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Land Use Planning in Integrated Watershed Development Program for Improving Livelihoods

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Globally, rain-fed agriculture plays an important role to achieve food security (Rockstrom *et al.* 2007) as 80% of the world's agricultural land area is rain-fed and generates 58% of the world's staple foods (SIWI 2001). Most food for poor communities in the developing countries is produced in rain-fed areas for *e.g.* in sub-Saharan Africa (SSA) more than 95% of the farmed land is rain-fed, whereas the corresponding figure for Latin America is nearly 90%, for South Asia about 60%, for East Asia 65% and for Near East and North Africa 75%. In India, 60% of 142 million ha (Mha) arable land is rain-fed. The rain-fed areas are the hot spots of poverty, malnutrition, water scarcity, severe land degradation; and the investments in the rainfed agriculture pose serious challenges as large numbers of households are small land holders (Wani *et al.* 2009). These areas are also prone to more adverse impacts of climate change due to lack of technologies and necessary resource to cope with the challenges of global warming.

The vast potential of rain-fed areas remains untapped as the current farmers' crop yields are lower by two to five folds than the achievable yields with large yield gaps in the semi-arid and sub humid tropical regions (Falkanmark 2000; Rockstrom *et al.* 2007; Wani *et al*. 2006, 2009; Singh *et al.* 2009). However, upgrading rainfed agriculture is a challenging task and needs a paradigm shift from the "business as usual" mental frame and adopting science-led integrated genetic and natural resource management (IGNRM) using a participatory research and development (PR&D) approach (Wani *et al*. 2008, 2008a, 2009). 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. The missing links for scaling-up and scaling-out upgrading rainfed agriculture are institutions and social and economic processes which can link to suitable policies (Sreedevi and Wani 2009). It also requires that technologies (indigenous or improved) are strongly adapted to local biophysical and socio-cultural conditions along with the institutional and behavioural changes (Harris *et al*. 1991). Agricultural development and extension is a knowledge-intensive effort, which suffers from limited information about 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 (Wani *et al*. 2009). Integrated watershed management approach has shown the potential for scaling-out the benefits ensuring community participation largely due to tangible economic benefits as well as capacity development through knowledge sharing (Wani *et al.* 2000, 2003).

Watershed – A Suitable Unit for Sustainable Management of Natural Resources

A watershed is a catchment area from which all water drains into a common point, making it an attractive hydrological unit for the technical efforts to manage water and soil resources. Watershed is a spatial unit that includes diverse natural resources (soil, water, trees, biodiversity, *etc*.) that are unevenly distributed within a given geographical area (Knox and Gupta 2000; Johnson *et al*. 2002). The water flowing in a watershed interconnects up-stream and down-stream areas and provides life support to rural people holding unequal use rights making people and animals an integral part of watersheds. Activities of people/animals affect the health and sustainability of watersheds and *vice versa*. Clearly, watersheds are geologically, ecologically, and socially complex geographical units characterized by temporal and spatial interdependence between resources as well as resource users. This implies that effectiveness of the watershed interventions will depend on the ability to treat the entire hydrological landscape, following the ridge to valley approach and not just a portion of it. In a watershed, the quality and status of land, water, and vegetation vary as per the toposequence position; and suitable strategies are essential for their development and sustainable use considering their capability.

The terms catchment, sub-catchment and watershed are often synonymously employed as are defined by a single river system and further grouped in to macro, meso and micro levels in a hierarchical system for management using a codification system linking different levels. The concept of stream order is often followed in geomorphic analysis of natural drainage system. However, a participatory framework of watershed development calls for a different approach indicative of macro and micro level of delineation encompassing different communities and administrative units avoiding social conflicts. Earlier, watersheds of 500 ha were used for development in India as community watersheds covering one village or a cluster of inhabitations. However, it was found that small watersheds were not effective in terms of economic, environmental and social impacts and watersheds >1200 ha were recommended (Joshi *et al*. 2005, 2008; Wani *et al.* 2008a). The Common Watershed Guidelines released by the Government of India (2008) adopted larger size watersheds of 1000-5000 ha by developing watersheds in clusters. Each of the big drainage system is divided and sub-divided through stages using different codes to indicate various stages starting with macro-level and going down to micro level.

Importance of Land Use Planning in Watershed Development

The unevenly distributed, diverse, and interconnected natural resources and interdependence of human beings and animals for their living and sustainability calls for proper planning for development, management, and use of land resources. Adinarayana (2008) employed Watershed Management Information System (WATMIS) to evaluate agro-ecological characteristics using primary data, soil erosion assessment and aspects of conservation management. Data from various sources such as NBSS&LUP, remote sensing, groundwater, agriculture, forestry and rural development departments can be effectively used with the help of geographical information system (GIS), simulation models (crop, water, soil loss, runoff), and bioeconometric models for the sustainable development and management of watersheds (Wani *et a*l. 2008, 2008a, 2009; Sreedevi *et al*. 2009).

Land Use Mapping for Assessing Fallows and Cropping Intensity using Satellite Data

A deductive approach using the Indian Remote Sensing Satellite data of rainy season fallows in the state of Madhya Pradesh were delineated (Fig. 1). The digital multispectral data from WiFS aboard IRS-1D/-P3 over the area acquired during the 1999–2000 and 2000–01 seasons was utilized for deriving information on fallow lands along with the use of topographic maps at 1:250,000 scale. It was estimated that 2.02 million ha (Mha) accounting for 6.57% of the total area of the state, were under fallowing (Fig. 1). Madhya Pradesh is endowed with well distributed rains ranging from 700 to 1200 mm. Vertisols with good moisture holding capacity can be used to grow short-duration soybean by adopting sound land management practices (Dwivedi *et al*. 2003). This helped in developing water and land management strategies in the watersheds in Madhya Pradesh which helped increasing cropping intensity, crop production and farmers' income while minimizing land degradation.

Rice, the most extensively grown crop in South Asia, is cultivated on approximately 50 Mha. This study describes the use of satellite remote sensing and GIS technology to quantify and assess the spatial distribution of rice-fallow lands and a corresponding classification of their potential and constraints for the growing of post-rice legumes (such as soybean, mung bean, black gram, pigeonpea, groundnut, chickpea, lentil, *khesari*, faba bean and pea) in South Asia (Bangladesh, India, Nepal and Pakistan) (Fig. 2). Rice fallows during 1999/2000 season were estimated at 14.29 Mha in Bangladesh, India, Nepal and Pakistan; and this amounts to nearly 30% of the rice-growing area. Nearly 82% of the rice-fallows are located in the Indian states of Bihar, Madhya Pradesh, including Chhattisgarh, West Bengal, Orissa and Assam. An economic analysis has shown that growing legumes in the rice-fallows is profitable for the farmers with a benefit-cost ratio exceeding 3.0 for many legumes. Also, utilizing rice-fallows for legume production could result in the generation of 584 million person-days employment for South Asia. That includes the use of short-duration chickpea varieties, block planting so as to protect the crop from grazing animals, sowing using rapid minimum tillage as soon as possible after harvesting rice, seed priming for 4-6 hours with the addition of sodium molybdate to the priming water at a rate of 0.5 g L^{-1} (kg^{-1} seed) and *Rhizobium* inoculum at the rate of 5 g L^{-1} (kg^{-1} seed), application of manure and single superphosphate. Chickpea yields following rice ranged from 0.4 to 3.0 t ha^{-1} across various rice fallow areas in

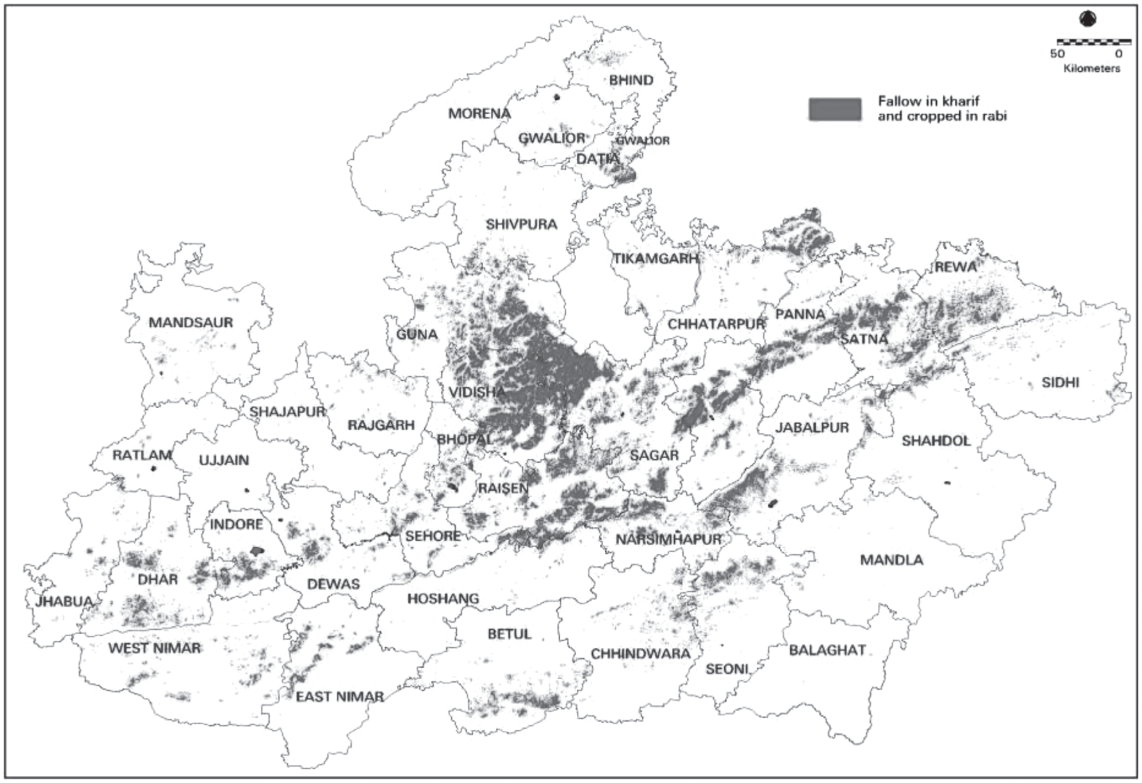

Fig. 1. Spatial distribution of rainy season fallows in districts of Madhya Pradesh

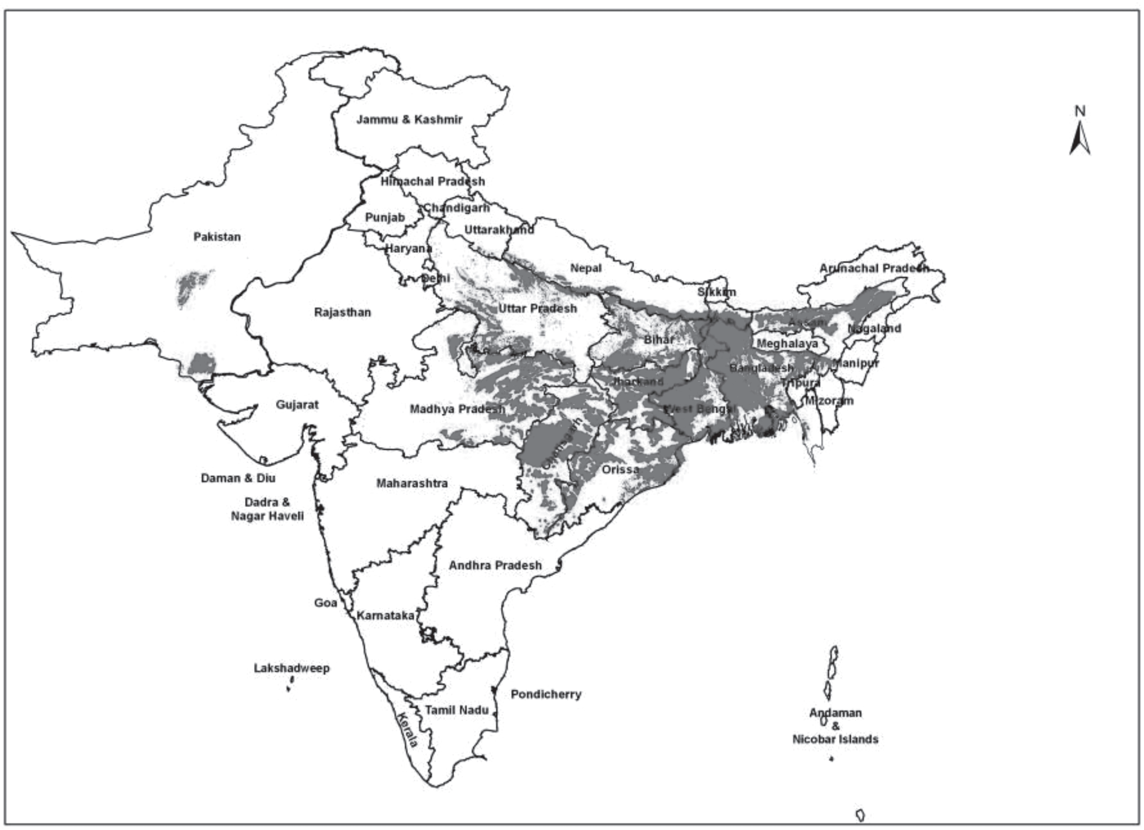

Fig. 2. Spatial distribution of rice-fallows in Indo Gangetic Plains of South Asia

eastern India. More than six thousand farmers who have been exposed to this technology are now convinced that a second crop can be grown without irrigation in the rice fallows (Subba Rao *et al.* 2001).

Criteria for Prioritization of Watersheds

One of the conventional approach for the prioritization of the watershed was based on the silt yield index method (SYI) developed by the AISLUS (now SLUSI), which consumed a lot of time and sizable human and financial resources. Sidhu *et al.* (1998) used these approaches and prioritized the development of detailed work plan for Machkund watershed in Andhra Pradesh state. To provide efficient framework of watersheds in the country, AISLUS (1990) developed first Watershed Atlas of India comprising 17 sheets at a 1:1 million scale. The country was hydrologically demarcated into 6 major water resource regions, 35 river basins, 112 catchments, 500 sub-catchments and 3237 watersheds (All India Soil and Land Use Survey 1991). Subsequently, Digital Watershed Atlas of India was developed by the AISLUS for a GIS-based Web service on watershed, soil and land information.

The Andhra Pradesh Rural Livelihood Program (APRLP) devised a nine-point selection criteria (Sreedevi and Wani 2009) for watersheds, integrating the 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 SYI indicators of land degradation due to erosion and the dependability of precipitation and evapo-transpiration, which depend on the variability and deviation of rainfall.

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 APRLP took a holistic view of people towards their livelihoods and opportunities, it integrated the indices of natural resource degradation and multiple deprivations, and a matrix was drawn up where each was given equal importance, while selecting the watersheds. A probation period of up to 18 months was made mandatory for capacity building plans for the primary and secondary stakeholders and the preparation of strategic (perspective plan for 5 years) and annual action plans. Thus, it is a farmer-friendly and Participatory Net Planning (PNP) approach.

Community Watershed as Growth Engine for Development of Dryland Areas

Although, watershed development approach is embraced as a policy for development of drought-prone regions in the country, a number of evaluations, however, showed that not all had gone well with the watershed programmes (Kerr *et al*. 2002, Wani *et al*. 2002, 2003, Joshi *et al*. 2005). For example, a meta-analysis of 311 watershed case studies from different agro-eco-regions in India indicated that the watershed programmes were economically viable and productive with a benefit–cost ratio of 2.14 and the internal rate of return of 22%. The watersheds also benefited farmers through enhanced irrigated areas by 33.5%, increased cropping intensity by 63%, reducing soil loss to 0.8 t ha^{-1} and runoff to 13%, and improved groundwater availability (Joshi *et al.* 2005). With these considerations, the watershed programmes have been looking beyond soil and water conservation into a range of activities from productivity enhancement through interventions in agriculture, horticulture, animal husbandry to community organization and gender equity. The conventional watershed approach attempted to optimize the use of precipitation through improved soil, water, nutrient and crop management, but lacked the strategy for efficient use of the conserved natural resources. People and livestock being an integral part of the agricultural watershed, traditional watershed programmes, which are structure-driven alone, cannot offer solutions to improve rural livelihoods. Though watershed serves as an entry point, a paradigm shift is needed from these traditionally structure-driven watershed programmes to a holistic system's approach to alleviate poverty through increased agricultural productivity by environment-friendly resource management practices (Wani *et al*. 2008b).

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

The meta analysis of 636 watershed case studies revalidated the results of the earlier meta analysis study (Joshi *et al.* 2008) and showed that watershed programmes were silently revolutionalising dryland areas with average B:C ratio of 1:2, internal rate of return of 27%, reduced run off by one-third and reduced soil loss (0.8 t ha^{-1}). Only <1% of watershed projects were not economically remunerative, however, the impacts of watershed programmes can be substantially enhanced by improving the performance of 68% of watersheds performing below average (Fig. 3). The CA has recommended that watersheds be developed as business model through public private partnership mode and the convergence of actors and programmes with full community participation for addressing the issues of enhancing crop productivity, income generation through targeted activities for small and marginal farmers, women, and vulnerable groups of the society, conserving natural resources and most importantly building the resilience of natural resources and the community to cope with the climate change (Wani *et al*. 2008a).

The government has moved the watershed agenda forward in various ways: with constitutional amendment to enforce more responsibility on Panchayati Raj departments for rural development; by refining watershed guidelines as lessons have been absorbed; and by converging the drought-prone area programmes with National Rural Employment Guarantee Scheme (NREGS). The Planning Commission has taken cognisance of the recommendations of various task force groups and has emphasized on the development of rainfed areas for inclusive and sustainable development. The Common Watershed Guidelines (Government of India 2008) have facilitated the convergence of the watershed programmes implemented by different ministries and Department of Land Resources (DOLR) of Ministry of Rural Development as the nodal agency to implement all the watershed programmes in India with common guidelines.

Operationalizing Community Watershed as Growth Engine

For community watershed development programme to become the growth engine for sustainable development of rainfed areas, the major challenge is the scaling-up to large areas as successful watersheds remained few and unreplicated (Kerr *et al*. 2002; Joshi *et al*. 2005). An integrated consortium approach for the sustainable development of community watersheds with technical backstopping and convergence is developed and evaluated in Asia (Wani *et al*. 2002, 2003). It encompassed integrated solutions, with genetic, natural resource management (NRM) and socio-economic related components to develop dynamic cropping systems that respond to the 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 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 natural resource base (Rockström *et al*. 2007; Wani *et al*. 2008a). The scaling-up of these innovations with technical support from ICRISAT-led consortium has been attempted in Andhra Pradesh, India through Andhra Pradesh Rural Livelihoods Programme (APRLP) supported

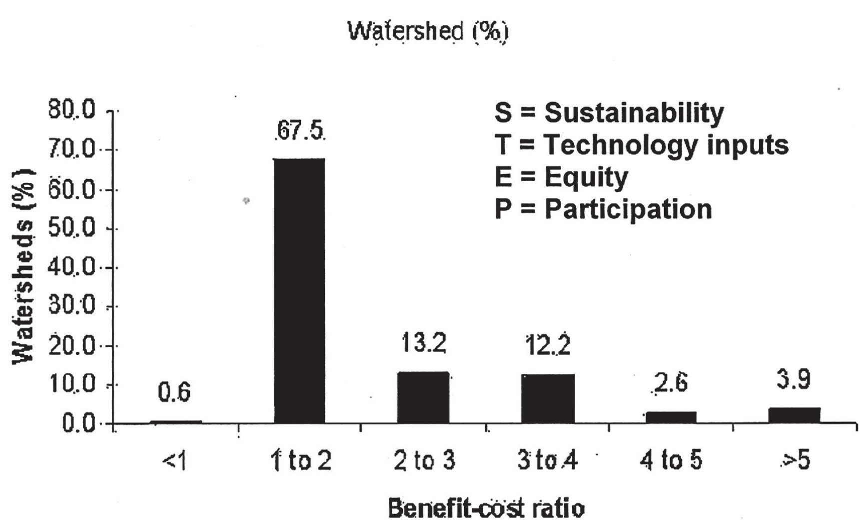

Fig. 3. Performance of different watersheds analyzed during meta analysis, with regards to BC ratio

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 the support from Sir Dorabji Tata Trust (SDTT), Mumbai, India; and four countries in Asia (India, Thailand, Vietnam and China) with the support of Asian Development Bank (ADB), Philippines.

Watershed as an Entry Point to Improve Livelihoods

Watershed, as an entry point should lead to exploring multiple livelihood interventions (Wani *et al*. 2006, 2006a, 2007, 2008). The overall objective of the whole approach being poverty elimination through sustainable development, the new community watershed management provides an envelop that fits into the framework as a tool to assist in sustainable rural livelihoods. 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.

ICRISAT's consortium model for community watershed management espouses the principles of collective action, convergence, cooperation and capacity building (4 Cs) with technical backstopping by a consortium of institutions to address the issues of equity, efficiency, economics and environment (4Es) (Wani *et al*. 2003a, 2006). The new integrated community watershed model provides technological options for management of runoff 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 ICRISAT watershed consortium team, involves environment-friendly options and use of new science tools (Wani *et al*. 2000, 2002, 2008a; Sreedevi *et al*. 2004).

Adarsha watershed (in Kothapally, Ranga Reddy district in Andhra Pradesh) led by the ICRISAT consortium, has clearly demonstrated increased crop productivity from rainfed systems through integrated watershed management approach (Table 1).

Convergence in Watershed

Convergence in the watersheds evolved with community watershed management model, which apart from IGNRM strategy encompasses several other entities. The holistic 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. Convergence takes place at different levels, at the village level it 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. The activities in

Table 1. Crop yields in Adarsha watershed, Kothapally during 1999-2007

Crop	1998 base-line yield	Yield (kg ha^{-1})									
		1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	Average yields	SE±
Sole maize	1500	3250	3750	3300	3480	3920	3420	3920	3635	3640	283.3
Maize intercrop (improved)	-	2700	2790	2800	3083	3129	2950	3360	3180	3030	263.0
Maize intercrop (traditional)	-	700	1600	1600	1800	1950	2025	2275	2150	1785	115.6
Pigeonpea intercrop (improved)		640	940	800	720	950	680	925	970	860	120.3
Pigeonpea intercrop (traditional)	190	200	180	-	-	-	-	-	-	190	-
Sole sorghum (improved)	-	3050	3170	2600	2425	2290	2325	2250	2085	2530	164.0
Sole sorghum (traditional)	1070	1070	1010	940	910	952	1025	1083	995	1000	120.7
Sorghum in intercrop	-	1770	1940	2200	-	2110	1980	1960	1850	1970	206.0

integrated watershed management approach where convergence mode works included:

- Rainwater conservation and harvesting
- Productivity enhancement through improved crops and management options
- Soil-test based integrated nutrient management options including micronutrients
- Soil conservation
- Crop diversification using high-value crops
- Establishing village seed banks through self-help groups (SHGs).
- Processing for value addition (seed material, poultry feed, animal feed, grading and marketability, quality compost preparation)
- Rehabilitation of degraded common lands with suitable SWNM options using grass and plantation systems
- 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 provides 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*. 2003; Sreedevi *et al*. 2004; Joshi *et al*. 2005) and it is complex and needs careful consideration.

The consortium approach enables to address equity, gender, sustainability and improved livelihoods which are the pillars of inclusive and sustainable development. Drivers of higher impacts in 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 amongst 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 midcourse correction (Sreedevi *et al*. 2004; Shiferaw *et al*. 2006; Joshi *et al*.2009).

Multiple Benefits from Integrated Watershed Development

Adoption of integrated watershed management effected remarkable multiple impacts on SAT resource-poor farm households.

Reducing rural poverty in the watershed communities was evident in the transformation of their economies. The improved productivity with the adoption of cost-efficient water harvesting structures (WHS) as an entry point improved livelihoods through crop intensification and diversification with high-value crops (Wani *et al*. 2003b, 2008, 2009; Sreedevi and Wani 2009). It also benefited women, landless and vulnerable members through income-generating activities.

Building on social capital made the huge difference in addressing rural poverty of watershed communities. Crop livestock integration is another facet harnessed for poverty reduction. The Lucheba watershed, Guizhou province of southern China has transformed its economy through modest injection of capital-allied contributions of labour and finance, to create basic infrastructures like access to roads and drinking water supply. In Tad Fa and Wang Chai watersheds in Thailand, there was a 45% increase in farm income within three years. Farmers earned an average net income of US$ 1195 per cropping season.

Increasing crop productivity is a common objective in all the watershed programmes; and the enhanced crop productivity is achieved after the implementation of soil and water conservation practices along with appropriate crop and nutrient management. Overall, in the 65 community watersheds in Andhra Pradesh and 30 watersheds in Karnataka (Table 2) (each measuring approximately 500 ha), implementing best-bet practices resulted in significant yield advantages in sorghum (35-270%), maize (30-174%), pearl millet (72-242%), groundnut (28-179%), sole pigeonpea (97-204%) and intercropped pigeonpea (40-110%). In Thanh Ha watershed of Vietnam, yields of soybean, groundnut and mung bean increased by threefold to fourfold (2.8–3.5 t ha^{-1}) as compared with baseline yields (0.5 to 1.0 t

Table 2. Different crop yields as influenced by best-bet options in Andhra Pradesh and Karnataka

	Watershed	Grain yield (t ha^{-1})		Yield advantage (%)
		Improved practice (Can it be detailed elsewhere in the MS?)	Traditional practice (Details may please be provided somewhere in the MS)	
Andhra Pradesh				
	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
Karnataka	District & Crop			
	Kolar & Tumkur (Groundnut)	2260	915	247
	Kolar & Tumkur (Finger millet)	1934	1154	167
	Chitradurga (Sunflower)	2265	760	298
	Chitradurga (Maize)	5870	3450	170
	Haveri (Sole groundnut)	1720	1100	156
	Dharwad (Soybean)	2470	1350	183
Mean		2753	1454	203

Source: Adapted from Sreedevi and Wani (2009)

ha^{-1}), reducing the yield gap between potential farmers' yields. A reduction in nitrogen fertilizer (90–120 kg urea ha^{-1}) by 38% increased maize yield by 18% in Thanh Ha watershed in Vietnam. In Tad Fa watershed of northeastern Thailand, maize yield increased by 27-34% with improved crop management (Sreedevi and Wani 2009).

Improving water availability in the watersheds was attributed to efficient management of rainwater and *in-situ* conservation, establishment of WHS and improved groundwater levels. Even after the rainy season, the water level in wells nearer to WHS sustained good groundwater yield and benefited village women through drinking water availability as well as men with increased irrigation (Wani *et al*. 2006a; Sreedevi and Wani 2009; Pathak *et al*. 2009). Supplemental irrigation played a very important role in reducing the risk of crop failures and in optimizing the productivity in the SAT. On-farm studies made during 2000-03 post-rainy seasons, showed increased chickpea yield by 127% and groundnut pod yield by 59% over the control yield (0.82 t ha^{-1}) by application of two supplemental irrigations of 40 mm (Pathak *et al.* 2009).

Sustaining development and protecting the environment are the two-pronged achievements of the watersheds reducing soil loss and run-off loss. Introduction of IPM in cotton and pigeonpea substantially reduced the number of chemical insecticidal sprays in Kothapally, India during the season and thus reduced the pollution of water bodies with harmful chemicals. Introduction of integrated pest management (IPM) and improved cropping systems decreased the use of pesticides worth US$ 44 to 66 per ha (Ranga Rao *et al*. 2007). Increased carbon sequestration of 7.4 t ha^{-1} in 24 years was observed with improved management options in a long-term watershed experiment at ICRISAT. By adopting fuel-switch for carbon, women SHGs in Powerguda (a remote village of Andhra Pradesh) have pioneered the sale of carbon units (147 t CO_2 C) to the World Bank from their 4,500 *Pongamia* trees, seeds of which are collected for producing saplings for distribution/promotion of biodiesel plantation. Normalized difference vegetation index (NDVI) estimation from the satellite images showed that within four years, vegetation cover could increase by 35% in Kothapally (Wani *et al*. 2005).

Conserving biodiversity in the watersheds was engendered through participatory NRM. Pronounced agro-biodiversity impacts were observed in Kothapally watershed where farmers now grow 22 crops in a season with a remarkable shift in cropping pattern from cotton (200 ha in 1998 to 100 ha in 2002) to a maize/pigeonpea intercrop system (40 ha in 1998 to 180 ha in 2002), thereby changing the CAF from 0.41 in 1998 to 0.73 in 2002. In Thanh Ha, Vietnam the CAF changed from 0.25 in 1998 to 0.6 in 2002 with the introduction of legumes (Wani *et al*. 2005).

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