally.

Participatory community watershed

The consortium model is a participatory community watershed system with a multi-disciplinary and multi-institutional approach, a process involving people who aim to create a self-supporting system essential for sustainability. The process begins with the management of soil and water, which eventually leads to the development of other capitals such as human, social, physical infrastructure and financial resources. However, large-scale community participation is essential since finally it is the people who have to manage their resources. Access to productive resources, empowering women, building on local knowledge and traditions, and involvement of local farmers or villagers in the local communities in watershed activities contributed to the success story at Adarsha watershed. Farmers' participation and involvement is critical in integrated community watershed management (Wani *et al*., 2003a; Sreedevi *et al*., 2004; Joshi *et al*., 2005) and it is complex and needs careful consideration. There is a need to harmonize working between existing institutions such as *panchayats* and watershed management and users' associations.

Strategies for integrated farm management

To achieve the goal of increased productivity in rainfed systems and enhance livelihoods, the following strategies are critical for integrated farm management practices:

- Need-based selection of watersheds to ensure that programmes are demand driven rather than supply driven, as is the case generally.
- Participatory approach involving different stakeholders (farmers, NGOs, local institutions (Krishi Vigyan Kendras (KVKs)), and regional research stations) for planning, execution and evaluation of project activities.
- A multi-institutional consortium approach for technical backstopping to empower farmers and develop human and institutional resources through capacity-building measures by integrating the activities of KVKs, Farmers' Training Centres, NGOs, research organizations and line departments of the state government for technical backstopping to undertake the action research at watershed level. Good and honest facilitator for effective and efficient functioning of the consortium.
- Productivity enhancement measures for increasing the farmers' incomes through *in-situ* conservation of soil and water, stress-tolerant high-yielding cultivars, improved crop, nutrient and pest management options, and equipment in addition to the normal soil and water conservation measures.
- Convergence of crop–livestock-based activities and other income-generating micro-enterprises in the watersheds by linking watershed development and research activities to increase the effectiveness of holistic watershed programmes through efficient use of conserved/harvested water and other natural resources for increasing production and incomes of the rural poor.
- Create awareness among NGOs and farmers about environment-friendly resource management options to minimize land degradation and improve natural resource base.
- Construction of small and low-cost water-harvesting structures throughout the topo-sequence to benefit all farmers, as against the large storage structures at the lower end of the watershed that benefit only a few, and thus address equity issues for water use.
- Complementary action-research designs for making effective links between on-farm problems and solutions to ensure the success of watershed development programmes by bringing together the knowledge gained through national and international experiences to the farmers.
- Networking of community-based organizations (CBOs) to achieve the common goals with appropriate incentives of increasing productivity and alleviating poverty.
- Participatory identification of farmer-acceptable crop cultivars to increase the systems' productivity in watersheds.
- Use of new science tools such as remote sensing (RS), information and communication technologies (ICTs), geographic information systems (GIS) and crop simulation models for efficient management of natural resources.
- Collective action through SHGs and micro-financing institutions to benefit voiceless vulnerable group members.
- Enrich human resources with special emphasis on women and youth to undertake income-generating activities through SHGs.
- Establish an ICT-enabled learning system for encouraging interactions among farmer groups to empower the community.
- Participatory monitoring and evaluation using new science tools as a measure for mid-course correction for enhancing impacts rather than for post-programme intervention.

The consortium approach enables the addressing of equity, gender, sustainability and improved livelihoods, which are the pillars of inclusive and sustainable development. Drivers of higher impacts in the community watershed are acute water scarcity, predisposition to work collectively for community development, good local leadership, tangible economic benefits to individuals, equal partnership, trust and shared vision among the stakeholders, transparency and social vigilance in the financial dealings, high confidence of the farmers, low-cost structures and equitable sharing of benefits, knowledge-based entry point activity, capacity building and empowerment of community, no free rides through subsidized activities for few individuals, and participatory and continuous monitoring and evaluation for mid-course correction (for details see Sreedevi *et al*., 2004; Shiferaw *et al*., 2006; Chapter 14, this volume).

Upscaling of Consortium Approach for Integrated Watershed Management

Based on the knowledge gained from Adarsha watershed, Kothapally, India, where the consortium approach was developed and piloted, the ICRISAT-led consortium scaled-out the approach in different states of India and selected provinces in Thailand, Vietnam and China. In India, the APRLP (supported by DFID, UK) adopted the watershed as an entry point for improving rural livelihoods in 500 pilot watersheds in five districts of Andhra Pradesh. The ICRISAT-led consortium established 150 watersheds (one nucleus; four satellites) as a pilot for the integrated watershed approach for improving rural livelihoods.

This project has joined the ongoing, statewide watershed programme to promote a change in focus so that the livelihoods of the poorest people in rainfed areas take centre stage. The project has fully financed all activities for 500 watersheds in five districts, Anantapur, Kurnool, Mahabubnagar, Nalgonda and Prakasam in Andhra Pradesh, which are semi-arid, drought-prone and among the poorest in the state. The project also provided extra finance to the Government of Andhra Pradesh for 'watershed plus' activities such as capacity building, productivity enhancement, livelihood support and convergence with other schemes and services, in 2000 more watersheds. In 2004–2005, the APRLP approach was extended to all the watersheds in all 22 rural districts of Andhra Pradesh.

APRLP approach

The convergence system forms the strategy of APRLP for maximizing the efforts so as to meet strategic and practical livelihood concerns of the poor, small and marginal farmers and women in the communities. Watershed management is used as an entry point to increase cropping intensity and also to rehabilitate degraded lands in the catchments with the aim of increasing productivity, enhancing biodiversity, increasing incomes and improving livelihoods. Such an approach demands integrated and holistic solutions from seed to final produce with involvement of various institutions and actors with divergent expertise varying from technical, social, financial, market, human resource development and so on (Wani *et al*., 2003c, 2007; Sreedevi *et al*., 2006).

As discussed earlier, in the Adarsha watershed, ICRISAT has clearly demonstrated increased crop productivity from rainfed systems through an integrated watershed management approach, which further helped in improving the soil quality and reducing the land degradation. Farmers adopted improved management practices such as sowing on a broadbed and furrow (BBF) landform, *Gliricidia* planting along bunds, integrated nutrient management (INM) treatment including inoculation with *Rhizobium* or *Azospirillum* spp., environment-friendly IPM, using improved bullock-drawn tropicultor for sowing and interculture operations, and *in-situ* conservation and harvesting of excess rainwater and storage for use as supplemental irrigation and for increased groundwater recharge (Wani *et al*., 2003a; Chapters 6 and 11, this volume). These innovations have been scaled up by APRLP in all the districts of Andhra Pradesh.

APRLP has also adopted the path with technical backstopping from research organizations like ICRISAT, the Central Research Institute for Dryland Agriculture (CRIDA), and Acharya NG Ranga Agricultural University (ANGRAU) for improving the rural livelihoods in the state of Andhra Pradesh. The concept of consortium is an integral part of the new integrated watershed management model.

Selection of watersheds and unique features in APRLP

APRLP devised a nine-point selection criteria (Table 12.1) for watersheds integrating natural resource degradation criteria with multiple deprivation criteria (social and material deprivation) in order to arrive at reliable indicators for both technical and social features. Micro- and macro-watersheds were identified and prioritized, based on the Sediment Yield Index indicating land degradation due to erosion and the dependability of precipitation and evapotranspiration, which depends on the variability and deviation of rainfall. Habitations were ranked according to the levels of degradation and the categories renamed as natural resource deprivation typologies.

Multiple deprivation criteria are indices of poverty, considering the multiple dimensions of poverty as reflected in deprivations of income, accessibility to services and social status. Since

Table 12.1. Nine-point selection criteria for selection of watersheds used in APRLP.

Parameters	Range	Mark	Weightage
% of small and marginal farmers	<25	5	
	>25–50	10	
	>50	15	15
% of SC/ST holdings	<10	3	
	>10–25	10	10
% of women organized in self-help groups	<20	3	
and participating in the programme	>20–50	5	
	>50	10	10
Status of groundwater (m)	<10	2	
	>10–15	3	
	>15	5	5
Andhra Pradesh Remote-sensing Application	Very low	6	
Centre (APSRAC) prioritization	Low	12	
	Medium	18	
	High	24	
	Very high	30	30
Livestock population	<1000	2	
	>1000–<2000	3	
	>2000	5	5
Number of families affected/involved in migration	<50	3	
	>50–<100	5	
	>100	10	10
Contiguity	Yes	5	
	No	0	5
Availability of fallow/wasteland and common property	<10	3	
resources for the poor to utilize usufruct (%)	>10–<20	5	
	>20	10	10
Total			100

APRLP takes a holistic view of people towards their livelihoods and opportunities, it sought to integrate the indices of natural resource degradation and multiple deprivation, and a matrix was drawn up where each was given equal importance, while selecting watersheds.

A probation period of up to 18 months was made mandatory in watersheds, during which the major activities were the preparation of capacity-building plans for primary and secondary stakeholders and the preparation of strategic (perspective plan for 5 years) and annual action plans. In each watershed 50 ha of land was selected as an entry point, out of which 20–30 ha of land belonging to small and marginal communities were selected for the treatment during the probation phase. The success of the probation phase was assessed using a set of agreed objective performance indicators (Table 12.2) by the community themselves, by which the project empowered the community and instilled a sense of ownership of the project, leading to its sustainability. APRLP adopted a site-specific and farmer-friendly participatory net planning (PNP) approach for preparing action plans for the individual farm holdings. Similarly, the poorest of the poor are identified through participatory situational analysis and wealth ranking of different households, based on their social and economic conditions.

Operationalizing APRLP–DFID–ICRISAT watersheds

A coalition of partners consisting of CRIDA, ANGRAU, National Remote Sensing Agency

Table 12.2. Parameters assessing the success of the probation phase for new watersheds in APRLP, Andhra Pradesh, India.

Item	Activity	Expected outcome
Situation analysis	Conducting participatory situation analysis	Strategic action plan of watershed (for 5 years)
	Conducting participatory rural appraisal	Probation-phase action plan
	Situational analysis of ground conditions	Livelihood action plan
	Wealth ranking exercise	Identification of poorest of the poor
Capacity building	Capacity needs assessment survey	Capacity-building plan of watershed incorporated in the district-level calendar
	Organizing mandatory training for community-based organizations (SHGs, user groups, watershed committees, watershed associations) and project-implementing agency/watershed development team	Completion of mandatory training of: • Project-implementing agency/watershed development team at MANAGE • SHGs /user groups/watershed committees at district level
	Identification and training of paraworkers – agriculture, animal husbandry, health, etc.	At least one paraworker for agriculture, animal husbandry from each watershed village trained
Consolidating SHGs	Categorizing existing SHGs as per District Rural Development Agency norms	• Self-monitoring through the Participatory Situational Analysis charts • About 50% of SHGs in 'A' category or show upward trend
	Organizing poor families who had not joined any SHGs into new SHGs	About 50% of target population organized into SHGs
	Promoting federation of SHGs into village organization	About 70% of SHGs federated into village organization
	Linking with revolving fund/bank loan	About 50% of SHGs linked with banks
Village organization	If it does not exist, then forming of village organization	Constitution of village organization if it does not exist
	If it already exists, ensuring linkage with newly formed SHGs	• Village organization strengthened to show improvement in category and scores 60 marks as per defined norms • Documentation on functioning process of village organization • Signing MoU with village organization
	Linking with livelihood fund	• Finalization of livelihood plan • Approval for the release of Livelihood Revolving Fund
Identification of probation-phase area, say 50 ha	Preparing action plan for probation area • Preferable location – ridge/valley • Area type – private land of about 25–30 ha (poor, marginal/small farmer) and common land of about 25–30 ha	• Watershed implementation should start from ridge to valley • Priority to common property resource • No work on private lands of large/medium farmer should take place till lands of marginal/small farmers get saturated
	Integrating with annual/strategic plan	Preparation of perspective plan
	Forming user groups	2–3 user groups formed
	Planning for low-cost structures	Priority to cost-effective structures
	Collection of contribution	Identification and evaluation of natural leaders and SHGs having potential for converting to watershed committees
Promotion of common pool resources	Plantation on common lands	Identification of common lands for plantation activities
	Accessibility to poor	• Usufruct rights to the poor • MoU for usufruct rights to the poor

(NRSA), Drought Prone Area Programme (DPAP) (now District Water Management Agency (DWMA)), Department of Agriculture (DoA), Project Implementing Agencies (PIAs), APRLP Programme Support Unit and ICRISAT was operationalized through a set of roles and shared responsibilities with a common vision. The emphasis was on empowerment of the community and gender equity through knowledge-based technological and institutional interventions, targeting multiple development constraints. The representative benchmark watersheds were identified for testing the technological findings. In the three target districts (Mahabubnagar, Kurnool and Nalgonda) of Andhra Pradesh, 50 watersheds (10 nucleus and 40 satellite) were selected based on several criteria: (i) representative typology; (ii) extent of rainfed area; (iii) productivity levels; and (iv) willingness of farmers to participate in the test sites for implementing the project activities (ICRISAT, 2006a). An additional 100 watersheds were added later. The nucleus watersheds served as the sites for undertaking action research for development and critical monitoring and also as sites of learning where farmers conducted experiments with improved soil, water, crop, nutrient and pest management options with technical backstopping from the consortium partners.

The farmers from nucleus watersheds, when empowered, became trainers to fellow farmers in both nucleus and satellite watersheds, while the PIAs empowered and developed as master PIAs and trained other PIAs in the districts. A detailed baseline socio-economic household survey was conducted in selected nucleus watersheds through participatory rural appraisal, a structured questionnaire and secondary data to study major socio-economic and biophysical constraints for sustainable crop production and to document detailed baseline data for impact monitoring at the end of the APRLP project in each village.

Equity issues were addressed appropriately while preparing action plans for sharing benefits from the interventions. Similarly, micro-enterprises had been promoted under plus activities to generate income for the communities during the off-season. This also reduced migration of rural people during the non-agricultural season to urban areas. A microfinance component had given priority to poor communities (SHGs) by linking local microcredit institutions for generating their revolving funds and for sustainability.

Knowledge-based entry point – widespread micronutrient deficiencies in SAT soils

The ICRISAT consortium team assessed 3622 soil samples from the farmers' fields in different states of India (Andhra Pradesh, Karnataka, Rajasthan, Madhya Pradesh, Gujarat and Tamil Nadu) and observed widespread deficiencies of sulfur (S), zinc (Zn) and boron (B), along with total nitrogen (N) and phosphorus (P) (Table 12.3) (Sahrawat *et al*., 2008). For rapport building – knowledge-based entry point activity, for example – the results of the soil analysis were presented in the *gram sabhas*, and the importance of soil analysis and nutrient deficiencies in crop production were discussed (Fig. 12.3). A large number of farmers were convinced about the importance of balanced nutrition in crop production and came forward as volunteers to evaluate the INM options.

Table 12.3. Percentage of farmers' fields deficient in soil nutrients in different states of India.

State	No. of farmers' fields	Org. C (%)	Nutrients (mg/kg soil)				
			Av. P	K	S	B	Zn
Andhra Pradesh	1927	84	39	12	87	88	81
Karnataka	1260	58	49	18	85	76	72
Madhya Pradesh	73	9	86	1	96	65	93
Rajasthan	179	22	40	9	64	43	24
Gujarat	82	12	60	10	46	100	82
Tamil Nadu	119	57	51	24	71	89	61
Kerala	28	11	21	7	96	100	18

Fig. 12.3. Scientists explaining results of soil analysis to villagers in a *gram sabha* in a village at Palem, Mahabubnagar, Andhra Pradesh, India.

Land and water management

In drought-prone areas *in-situ* rainwater conservation measures improve the security for growing the crops. The approach has been to store as much rainwater in the soil as possible before channelling run-off from the fields for storage in the tanks. The bullock-drawn tropicultor, which is referred to as the poor man's tractor, provides all the help to undertake timely land preparation operations. Farmers have evaluated the following landform treatments:

- Flat sowing on contour.
- Flat sowing on contour and a dead furrow at 10–15 m distance.
- Planting on ridges.
- Broadbed and furrows on 0.4–0.8% grade.

About 1000 farmers in nine nucleus watersheds evaluated improved crop and soil management options in their fields with the technical support. Several farmers in nucleus watersheds have sown sole and intercrops in lines along with fertilizers using tropicultors (Fig. 12.4).

Integrated nutrient management (INM)

On the basis of soil test results, farmers used micronutrient amendments on various crops such as mung bean, sorghum, maize, pigeonpea, castor and groundnut. In spite of drought in 2002, the farmers in Nalgonda district, Andhra Pradesh recorded 17–125% increase in mung bean yield (with 44% more yield, i.e. 1110 kg/ha versus 770 kg/ha) in their village in spite of the prevailing drought condition during the season. Farmers recorded 13–230% increase in maize yields with an average increase of 72% over the base yield of 2980 kg/ha; the increase in castor yields was 21–70% with an average increase of 60% over the base yield of 470 kg/ha. Similarly groundnut yield increased by 28% over the base yield of 1430 kg/ha.

Based on the experience in the first year, participatory R&D trials were designed to study the response of crops like mung bean, sorghum, maize, pigeonpea, castor and groundnut to each deficient nutrient over farmers' nutrient inputs as well as to secondary and micronutrients with optimum N and P nutrients. Good response has been observed in maize, sorghum, mung bean and groundnut not only to combined application of S, B and Zn but also to individual application of these nutrient elements (Table 12.4). The balanced nutrient supply resulted not only in significant increases (70–119%) in grain production but also in substantial additional incomes (Table 12.5).

Fig. 12.4. Sowing with a tropicultor.

Table 12.4. Yield and total dry matter (TDM) of different crops based on response to nutrients during the rainy season, 2003 in APRLP watersheds.

Crop	No. of farmers	Control (C)	Sulfur (S)	Boron (B)	Zinc (Zn)	C+SB+ Zn	C+NP+SB +Zn	SE	CV (%)
Maize grain (kg/ha)	24	2,790	3,520	3,710	3,710	4,140	4,880	466	12
% increase over control			26	33	33	49	75		
Maize TDM (kg/ha)		6,370	7,650	8,120	7,950	9,060	104,00	947	12
% increase over control			20	27	25	42	63		
Groundnut pod (kg/ha)	30	830	930	1,000	1,050	1,230	1,490	134	12
% increase over control			12	20	27	48	78		
Groundnut TDM (kg/ha)		2,920	3,150	3,453	3,590	4,140	4,730	333	9
% increase over control			8	18	23	42	62		
Mung bean grain (kg/ha)	6	900	1,210	1,130	1,320	1,390	1,530	114	9
% increase over control			33	24	46	54	70		
Mung bean TDM (kg/ha)		2,900	4,140	3,840	4,510	4,840	5,410	335	8
% increase over control			43	32	55	67	86		
Sorghum grain (kg/ha)	6	900	1,190	1,160	1,330	1,460	1,970	190	14
% increase over control			32	29	47	62	119		
Sorghum TDM (kg/ha)		4,800	5,460	5,480	6,420	6,640	8,030	790	13
% increase over control			14	14	34	38	67		

Table 12.5. Economic returns through application of micronutrients to different crops during 2003.

	Economic returns (Rs/ha)			
Particulars	Maize	Groundnut	Mung bean	Sorghum
Farmers inputs (FI)	13,930	12,490	13,570	4,510
FI + B	18,350	14,850	16,710	5,970
FI + S	17,230	13,650	17,770	5,620
FI + Zn	17,480	14,780	18,760	5,590
FI + B + S + Zn	19,430	16,850	19,290	5,730
FI + B + S + Zn + NP	21,770	19,520	20,330	7,170

Soil organic matter: an important driver of increased productivity

Soils in the dryland tropical areas are marginal to irrigated. Assessment of the fertility status of farmers' fields showed that almost all farmers' fields sampled were low in organic carbon (Sahrawat *et al.*, 2008). It is, however, recognized and emphasized that the productivity of tropical drylands is low due to water shortages. However, rather than water quantity per se, management of available water with enhanced water use efficiency is a problem and soil fertility is an important limitation (Wani *et al.*, 2008c; Chapter 2, this volume).

Farmyard manure is in short supply and is generally applied to high-value irrigated crops in drylands. *In-situ* generation of N-rich organic matter by growing *Gliricidia sepium*, *Cassia semia* and other N_2-fixing legumes on contour and property bunds and maintaining as shrubs helps in adding organic matter to the soil (Fig. 12.5). *Gliricidia sepium* is drought tolerant, sturdy under varying temperature conditions and animals do not like it. Once established, from the second year onwards *G. sepium* loppings provide 30–50 kg N/ha, which is largely fixed from the atmosphere, and other plant nutrients are also recycled from deeper soil layers. In addition it provides valuable organic matter, much needed in the tropics for maintaining soil fertility. The SHGs grew the nurseries of *Gliricidia* in the villages as an income-generating micro-enterprise and provided the plants for planting on the field bunds.

Vermicomposting

Large quantities of organic wastes are generated regularly in farms as well as in houses. Disposal of such residues is difficult and generally becomes a serious problem. Most of the organic waste is either burned or used as land fillings. These residues contain valuable plant nutrients and can be effectively recycled and used for increasing the agricultural productivity. Earthworms convert the residues into a valuable source of plant nutrients by feeding on the organic material and excreting valuable organic manure. The role of earthworms is to improve soil fertility and soil health. They eat farm residues and vegetable peelings and convert these into an N-rich compost called vermicom-

Fig. 12.5. *Gliricidia* plants on field bund conserving soil and generating nitrogen-rich organic matter.

post. Vermicompost increases the water-holding capacity of the soil, promotes crop growth, increases production and improves food and fodder quality. Generally, rock-phosphate-enriched vermicompost contains 1.0–1.4% N, 0.6% P, 0.7% potassium (K) and also many other micronutrients (Ca, Mg, Cu, Fe, Zn) which are very important for increasing crop productivity and maintaining soil quality.

These alternate sources supply sizeable quantities of nutrients, reducing the need for huge quantities of costly fertilizer, and also provide an alternate source of income for the women SHGs as a micro-enterprise (Fig. 12.6). However, suitable capacity building and awareness measures are needed to harness multiple benefits such as recycling valuable plant nutrients, disposal of organic wastes through environment-friendly methods and generating additional income for women SHGs.

A commercial model of vermicomposting developed at ICRISAT, Patancheru consists of four chambers enclosed by walls (1 m high, 1.5 m wide, total of 4.5 m long). The walls can be made up of different materials such as normal bricks, hollow bricks, Shabad stones, asbestos sheets or locally available rocks. The partition walls contain small holes to facilitate the easy movement of earthworms from one chamber to another (Fig. 12.7). The outlet provided at the

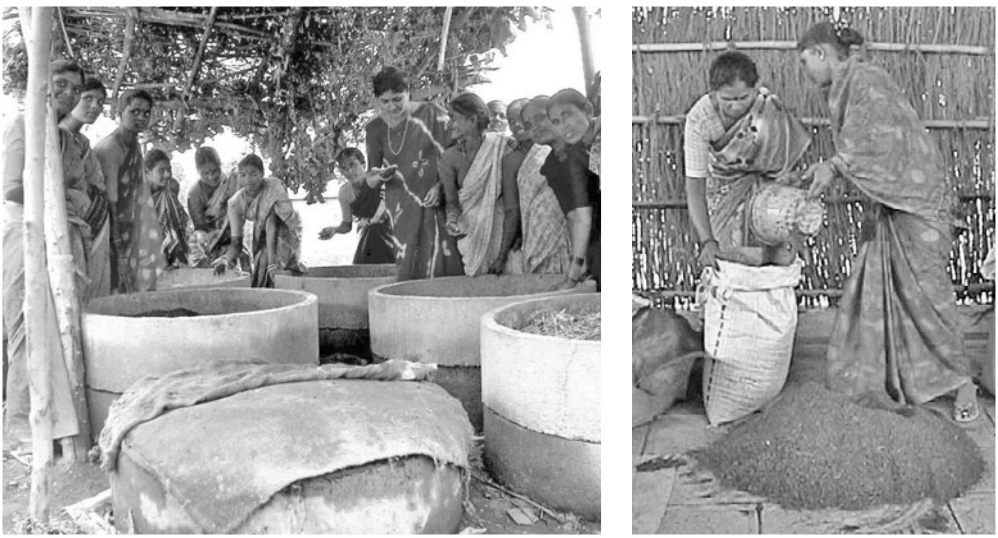

Fig. 12.6. Vermicomposting by women's self-help groups in a village in Andhra Pradesh, India.

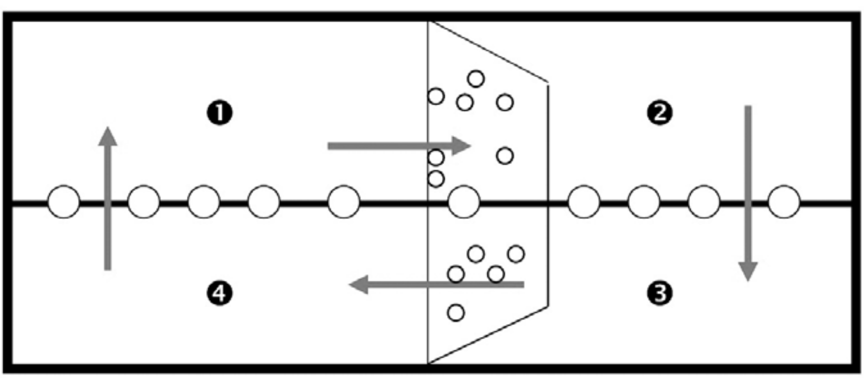

Fig. 12.7. Commercial model of vermicomposting.

corner of each chamber helps collect excess water, which can be reused. The four components are filled with plant residues one after another and earthworms are released once the first chamber is filled. Once the contents in the first chamber are decomposed the earthworms move to the second chamber and so on. This facilitates continuous supply of vermicompost, saving on labour and introduction of earthworms each time.

Integrated pest management

Crop production in the semi-arid tropics is severely threatened by increased difficulties in controlling insect pests and diseases of crop plants, as pests are developing resistance against the pesticides used, which results in an increase in cultivation costs and environmental problems with pesticide residues. The IPM measures include use of improved pest-tolerant cultivars, pest monitoring, use of biopesticides and plant-based pesticides, cultural practices such as use of trap crops and need-based use of chemicals. The major purpose of monitoring is to ensure protection of crops of the partner farmers in the watersheds from insect pests using scientifically accepted and economically viable field-applicable practices (Fig. 12.8). This was achieved by: (i) familiarizing the partner farmers on scouting for insect pests and monitoring their population; and (ii) using the data/information thus collected for decision making on spray material for protection against the insect pest threatening a given crop.

Shaking off larvae of *Helicoverpa armigera* from pigeonpea stems and manual killing of *Spodoptera* larvae on castor leaves were laborious but effective methods. Neem fruit extract (25 kg/ha) in boiling water was recommended for control of semilooper on castor and *Helicoverpa* on pigeonpea, when the larvae were in early instar stages. As a continuous effort to enhance capacity building, community video shows on IPM in groundnut, pigeonpea and chickpea were organized in these villages. In north-east Thailand, Tad Fa watershed farmers use low-cost sugarcane molasses kept in open plastic bottles to attract insects and control the pests. In vegetable plots, 700 ml capacity bottles with two side openings are filled with molasses and placed at 30 cm above ground level (Fig. 12.9). The insects are attracted by molasses, get trapped and die. About 3–73% damage is caused in cabbage fields due to loopers, leaf-eating beetles and cabbage cutworms (Table 12.6). At Wang Chai and Tad Fa watersheds in north-east Thailand, farmers are successfully and effectively using

Fig. 12.8. Farmers in India monitoring pest population with pheromone traps.

Fig. 12.9. Simple IPM system installed in a cabbage field in north-east Thailand.

Table 12.6. Estimation of damage to cabbage crop by insects without using IPM technique in Thailand[a].

Adult insects (worms source)	Insects trapped in bottle (no.)	Total worms (eggs) that could have been produced by trapped insects (no.)	No. of worms to potentially damage one plant completely	Degree of damage without IPM (%)
Cabbage loopers	165	123,750	150	15
Cabbage cutworms	115	28,750	7	73
Leaf-eating beetles	108	15,050	100	3
Total	388	167,550	257	91

[a]Calculated based on 25 IPM trap sets used in 5,600 cabbage plants.

molasses to control pests in vegetable fields (Table 12.6). Similarly, in China watersheds, farmers are successfully using light traps and tobacco waste to control pests in vegetable fields in Xiaoxincun watershed, Yuanmou in south China.

Crop intensification and diversification

Farmers' participatory selection of improved varieties

One of the important weak links in increasing crop productivity is poor crop stand due to poor seed quality and use of traditional varieties. Watershed farmers were empowered through technical backstopping, and the dependency of farmers on subsidies was minimized. The farmers selected improved cultivars and established village seedbanks. To build the stocks of seeds of improved crop cultivars in the watershed villages, activities on continued strengthening of village-based seedbanks were taken up by increasing the quantity of breeders' seeds of different crops.

The empowered farmers and SHG members operated village seedbanks based on the demand from the farmers who had identified suitable cultivars through participatory R&D. The SHGs buy back the seeds of varieties (not the hybrids) produced under the technical guidance of the consortium partners. The improved seeds of high-yielding varieties of all the crops proved remunerative because of their high yields (Table 12.7). Similarly, farmers in Rajasthan, Madhya Pradesh and Karnataka have selected cultivars and established village seedbanks. In Andhra Pradesh, the government has scaled-out the village seedbank initiative by institutionalizing the concept with revolving funds provided by the government.

Yield maximization trials

Farmers' yields are two- to fivefold lower than the potential yields realized at research stations or obtained by progressive farmers (Rockström *et al.*, 2007; Wani *et al.*, 2008a). Yield maximization in participatory R&D trials on prominent crops (castor, pearl millet, maize, sorghum, pigeonpea, groundnut, soybean and sunflower) with best-bet options (improved seed, integrated nutrient and pest management and improved crop husbandry practices) resulted in spectacular yield advantages in sorghum (35–257%), maize (30–174%), pearl millet (72–242%), groundnut (28–179%), pigeonpea (97–204% in sole and 40–110% in intercropping) and mung bean (42–111%) crops despite a not so favourable cropping season due to prolonged early and mid-season drought (Tables 12.8–12.12 and Fig. 12.10).

Crop intensification in watersheds

Double cropping (sorghum–chickpea, maize–chickpea) introduced in the traditionally *rabi* (post-rainy)-season-cropped vertisol areas of Kurnool and Nalgonda districts (850 ha) and intercropping (sorghum/pigeonpea, castor/pigeonpea, groundnut/ pigeonpea, groundnut/pearl millet, cotton/pigeonpea) in the alfisol areas (2500 ha) of Mahabubnagar, Nalgonda and Kurnool (Fig. 12.11) gave substantial yield advantages and captured farmers' interest, and considerable area increase is envisaged.

Water management: key investment for diversification of agricultural income

Established but incomplete evidence indicates that off-farm employment in rural areas usually expands parallel to agricultural growth. It has been estimated that a 1% growth in agricultural yields brings about a 0.5–0.7% reduction in the number of poor (World Bank, 2005). Thus rural employment, both on-farm and off-farm, is strongly conditioned by the rate of agricultural growth.

A recent study in the developed Rajasamadhiyala watershed in Gujarat, India

Table 12.7. Farmer participatory selection of groundnut varieties in Karivemula in Andhra Pradesh, India during 2003.

Improved practice		Farmer practice			
Variety	Yield (kg/ha)	Variety	Yield (kg/ha)	% Increase	Increase in income (Rs/ha)
ICGS 11	1730	TMV-2	1140	52.0	8850
ICGS 76	1480	TMV-2	900	64.0	8700
Mean	1605		1020	58.0	8775

Table 12.8. Mung bean yields as affected by best-bet options in Nalgonda district in in Andhra Pradesh, India during rainy season 2003.

	Grain yield (t/ha)		
Watershed	Improved practice[a]	Traditional practice[b]	Yield advantage (%)
Nandyal Gudem	1.42	1.00	42
Atmakur	1.44	0.92	57
P. Suryapet	2.15	1.02	111
Mean	1.67	0.98	70

[a] Improved seed, integrated nutrient and pest management, and targeted crop husbandry; [b]Farmers' normal crop husbandry practices with or without improved seed.

Fig. 12.10. Performance of crops with best-bet options in community watersheds in Karnataka, India.

Table 12.9. Pearl millet yields as influenced by best-bet options in Kurnool district in Andhra Pradesh, India during rainy season 2003.

		Grain yield (t/ha)		
Crop	Watershed	Improved practice	Traditional practice	Yield advantage (%)
Pearl millet	Devanakonda	2.29	1.33	72
	Obulapuram	2.50	0.73	242
	Madhapuram	1.62	0.59	175

revealed that public investments in rainwater harvesting enabled individual farmers to invest in digging open wells and bore wells, pump sets, sprinkler sets and drip irrigation systems in addition to investments in fertilizers, and improved pest and disease management options (Sreedevi *et al*., 2006; Wani *et al*., 2006a). Integrated watershed development triggered a shift towards commercial cereal crop production, such as maize, whereas in the surrounding villages without watershed development, farmers continued to grow low-value cereals like sorghum. In addition, farmers put more area under vegetables and horticultural crops in the developed watershed village, Kothapally, as compared with the surrounding non-project villages in Andhra Pradesh (Wani *et al*., 2006b) (Fig. 12.12). A prerequisite for such a diversification is the access to markets. In India the output from rainfed agriculture has in many areas increased

Table 12.10. Maize yields as influenced by best-bet options in Nalgonda and Mahabubnagar districts in Andhra Pradesh, India during rainy season 2003.

	Grain yield (t/ha)		
Watershed	Improved practice	Traditional practice	Yield advantage (%)
Nalgonda			
Kacharam	4.40	1.68	162
D. Gudem	2.96	2.25	32
K. Gudem	3.83	2.34	64
Sadhuvelli	4.02	2.84	42
Gouraipalli	3.85	1.91	102
Mean	3.81	2.20	73
Mahabubnagar			
Sripuram	5.76	4.44	30
Uyyalawada	3.90	2.02	93
Aloor	4.37	2.40	82
Nallavelli	5.81	4.27	36
Vanapatla	5.92	4.31	37
Naganool	5.64	4.20	34
Malleboinpally	3.89	1.62	140
Sripuram	8.32	3.04	174
Naganool	8.00	3.12	156
Vanapatla	8.39	5.52	52
Gollapally	4.73	3.56	33
Mean	5.88	3.50	68
Grand mean	5.24	3.10	69

Fig. 12.11. Pearl millet/groundnut intercropping in Devanakonda, Andhra Pradesh, India.

Table 12.11. Groundnut yields as influenced by best-bet options in Nalgonda and Kurnool districts in Andhra Pradesh, India during 2003.

Groundnut	Watershed	Grain yield (t/ha)		Yield advantage (%)
		Improved practice	Traditional practice	
	Nalgonda			
	Nemmikal	1.98	0.75	164
	P.Suryapet	1.36	0.83	64
	Gattikal	1.00	0.53	89
	Nassempet	1.09	0.58	88
	Mean	1.36	0.67	102
	Kurnool			
	Karivemula	1.44	0.85	69
	Karidikonda	1.78	1.02	75
	Jilledabudakala	1.21	0.74	64
	Devanakonda	1.99	1.55	28
	Burrakunta	1.14	0.73	56
	Karivemula	2.37	0.85	179
	Karidikonda	1.66	1.16	43
	Jilledabudakala	1.15	0.81	42
	Burrakunta	2.23	1.47	52
	Venkatapuram	0.81	0.46	76
	Rallakottur	1.55	1.03	50
	Mean	1.58	0.97	62
	Grand mean	1.52	0.89	70

Table 12.12. Sorghum yields as influenced by best-bet options in Nalgonda and Mahabubnagar districts in Andhra Pradesh, India during 2003.

Sorghum	Watershed	Grain yield (t/ha)		Yield advantage (%)
		Improved practice	Traditional practice	
	Nalgonda			
	Sadhuvelli	2.68	1.59	69
	Dharmareddigudem	2.14	1.58	35
	Mean	2.41	1.59	52
	Mahabubnagar			
	Burreddypally	1.92	0.94	104
	Gangapuram	1.47	0.93	58
	Burreddypally	3.18	0.89	257
	Nandipet	3.07	0.97	217
	Gollapally	1.65	0.98	68
	Mean	2.26	0.94	140
	Grand mean	2.30	1.13	104

rapidly and at the same pace as in irrigated areas, including widespread adoption of high-yielding varieties in rainfed areas (Kerr, 1996).

Similarly, in many parts of Tanzania, rainwater harvesting has enabled farmers in semi-arid areas to upgrade rainfed farming by shifting from the cultivation of sorghum and millet to rice or maize, with follow-up legume crops that exploit residual moisture in the field. Currently, production of rice in semi-arid areas using rainwater harvesting accounts for over 35% of the rice produced in the country (Gowing *et al*., 1999; Meertens *et al*., 1999). Most importantly, upgrading rainfed farming through rainwater harvesting has enabled farmers to grow a marketable crop in dry areas,

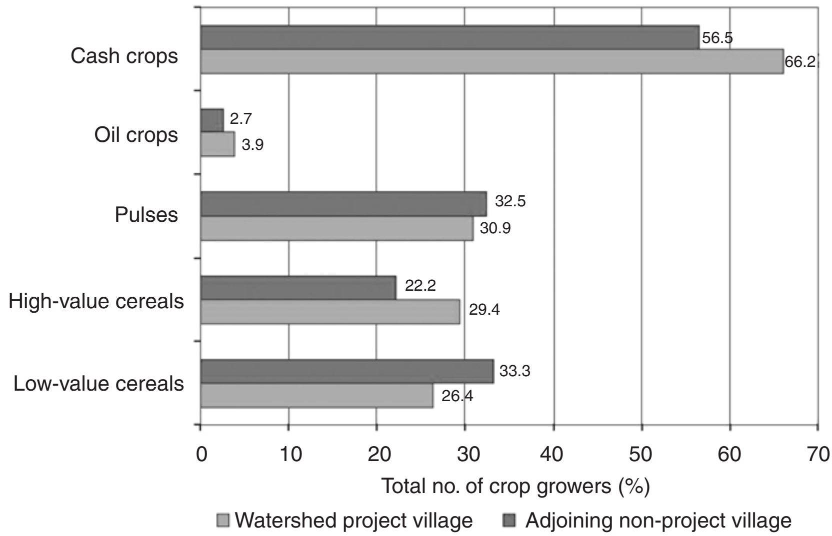

Fig. 12.12. Income stability and resilience in Kothapally, Andhra Pradesh, India.

thus providing opportunity for poverty reduction (Rockström *et al.*, 2007). In China, rainwater harvesting and storage on a small scale enabled farmers to grow vegetables and market collectively to earn more income (see Box 12.1).

Multiple benefits of farm-scale water management

Investments in water management in rainfed systems can have important additional benefits due to the multiple roles of water for livelihoods and health. Benefits from rainwater in supporting all forms of biomass growth of cultivated crops, pasture for livestock, non-cultivated food plants, and fuel and construction wood indicate that rainwater plays an important role in determining overall resilience of rural communities practising rainfed agriculture. Rural livelihoods are also strongly dependent on non-agricultural income, i.e. other livelihood strategies (remittances, seasonal off-farm work, rural complementary sources of income, etc.), which reduce vulnerability to rainfall variations (Rockström *et al.*, 2007). A study in East Africa shows that strategies for poverty reduction to meet the Millennium Development Goals require investments that promote productivity growth in: (i) major staples, which were found to be key for overall economic growth and poverty reduction. Since rainfed systems dominate the production of staples, this is proof of the importance of investing in the upgrading of rainfed systems; (ii) the livestock subsector, which consists of predominantly rainfed systems, is a key livelihood source for the people in the SAT region; and (iii) non-farm rural enterprises, especially those linked to value-adding processing of crop and livestock produces (ASARECA-IFPRI, 2005).

Apart from livestock enterprises, there are other options available for generating more benefits from systems such as forests and rangelands, which deplete rainwater naturally. They include investments to further add value to rain, e.g. the development of micro-enterprises associated with natural resources such as vermicomposting, nursery raising, biodiesel plants, oil extraction and value addition through processing of farm produce. These activities ensured diversified livelihood options for women as well as youth and provided resilience during the drought years (Wani *et al.*, 2003b, 2006b; Joshi *et al.*, 2005). Micro-enterprises benefited women and vulnerable groups in the society and addressed equity issues in rainfed areas (Box 12.2).

Box 12.1. Contribution to women's development.

Women's tenacity in householding is remarkable. In the watershed villages, women's propensity to work against all odds is shown in the management of household consumption and production under conditions of increasing poverty.

Lakshmi, a poor resident of Kothapally village, Andhra Pradesh, India, eked her livelihood as a farm labourer until she was introduced to vermicomposting, i.e. converting degradable garbage, weeds and crop residues into valuable organic manure using earthworms. She earned US$36 per month from this activity. She has also inspired and trained 300 peers in 50 villages of Andhra Pradesh. Lakshmi has also achieved a singular recognition by becoming a Fellow of the Jamsetji Tata National Virtual Academy for Rural Prosperity for her achievement of empowering women members.

Subhadrahbi is the key person in the change in the role of women and the transformation of Powerguda, a tribal village in Andhra Pradesh, into one of self-sufficiency. She pioneered the integrated watershed management approach and biodiesel enterprise, specifically *Pongamia* nursery raising and extraction of oil in the village. With this, her women's group sold carbon credits to the World Bank and gained worldwide accolade.

A woman in Wang Chai watershed, Thailand who had the chance to be part of a cross-visit sponsored by the watershed project learned much about cooperative work. This paved the way for the various self-help groups organized, such as fish sauce, soap making, shampoo and fish feed.

In Addakal *mandal*, India, a group of 500 women from 17 villages federated to form the *Mahila Samaikhya*. To date, they operate a bank, a resource centre for training and a knowledge hub. They are connected worldwide through information technology and facilitated empowerment of other women, especially of their district.

These cases epitomize how women in certain situations and relationships can wield power and use possibilities for maneuvering to achieve better livelihoods. Watershed projects provided the platform for creativity and innovations without jeopardizing social norms.

Box 12.2. Poultry farming leading the way to prosperity in Lucheba.

Mr Peng Fay Ou, a normal farmer with a 1 ha landholding in Lucheba watershed in China, has seven members in the family and was earning 3000 CNY per year. However, with the watershed project interventions his agricultural income has been raised by threefold to 10,000 CNY per year and it is largely owing to growing vegetables three times in a year using the harvested rainwater. The way Mr Peng Fay has moved out of poverty, leveraging the allied sector activities through increased income is exemplary. He has 200 chicks and plans to sell these when they are 70 days old. He is expecting 30 CNY per bird and a total income of 6000 CNY. He has two female pigs, seven male pigs and 15 piglets, which he sold at 1500 CNY. He also has one buffalo. His income has increased to 4000–5000 CNY per year. In this village he says that his family is one of the few (15) families having higher income, although the income of all the families has substantially improved due to the project activities.

Mr Chen Shao Bao is another enterprising farmer, who has 1500 chicks in his unit for the first time. He said that income from pigs was less and they decided to invest more in poultry to earn more income. From pigs he got 10,000 CNY total income whereas by investing 4000 CNY in chicks he will get 7000 CNY net income in less time. He plans to have a 20-day cycle for the poultry. His mother Liu Yun Zhen helps him in taking care of the poultry. His family is a joint family with eight members. Similarly there are ten other farmers who are rearing poultry in this group of 44 farmers.

Run-off and soil loss from the APRLP watersheds

At each of the ten watersheds of APRLP in Andhra Pradesh, a digital run-off recorder and microprocessor-based automatic sediment sampler were installed, which measured run-off and soil losses. Among the ten watersheds, considerable variations in seasonal run-off, peak run-off rate and soil loss were recorded (Table 12.13). The highest seasonal run-off of 68.9 mm (12.8% of the seasonal rainfall)

Table 12.13. Rainfall, run-off, peak run-off rate and soil loss in APRLP watersheds during 2003.

District	Nucleus watershed	Seasonal rainfall (mm)	Seasonal run-off (mm)	Peak run-off rate (m^3/h/ha)	Soil loss (t/ha)
Mahabubnagar	Appayapally	540	69	58.7	1.04
	Malleboinpally	654	55	57.6	NA[a]
	Mentapally	335	29	10.8	0.28
	Sripuram	474	46	25.2	0.98
Nalgonda	Kacharam	700	30	7.2	0.58
	Tirumalapuram	474	17	79.2	0.53
	Nemmikal	695	75	82.8	1.45
Kurnool	Devanakonda	502	79	370.8	0.78
	Karivemula	320	25	61.2	0.69
	Nandavaram	354	Nil	Nil	Nil

[a] NA = data not available.

was recorded at Appayapally watershed in Mahabubnagar district and no run-off was recorded from Nandavaram watershed in Kurnool district, where vertisols were predominant. The highest peak run-off rate of 82.8 m^3/h/ha was recorded at Nemmikal watershed in Nalgonda district. Due to very low seasonal run-off, the soil loss in most of the watersheds was less than 1 t/ha. Only at Nemmikal and Appayapally watersheds was the soil loss higher than 1 t/ha (Table 12.13).

Revolving fund to improve livelihoods

The loans provided through the revolving fund mechanism to the SHGs and to the selected members of various categories of households provided monetary support for undertaking various activities in the villages. In Prakasam district (APRLP, 2006a), the households undertook a number of activities through the revolving fund. The majority of members (51%) have taken up milch cattle units for income generation through selling of milk in the village or nearby areas (Fig. 12.13). At least 8% of members have utilized the loan amount to set up grocery shops, followed by 9% for sheep and goats, and 3% for agricultural purposes. Interestingly, 28% of the members were reported to have invested the amount in miscellaneous activities like tea stalls, cloth shops, STD booths, cable business, tailoring, hotels, etc.

Capacity building

Empowerment of different stakeholders through capacity building in participatory integrated watershed management facilitated the scaling-up of the benefits from the nucleus and satellite watersheds in the target regions (Fig. 12.14).

Sensitization of policy advisors and policy makers

Policy advisors and policy makers are very critical for dissemination and upscaling of the benefits of improved technologies. The principle of 'seeing is believing' was adopted, and exposure visits as well as orientation programmes were organized for members of the district capacity-building centres, SHGs, PIAs and farmers, and also for sensitizing the policy makers. Specialized training courses tailored for the farmers, SHGs and youth are needed for enhancing the impacts.

ICT-enabled farmer-centred learning systems for knowledge exchange

It is increasingly realized that facilitation of knowledge flows is key in fostering new rural livelihood opportunities using modern information and communication technologies (ICTs). The concept adapted is one of intelligent

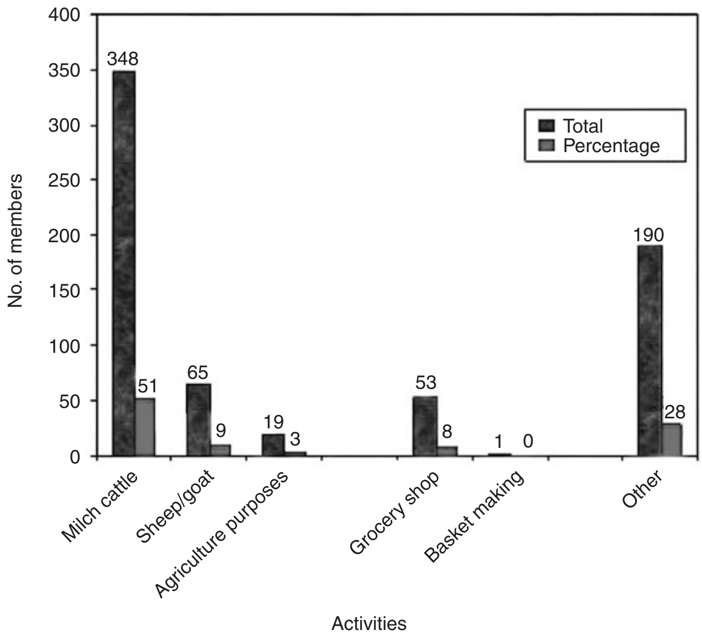

Fig. 12.13. Activities undertaken through the revolving fund in APRLP watersheds in Andhra Pradesh, India.

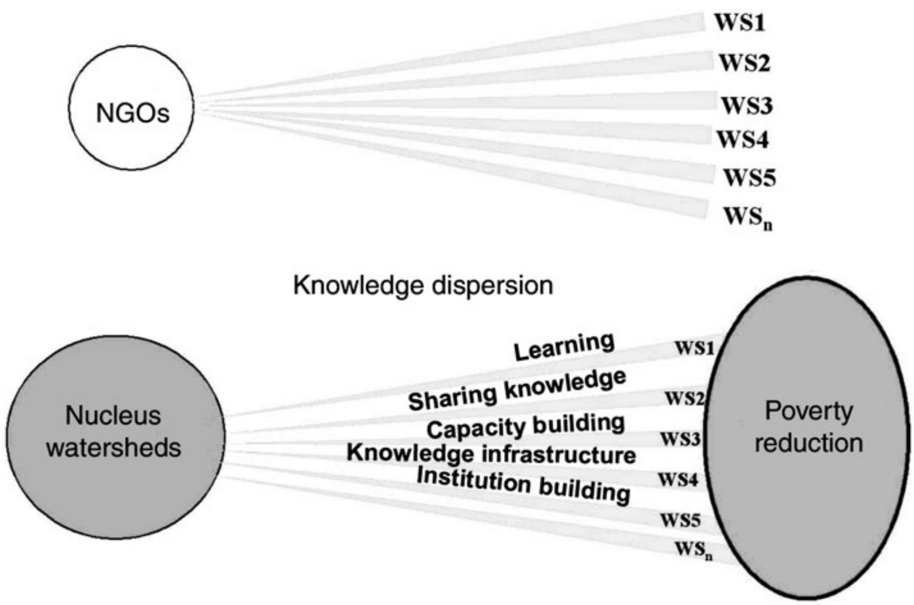

Fig. 12.14. Knowledge transfer within the institution and the region. (WS = watershed)

intermediation for facilitation of flows of information and knowledge. The community centre managed by the PIAs functions as a Rural Information Hub, connecting participating villages (or groups of villages, as the case may be) and also with other internet-connected web sites (Fig. 12.15). It is operated or managed by a rural group (women or youth SHGs) identified by the village watershed council through a consultative process. The activities on this module are planned to adopt a hub-and-spokes model for information dissemination among the participants and stakeholders. The electronic network across select nuclear watersheds enables sharing of experience and best practices.

Other Scaling-out Experiences

The success of the model watersheds of ICRISAT also attracted the Asian Development Bank, Philippines, to upscale the benefits in India, China, north-east Thailand and northern Vietnam. The Sir Dorabji Tata Trust and the Sujala watershed programme in Karnataka, with support from the World Bank, scaled-out the model in the states of Madhya Pradesh, Rajasthan and Karnataka in India to minimize land degradation and improve rural livelihoods through technical backstopping from the ICRISAT-led consortium. Results from the watershed interventions in these locations are very encouraging (Wani *et al*., 2007).

Improved land, soil and water management practices

Sowing on a BBF landform at Lalatora, Ringnodia (Madhya Pradesh) and Kothapally (Andhra Pradesh) on vertisols and alfisols maintained better moisture conditions, increased infiltration, reduced run-off during the entire crop growth period and increased crop yields (10–40%) through enhanced rainwater use efficiency. At Lalatora watershed the seasonal run-off from the treated watershed was less than one-fifth (55 mm) of that from the untreated watershed (291 mm) (ICRISAT, 2005a). At Tad Fa watershed, Thailand, less than half of seasonal run-off (194 mm) was recorded from the watershed under the improved (fruit trees and seasonal crops) land-use system compared with the watershed with the conventional (seasonal crop) land-use system (473 mm) (ICRISAT, 2006b). Improved watershed technologies were also quite effective in reducing soil loss; the improved technologies recorded a 70% lower seasonal soil loss compared with the untreated watershed at Lalatora. Similarly, at Tad Fa watershed a seasonal soil loss of 15.4 t/ha was recorded from the untreated watershed compared with 10.3 t/ha from the treated watershed (ICRISAT, 2006b), whereas in Karnataka (India) soil loss ranging from 0.7 to 2.0 t/ha was recorded (Table 12.14).

A major impact of improved watershed technologies was seen in improving the groundwater

Fig. 12.15. Information and communication technology services enabled in Mahabubnagar, Andhra Pradesh, India.

Table 12.14. Rainfall, run-off and soil loss at Sujala watersheds in Karnataka, India during 2006[a].

Watershed	Rainfall (mm)	Run-off (mm)	Run-off as % of seasonal rainfall	Peak run-off rate (m^3/s/ha)	Soil loss (t/ha)
Haveri					
(Aremallapur)	350	44	12.6	0.011	2.01
Dharwad					
(Anchatageri)	652	20	3.1	0.070	1.24
Kolar					
(Huttur)	547	22	4.0	0.025	0.80
Chitradurga					
(Toparmalige)	508	16	3.1	0.011	0.66
Mean	514	25.5	5.7	0.029	1.18

[a] Source: ICRISAT (2007).

recharge. Groundwater level rose by 5.75 m in the treated watershed at Lalatora compared with the groundwater level in the untreated watershed. Improvement of marginal lands with appropriate management has resulted in biodiversity improvement, as achieved in Bundi, a very dry watershed in Rajasthan, India (ICRISAT, 2005a).

At Thanh Ha watershed, northern Vietnam, polyethylene and straw mulch increased the soil temperature by 2–3 °C in autumn–winter and 1–2 °C in spring at 10 cm depth, with increased conservation of soil moisture in the entire soil profile (Long *et al*. 2003). Farmers harvested 71–100% increased groundnut yields in the watershed through improved cultivars and integrated soil, water, nutrient and pest management options, and this resulted in doubling the groundnut yield (1.5 t/ha) compared with the control (0.7 t/ha). Farmers in surrounding areas also started adopting this technology (ICRISAT, 2006b).

Introduction of improved crop cultivars and cropping systems

Improved cultivars of soybean, groundnut, wheat, pigeonpea, chickpea, sorghum, pearl millet, maize, vegetables and mung bean were evaluated for large-scale cultivation with improved soil, water and nutrient management options. At Lalatora, the introduction of chickpea varieties ICCV 10, ICCV 2 and ICCC 37 increased production by 4–50% (960–1470 kg/ha) over local varieties. Similarly, in other benchmark watersheds crop productivity increased by 10–50% through adoption of high-yielding cultivars. In Tad Fa watershed of north-east Thailand, maize yield increased by 27–34% over the maize–maize system when preceded by short-duration legumes (black gram, rice bean and sunnhemp). At Thanh Ha watershed, Vietnam, mungbean–groundnut–watermelon, mungbean–soybean–watermelon and groundnut–watermelon cropping systems gave highest income (262–268%) over the traditional maize–maize cropping system. In Rajasthan, short-duration pigeonpea, which is sturdy, drought tolerant and has N-fixing capability, was introduced in three districts and was a great success in the first year alone. About 100 farmers participated in the programme and have harvested up to 1500 kg/ha. Considering the low soil fertility and drought-proneness of the region, this kind of productivity, valued at about INRs 22,000/ha, is a good achievement for the farmers. Improved cultivars and proprietary hybrids of crops with better adaptation to biotic and abiotic stresses and with best practices resulted in more than doubling the crop yields (Table 12.15) in Sujala watershed of Karnataka (ICRISAT, 2007).

Farmers in the Bundi watershed in Rajasthan evaluated IPM options using pheromone traps and *Trichograma* for controlling *Helicoverpa* and *Lepidoptera* pests (ICRISAT, 2005a). They observed that they could reduce inputs by 9% with increased yield of 18% along with 39% higher net economic gain due to adoption of IPM in the case of vegetables. In the watershed

Table 12.15. Farmers' participatory evaluations for productivity enhancements in watersheds of five districts of Karnataka under ICRISAT Sujala project during 2005–2006.

District	Watershed villages	Crop	No. of trials	Cultivars	Yield (kg/ha)	
					FM[a]	Best bet
Kolar & Tumkur	7	Groundnut	63	JL 24, ICGV 91114, K1375, K6	915	2260
Kolar & Tumkur	9	Finger millet	62	MR 1, L 5, GPU 28	1154	1934
Chitradurga	2	Sunflower	30	KBSH-41, KBSH-44, GK 2002	760	2265
Chitradurga & Haveri	4	Maize	49	PA 4642, GK 3014	3450	5870
Haveri	4	Sole groundnut	16	ICGV 91114	1100	1720
Dharwad	4	Soybean	12	JS 335, JS 9305	1350	2470

[a] FM = farmers' management.

areas, farmers have started using 40–45% less chemical pesticides on vegetable cultivation than earlier.

Improved soil and water management and cropping systems (sorghum/pigeonpea intercrop) resulted in higher carbon sequestration in vertisols. Soils up to 120 cm depth contained about 34% more organic carbon than the traditional (fallow–sorghum) system and a gain of 335 kg carbon/ha/year was obtained (Wani *et al*., 2003b). When replicated on a large scale in Asian agriculture, substantial global environmental benefits in terms of reduced greenhouse gases and global warming are likely to be obtained.

Micronutrient amendments for enhancing incomes and rainwater use efficiency

During baseline characterization, soil analysis results showed that 80–100% of farmers' fields were critically deficient in B, Zn and S, in addition to N and P. Micronutrient amendments with Zn, B and S to overcome deficiency have shown remarkable gains. In Thanh Ha watershed, Vietnam, micronutrient application resulted in 27% higher pod yields over farmers' practice (2.75 t/ha) in groundnut. In the Lalatora watershed of India, micronutrient amendments increased the net profit by US$193/ha in the case of the soybean–wheat system over the profit of US$394/ha from the farmers' practice. At Lalatora, Madhya Pradesh, the economic analysis of the on-farm trials showed that intervention of combined application of B and S gave maximum benefit, with 1:1.8 benefit–cost ratio as compared with the control with traditional practices (1:1.3), and gave almost 49% higher benefits to the farmers (Patil *et al*., 2003). Farmers' participatory R&D trials in the states of Andhra Pradesh, Madhya Pradesh, Rajasthan and Gujarat showed 30–60% increased crop yields due to micronutrient amendments (Rego *et al*., 2005). Micronutrient amendments also increased rainfall use efficiency. In soybean, the rainfall use efficiency was increased by 25% through micronutrient amendments. Highest rainfall use efficiency of 117% was observed for sorghum. The rainfall use efficiency in terms of net economic returns for the rainfed crops was substantially higher by 1.5–1.75 times.

Crop harvests from INM trials in Karnataka, India indicate a gain of 2.5 t/ha maize grain yield and 0.5 t/ha additional fodder yield with application of micronutrients along with N and P (Fig. 12.16). In Haveri, farmers obtained 47% higher maize grain yield and in Dharwad 71% higher soybean seed yield with INM treatments compared with their own management (ICRISAT, 2005b).

Micro-enterprises and income-generating activities

Micro-enterprises, such as village seedbanks, vermicomposting, nursery raising, artificial insemination for animals, poultry, piggery, etc., are initiated for increasing income. Village seedbanks have provided access to farmers for improved varieties in the village itself at affordable costs and reduced their dependence on external seed sources. Women SHGs in several watersheds in India have set up vermicompost-

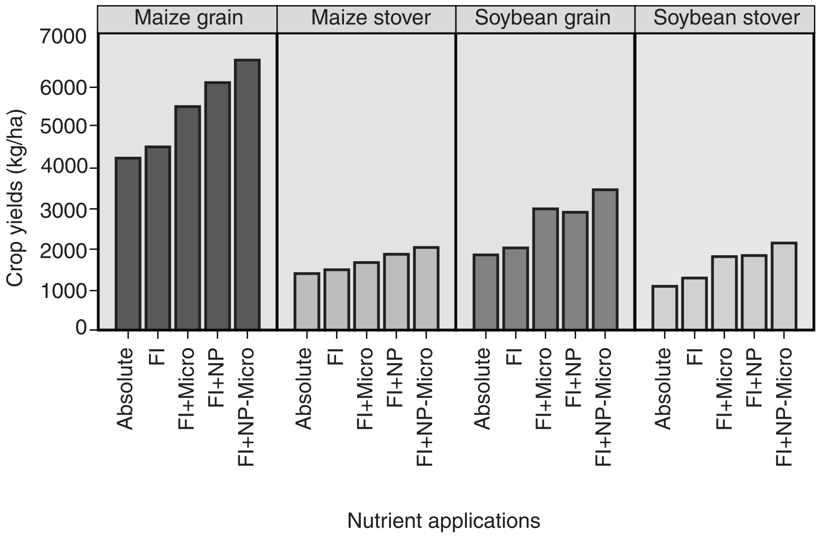

Fig. 12.16. Maize and soybean grain yields as affected by INM treatments in farmers' fields in Sujala watershed in Karnataka. Absolute = control with no fertilizer application; FI = farmers' management and inputs; FI+Micro = farmers' inputs + 5 kg borax + 200 kg gypsum + 50 kg zinc sulfate/ha; FI+NP = farmers' inputs + 70 kg DAP + 100 kg urea; FI+NP+Micro = farmers' inputs + 70 kg DAP + 100 kg urea + 5 kg borax + 200 kg gypsum + 50 kg zinc sulfate/ha (if the crop sown was a legume, application of nitrogen in the form of urea was reduced to 40 kg/ha instead of 100 kg/ha).

ing enterprises. Women members each earn about INRs 500/month. By becoming an earning member of the family, they are involved in the decision-making process, which has raised their social status. Vegetable cultivation, nursery raising and enhanced milk yields through better livestock management have improved rural livelihoods, particularly of women. In Thailand and Vietnam, farmers' incomes are substantially augmented through piggery, poultry and fish rearing.

Impact on National Policy

Integrated watershed management is identified as the most suitable approach to improve the rural livelihoods through increased productivity and efficient management of natural resources in the drylands of the SAT. The National Commission on Farmers (2004), India, has stated that the principal constraints observed in reaping the full benefits from dryland farming research are: (i) lack of a watershed approach with all members of the watershed community working together to save and share water; and (ii) lack of social synergy in the area of land and water use planning, with emphasis on collaborative efforts in both production and postharvest phase of farming. The Commission recommends that the highest priority should be given to augment water availability by vigorously promoting rainwater harvesting, restoring water bodies and a million wells recharge programmes. Convergence and synergy of all agricultural programmes around a watershed is the need of the day. The National Commission on Farmers has appreciated the success of the ICRISAT-led consortium model and pointed out that the holistic innovative model has changed the paradigms for watershed management in India, where the watershed is used as an entry point for improving the livelihoods and protecting the environment. Watershed programmes have a very high potential for bringing favourable changes in the drylands of the SAT. On-farm watersheds managed through community participation could sustain productivity of drylands and preserve the quality of the land resources and environment in the SAT. An holistic systems approach through integrated watershed management can result in sustainable and increased farm productivity and improve the livelihoods of the rural poor in the dry regions (National Commission on Farmers, 2004). The recent Comprehensive Assessment of watershed programmes in India (Wani *et al.*, 2008c) and new guidelines for watershed management by the NRAA (Government of India, 2008) clearly highlight the importance of rainfed agriculture for improving rural livelihoods.

Summary

Most farming problems require integrated solutions, with genetic, management-related, and socio-economic components. In essence, plant breeders and NRM scientists must integrate their work with that of private- and public-sector change agents, to develop flexible cropping systems that can respond to rapid changes in market opportunities and climatic conditions. The IGNRM approach is participatory, with farmers closely involved in technology development, testing and dissemination. ICRISAT, in partnership with National Agricultural Research Systems (NARS), has conceived, developed and successfully evaluated an innovative farmers' participatory consortium model for integrated watershed management. The model includes the consortium approach and adopts the concept of convergence in every activity in the watershed.

The new paradigm for upgrading rainfed agriculture can double the productivity in Asia and also reduce poverty without causing further degradation of the natural resource base. Successful scaling-up of these innovations in Andhra Pradesh, India through APRLP and in other states of India with support from the Sir Dorabji Tata Trust and the World Bank (Sujala Project, Karnataka) as well as in Thailand and Vietnam have opened up opportunities to upgrade rainfed agriculture in all these countries as well as in China.

Along with rainwater harvesting and agumentation, water demand management through enhanced water (rainwater and groundwater) use efficiency by adopting a holistic approach has benefited the farmers. Farmers obtained a 13–230% increase in maize yields, with an average increase of 72% over the base yield of 2980 kg/ha; the increase in castor yields was 21–70%, with an average increase of 60% over the base yield of 470 kg/ha. Similarly, groundnut yield increased by 28% over the base yield of 1430 kg/ha. The issues of equity for all in the watershed call for innovative approaches; institution and policy guidelines for equitable use of water resources are needed. Along with water use, equity issues concerning sustainable use of common property resources in the watershed also need to be addressed. Building on micro-enterprises enhanced the benefits for women and vulnerable groups in society. Knowledge management and sharing is an important aspect in management of natural resources for sustainable development. Use of ICTs to cover the last mile to reach the unreached is a must, as the existing extension mechanisms are not able to meet the ever-growing demand, as well as to share the new and vast body of knowledge with the large number of small and marginal farmers.

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