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Perspectives and Challenges

Surjit Singh
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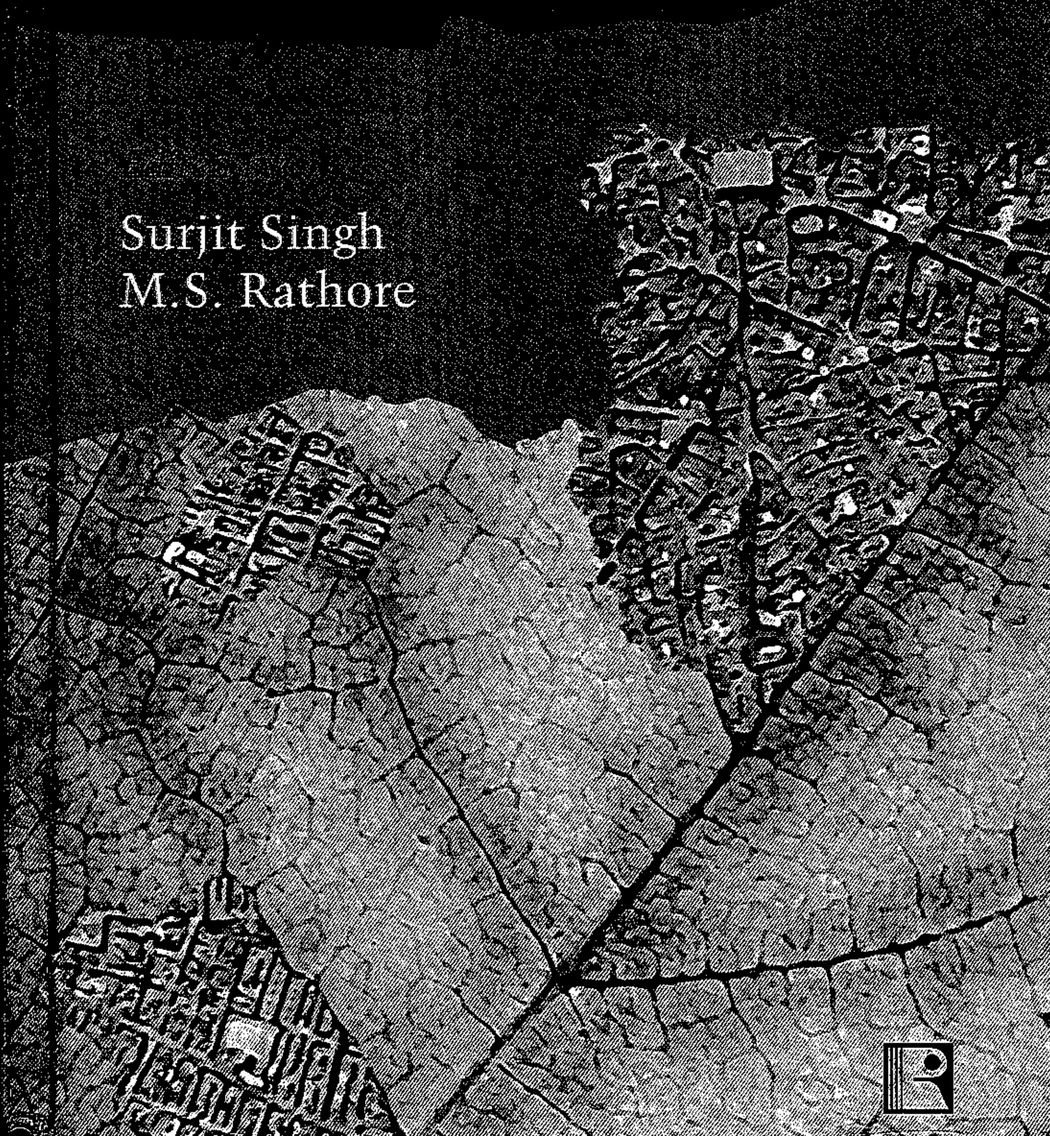

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Conservation of Natural Resources and their Efficient Use for Sustainable Development in Asia

Suhas P. Wani, T.K. Sreedevi, Yin Dixin, Thawilkal Wangkahart and N.V. Thang

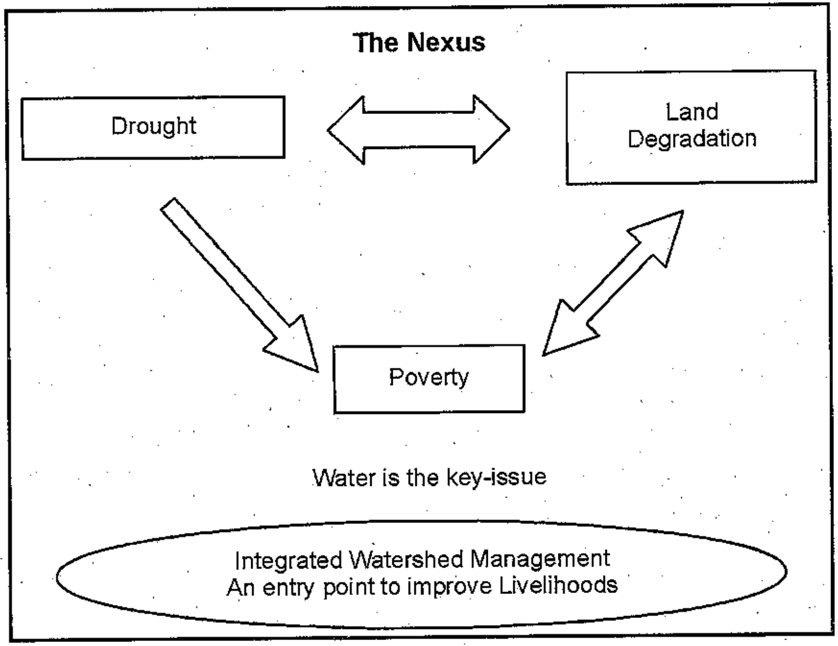
Reduction in the producing capacity of land due to wind and water erosion of soil, loss of soil humus, depletion of soil nutrients, secondary salinization, diminution and deterioration of vegetation cover as well as loss of biodiversity is referred to as land degradation. Land degradation in arid, semi-arid and dry sub-humid areas, resulting from various factors including climatic vicissitudes and human activities, is also referred to as desertification, where production function of soil is severely affected and survival of human beings and animals is threatened. A global assessment of the extent and form of land degradation showed that 57 per cent of the total area of drylands occurring in two major Asian countries, namely, China (178.9 m ha) and India (108.6 m ha) are degraded (UNEP, 1997). Accelerated erosion resulting in loss of nutrient rich top fertile soil, however, occurs nearly everywhere, where agriculture is practised and is irreversible. The torrential character of the seasonal rainfall creates high risk for the cultivated lands. Of the estimated 173 million tonnes of sediment discharged into the oceans annually, this region alone contributes nearly half of the load, even though the actual land area is just one-third. This is an eloquent testimony to the intensity of the process and the consequential damage to the producing ability of land. In India, erosion rates of 5 to 20 tonnes ha^{-1} (up to 100 t ha^{-1}) are reported. In India, alone some 150 million hectares are affected by water erosion and 18 million hectares by wind erosion. Thus, erosion leaves behind an impoverished soil on one hand, and siltation of reservoirs and tanks, on the other. This degradation-induced source of carbon emissions contributes also to far-reaching global warming consequences. Recent on-farm participatory research by ICRISAT-led consortium in India revealed widespread deficiency of zinc, boron and sulphur, along with nitrogen and phosphorus, in up to 100 per cent rainfed farmers' fields even with subsistence level of production largely due to mining of these nutrients over a long time and no replenishments through farm yard manure or chemical fertilizers (Rego et al., 2005). Most of 852 million hungry and malnourished people in the world are in Asia, which is also a hot spot of land degradation, particularly in India (221 million) and in China (142 million). In Asia, 75 per cent of the poor are in rural areas and they depend on agriculture for their livelihood. About half of the hungry live in smallholder farming households, while two-tenths are landless. About 10 per cent are pastoralists, fishfolk and forest users (Sanchez et al., 2005). If the current production practices are continued, the Asian countries will face a serious food shortage in the very near future. In the arid, semi-arid regions of Asia and Africa, the economy remains strongly dependent on agriculture. Water is a vital natural resource to sustain human development, poverty reduction, and health of the ecosystem. The current scenario of water availability indicates that Asia has the lowest water availability (2,500 cubic metres per head per annum) in the world. Numerous countries and river basins face acute physical scarcity. The future challenge at global as well as regional levels is to achieve water security that is directly related with food and health security of the humankind. The second World Water Forum was a landmark event in the evolution of global water consciousness making "water everybody's business" (Guerquin et al., 2003). All these findings impress the need for conservation of natural resources to support sustainable development and reduction of poverty.

Poverty-Land Degradation Nexus

The poverty of Asia's poor is both a cause and a consequence of accelerating land degradation and declining agricultural productivity. The hazards also include factors, such as insecure rights to land and other natural resources, lack of improved agricultural technology, inability to store produce after harvest, environmental degradation, lack of income-earning opportunities, poor health and so on (Sanchez et al., 2005). The challenge before R&D institutions is to understand the underlying determinants of poverty, the pathways to its alleviation. The sustainable livelihoods approach to understanding poverty was highlighted in the 1997 UK Government White Paper on International Development (DFID, 1997). There is a strong nexus between the water scarcity during the crop growing period or drought, associated land degradation due to poor land cover and soil erosion (water and wind) accompanied by nutrient depletion and poverty (Figure 1).

Figure 1

Nexus between Drought, Land Degradation and Poverty



This challenge is to break the unholy nexus through conservation of natural resources. Water or more specifically rainwater conservation could be an excellent entry point to improve rural livelihoods (Wani and Ramakrishna, 2005; Wani et al., 2004, 2005, 2006).

The Task Force on Hunger has recommended to improve soil health, improve and expand small-scale water management, improve access to better seeds and other on-farm enterprises with high-value products, establish effective agricultural extension services to increase agricultural productivity of food-insecure farmers (Sanchez et al., 2005). To meet the Millennium Development Goal (MDG) of halving the proportion of poor people, compared to 1990, by 2015 will require concerted research and development efforts in the rainfed areas (Rockstrom et al., 2007).

Potential for Conservation of Rainwater

Weekly water balances of selected watersheds in China, India, Thailand and Vietnam showed that potential evapotranspiration (PET) varied from about 890 mm at Lucheba in China to 1,890 mm at Tirunelveli in South India (Table 1). Actual evapotranspiration (AET) values are relatively lower at the watersheds in China and India compared to those in Thailand and Vietnam. Varying levels of water surplus (WS) and water deficit (WD) occur at the watersheds. Among all the locations, Tirunelveli in India has the largest water deficit (1,347 mm) and no water surplus (Figure 2). However, even in the most water-deficit locations during monsoon season, the nature of rainfall results in water surplus and provides an opportunity to conserve rainwater. Chine in Vietnam has the largest water surplus of 907 mm. These analyses defined the dependability of crop production for moisture availability and opportunities for water harvesting and groundwater recharge.

Figure 2
Excess Water Available for Harvesting as Runoff in the States of SAT India

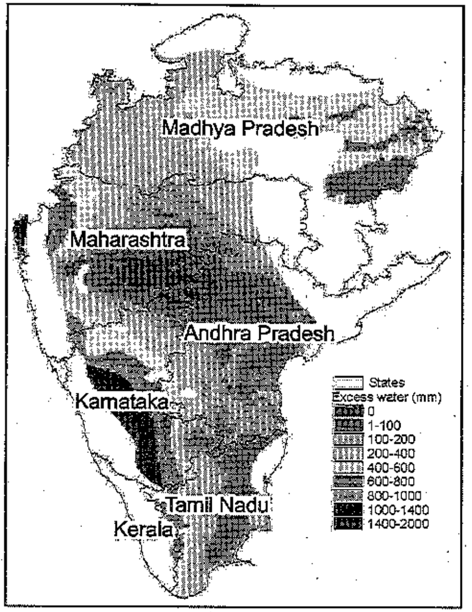


Table 1
Annual Water Balance Characters

(in mm)

Country	Location	Rainfall	PET	AET	WS	WD
China	Xiaoxingcun	641	1464	641	Nil	815
	Lucheba	1284	891	831	384	60
Thailand	Wang Chai	1171	1315	1031	138	284
	Tad Fa	1220	1511	1081	147	430
Vietnam	Chine	2028	1246	1124	907	122
	Vinh Phuc	1585	1138	1076	508	62
India	Bundi	755	1641	570	186	1071
	Guna	1091	1643	681	396	962
	Junagadh	868	1764	524	354	1240
	Nemmikal	816	1740	735	89	1001
	Tirunelveli	568	1890	542	Nil	1347

Source: Wani et al., 2007.

Potential of Rainfed Agriculture

In tropical regions, particularly in the sub-humid and humid zones, agricultural yields in commercial rainfed agriculture exceed 5–6 t ha^{-1} (Rockström and Falkenmark, 2000; Wani et al., 2003a & b). However, farmers' crop yields oscillate in the region of 0.5–2 t ha^{-1}, with an average of 1 t ha^{-1} in sub-Saharan Africa, and 1–1.5 t ha^{-1} in the SAT Asia and Central and West Asia and North Africa (CWANA) for rainfed agriculture (Rockström and Falkenmark, 2000; Wani et al., 2003a & b). Evidence from long-term experiments at ICRISAT, Patancheru, India since 1976, demonstrated the virtuous cycle of persistent yield increase through improved land, water and nutrient management in rainfed agriculture. Improved systems of sorghum/pigeonpea intercrops produced higher mean grain yields (5.1 t ha^{-1}) compared to 1.1 t ha^{-1}, average yield of sole sorghum in the traditional (farmers') post-rainy system where crops are grown on stored soil moisture (Figure 3). The annual gain in grain yield in the improved system was 82 kg ha^{-1} compared with 23 kg ha^{-1} in the traditional system. The large yield gap between attainable yield and farmers' practice as well as between the attainable yield of 5.1 t ha^{-1} and potential yield of 7 t ha^{-1} shows that a large potential of rainfed agriculture remains to be tapped. Moreover, the improved management system is still gaining in productivity as well as improved soil quality (physical, chemical, and biological parameters) along with increased carbon sequestration of 330 kg C ha^{-1}. Yield gap analysis, undertaken by the comprehensive assessment, for major rainfed crops in semi-arid regions in Asia and Africa, and rainfed wheat in West Asia and North Africa (WANA), reveal large yield gaps, with farmers' yields being a factor 2–4 lower than achievable yields for major rainfed crops grown in Asia and Africa (Rockström et al., 2007).

Soil Health, an Important Driver for Enhancing Water Use Efficiency

Soil health is severely affected due to land degradation and is in need of urgent attention. ICRISAT's on-farm diagnostic work in different community watersheds in different states of India as well as in China, Vietnam and Thailand showed severe mining of soils for essential plant nutrients. Exhaustive analysis showed that up to 100 per cent farmers' fields are deficient not only in total nitrogen but also micro-nutrients like zinc, boron and secondary nutrients such as sulphur (Table 2). In addition, soil organic matter an important driving force for supporting biological activity in soil is very much in short supply particularly in tropical countries. Targeted efforts and activities to augment soil organic matter are needed. Farm bunds could be productively used for growing N_2 fixing shrubs and trees to generate N-rich loppings. For example, growing *Gliricidia sepium* at close spacing of 75 cm on farm bunds could provide 28–30 kg N ha^{-1} in addition to valuable organic matter. Large quantities of farm residues could be converted in valuable source of plant nutrients through vermicomposting (Wani et al., 2005). Strategic long-term catchment research at ICRISAT has shown that legume-based systems particularly with pigeonpea could sequestor 330 kg C upto 150 cm depth in Vertisols at Patancheru under rainfed conditions (Wani et al., 2003). Under National Agricultural Technology Project (NATP), ICRISAT-NBSS & LUP-CRIDA and IISS have identified C sequestering systems for Alfisols and Vertisols in India (Bhattacharyya et al., 2006). Integrated nutrient management strategies go a long way in improving soil health for enhancing water use efficiency and increasing farmers incomes.

Table 2

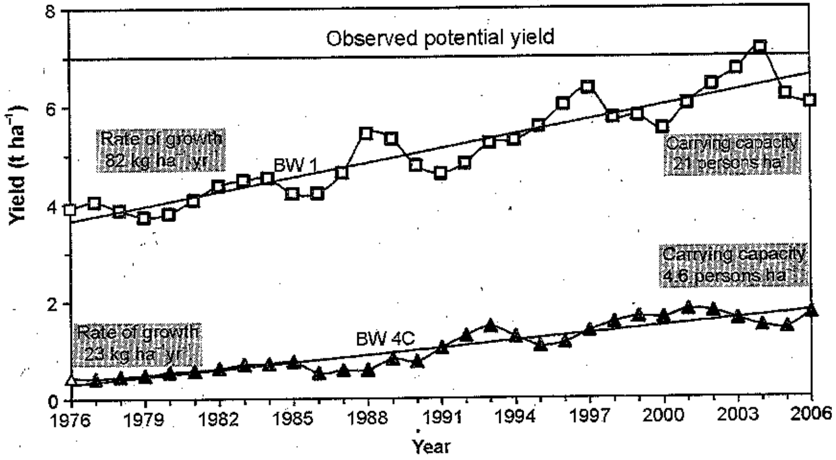
Percentage of Farmers' Fields Deficient in Soil Nutrients in Different States of India

State	*No. of farmers' fields*	*Org.C %*	*Av.P Ppm*	*K ppm*	*S ppm*	*B ppm*	*Zn ppm*
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

Source: Rego et al. 2005.

Figure 3

Three-Year Moving Average of Crop Yields in Improved and Traditional Management Systems during 1976–2006 at ICRISAT, Patancheru, India



Need for a New Paradigm for Water Management in Rainfed Agriculture

For enhancing rainwater use efficiency in rainfed agriculture management of water alone cannot result in enhanced water productivity as in these areas crop yields are limited by more factors than water limitation also. ICRISAT's experience in rainfed areas has clearly demonstrated that more than water quantity *per se* management of water resources is the limitation in the SAT.

Based on the policy on water resource management for agriculture remains focused on irrigation, and the framework for integrated water resource management (IWRM) at catchment and basin scales are primarily concentrated on allocation and management of blue water in rivers, ground water and lakes. The evidence from the comprehensive assessment indicated water for agriculture is larger than irrigation, and there is an urgent need for a widening of the policy scope to include explicit strategies for water management in rainfed agriculture including grazing and forest systems. However, what is needed is effective integration so as to have a focus on the investments options on water management across the continuum (range) from rainfed to irrigated agriculture. This is the time to abandon the obsolete sectoral divide between irrigated and rainfed agriculture, which would place water resource management and planning more centrally in the policy domain of agriculture at large, and not as today, as a part of water resource policy (Molden, 2007).

Furthermore, the current focus on water resource planning at the river basin scale is not appropriate for water management in rainfed agriculture, which overwhelmingly occurs on farms of less than 5 hectares at the scale of small catchments, below the river basin scale. Therefore, focus should be to manage water at the catchment scale (or small tributary scale of a river basin), opening for much needed investments in water resource management also 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, causing difficulties for integrated water management. Recently, steps have been taken to unify the programme according to the "Common Guidelines" (GoI, 2008).

Detailed meta analysis of 311 watershed case studies in India revealed that watershed programmes are silently revolutionalizing rainfed areas with positive impacts (B : C ratio of 1 : 2.14, IRR of 22%, increased cropping intensity by 63%, increased irrigated areas by 34%, reduced run-off by 13% and increased employment by 181 person days per year per hectares) (Table 3). However, 65 per cent of the watersheds were performing below average performance as they lacked community participation, programes were supply driven, equity and sustainability issues were eluding and compartmental approach was adopted (Joshi et al., 2004).

Table 3

Returns were Higher in Medium (2,000–4,000 Rs Ag GDP) and Low (<2,000 Rs Ag GDP) Income States

Indicator	*Particular*	*Unit*	*Per capita income of the region*		
			High	*Medium*	*Low*
Efficiency	B:C ratio	Ratio	1.98 (16.86)	2.21 (12.28)	2.46 (7.73)
Equity	Employment	Person days/ha/year	132.01 (4.14)	161.44 (5.29)	175.00 (4.66)
Sustainability	Irrigated area	Per cent	40.34 (9.73)	23.01 (6.24)	36.88 (4.19)
	Cropping intensity	Per cent	77.91 (8.67)	36.92 (11.99)	86.11 (7.64)
	Rate of run-off reduced	Per cent	12.38 (5.31)	15.82 (3.39)	15.43 (6.01)
	Soil loss reduced	Tons/ha/year	0.82 (40.32)	0.88 (37.55)	0.69 (4.60)
Extent of people's participation			High	High	Low

Source: Joshi et al., 2004.

Based on detailed studies and synthesis of the results, impacts, shortcomings, learnings from large number of watershed programmes and on-farm experiences gained, ICRISAT-led consortium developed an innovative farmers' participatory consortium model for integrated watershed management (Wani et al., 2002, 2003). ICRISAT-led watershed espouses the Integrated Genetic Natural Resources Management (IGNRM) approach where activities are implemented at landscape level. Research and development (R&D) interventions at landscape level were conducted at benchmark sites representing different SAT agro-ecoregions. The entire process revolves around the four E's (empowerment, equity, efficiency and environment), which are addressed by adopting specific strategies prescribed by the four C's (consortium, convergence, cooperation and capacity building). The consortium strategy brings together institutions from the scientific, non-government, government and farmers' groups for knowledge management. Convergence allows integration and negotiation of ideas among actors. Cooperation enjoins all stakeholders to harness the power of collective actions. Capacity building engages in empowerment for sustainability.

The important components of the new model, which are different from earlier models, are:

- Collective action by farmers and participation from beginning through cooperative and collegiate mode in place of contractual mode.
- Integrated water resource management (IWRM) and holistic system approach through convergence for improving livelihoods as against traditional compartmental approach.
- A consortium of institutions for technical backstopping.
- Knowledge-based entry point to build rapport with community and enhanced participation of farmers and landless people through empowerment.
- Tangible economic benefits to individuals through on-farm interventions enhancing efficiency of conserved soil and water resources.
- Low-cost and environment-friendly soil and water conservation measures throughout the toposequence for more equitable benefits to larger number of farmers.
- Income-generating activities for landless and women through allied sector activities and rehabilitation of wastelands for improved livelihoods and protecting the environment.

Integrated watershed management deals with conservation and efficient use of rainwater, groundwater, land and other natural resources for increasing agricultural productivity and improving livelihoods. Water 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 improved 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. The programme outputs are tuned to reduce poverty, minimize land degradation, increase productivity and production, building communities' resilience to shocks due to natural calamities such as drought and flooding as well as the climate variability due to global warming.

Impacts

Through the use of new science tools (i.e., remote sensing, GIS, and simulation modelling), couped with an understanding of the entire food production-utilization system (i.e., food quality and market) and genuine involvement of stakeholders, ICRISAT-led watersheds effected remarkable impacts to resource-poor SAT farm households.

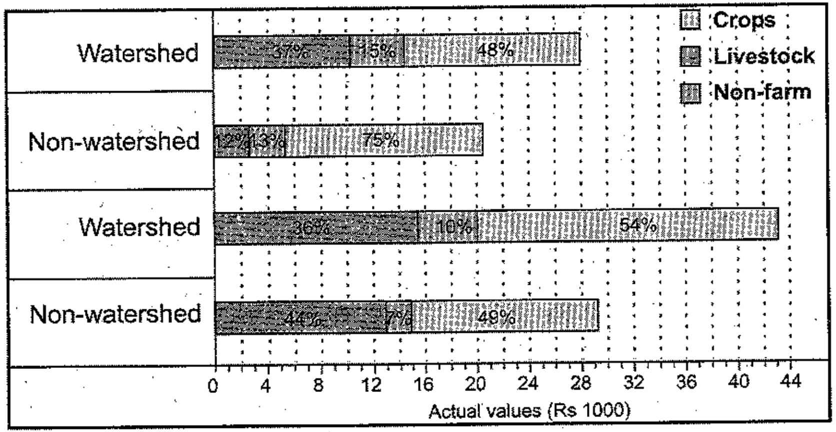
Reducing rural poverty in the watershed communities is evident in the transformation of their economies. The ICRISAT model ensured improved productivity with the adoption of cost-efficient water harvesting structures as an entry point for improving livelihoods. Crop intensification with high-value crops and diversification of farming systems are leading examples that allowed households to achieve production of basic staples and surplus for modest incomes.

Building capacity of farm households through training and networking for improved livelihood enhanced participation most, especially of the most vulnerable groups like women and the landless. The self-help groups (SHGs) common in the watershed villages of India and an improved initiative in China provided income and empowerment of women. The environmental clubs whose conceptualization is traced from Bundi watershed of Rajasthan inculcated environmental protection, sanitation and hygiene among the children.

Building on social capital made the huge difference in addressing rural poverty of watershed communities. A case in point is Kothapally in Andhra Pradesh watershed. Today, it is a prosperous village on the path

Figure 4

Income Stability and Resilience Effects during Drought Year (2002) in Adarsha Watershed, Kothapally, AP



of long-term sustainability and has become a beacon for science-led rural development. In 2001, the average village income from agriculture, livestock and non-farming sources was US$ 945 compared with the neighbouring non-watershed village with US$ 613 (Figure 4). The villagers proudly professed: “We did not face any difficulty for water even during the drought year of 2002. When surrounding villages had no drinking water, our wells had sufficient water”.

To date, the village prides itself with households owning five tractors, seven lorries and thirty auto-rickshaws. People from surrounding villages come to Kothapally for on-farm employment. There were evidences to suggest that with more training on livelihood and enterprise development, migration is bound to cease. Between 2000 and 2003, investments in new livelihood enterprises, such as seed oil mill, tree nursery and worm composting, increased average income by 77 per cent in Powerguda, a tribal village in Andhra Pradesh.

Crop-livestock integration is another facet harnessed for poverty reduction. The Lucheba watershed, Guizhou province of southern China has transformed its economy through modest injections of capital-allied contributions of labour and finance, to create basic infrastructures like access road and drinking water supply. With technical support from the consortium, the farming system was intensified from rice and rape to tending livestock (pig raising) and horticultural crops (fruit trees) like *Zizipus*, and vegetables like beans, peas, sweet potato and groundnut. Forage production, specifically wild buckwheat as an ally crop, was a good forage grass for pigs. This cropping technology was also effective in controlling erosion and increasing farm income in sloping lands. This holds true in many watersheds of India where the improvement in fodder production has intensified livestock activities like breed improvement (artificial insemination and natural means) and livestock centre/health camp establishment resulting in increased incomes.

In Tad Fa and Wang Chai watersheds in Thailand, there was a 45 per cent increase in farm income within three years. Farmers earned an average net income of US$1,195 per cropping season. A complete turnaround in livelihood system of farm households was inevitable in ICRISAT-led watersheds.

Increasing crop productivity is common in all the watersheds and evident in so short period from the inception of watershed interventions. To cite few cases, in benchmark watersheds of Andhra Pradesh, improved crop management technologies increased maize yield by 2.5 times and sorghum by 3 times (Table 4) Overall, in 150 community

Table 4

Crop Yields in Adarsha Watershed Kothapally during 1999–2006

Crop	*1998 baseline yield*	*Yield (kg ha^{-1})*								*Average yields*	*SE+−*
		1999–00	*2000–01*	*2001–02*	*2002–03*	*2003–04*	*2004–05*	*2005–06*	*2006–07*		
Sole maize	1500	3250	3750	3300	3480	3921	3420	3918	3635	3644	283.3
Inter-cropped maize	—	2700	2790	2800	3083	3129	2950	3362	3180	3029	263.0
Traditional		700	1600	1600	1800	1950	2025	2275	2150	1785	115.6
Inter cropped pigeonpea	190	640	940	800	720	949	680	925	970	861	120.3
Traditional		200	180	—	—	—	—	—	—	190	—
Sole sorghum	–1070	3050	3170	2600	2425	2288	2325	2250	2085	2530	164.0
Traditional		1070	1011	938	910	952	1025	1083	995	996	120.7
Inter-crop sorghum	—	1770	1940	2200	—	2109	1980	1958	1850	1971	206.0

Source: Wani et al. (unpublished).

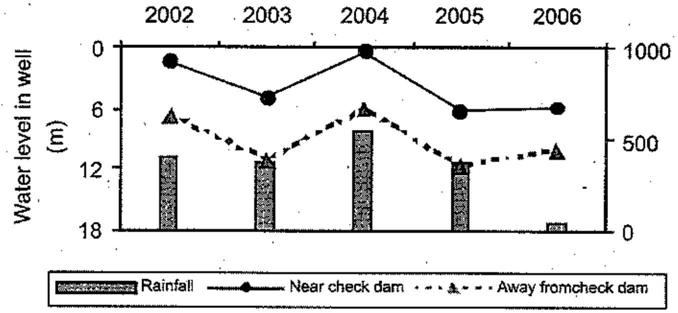
watersheds in India (each measuring approximately 500 hectares), implementing best-bet practices resulted in significant yield advantages in sorghum (35–270%), maize (30–174%), pearl millet (72–242%), groundnut (28–179%), sole pigeonpea (97–204%) and as an intercrop (40–110%). In Thanh Ha watershed of Vietnam, yields of soybean, groundnut and mungbean increased by three to four folds (2.8–3.5 t ha^{-1}) as compared with baseline yields (0.5 to 1.0 t ha^{-1}) reducing the yield gaps between potential yields in farmers' fields. A reduction in nitrogen fertilizer (90–120 kg urea ha^{-1}) by 38 per cent increased maize yield by 18 per cent. In Tad Fa watershed of northeastern Thailand, maize yield increased by 27–34 per cent with improved crop management (Thawilkal et al., 2005).

Improving water availability in the watersheds was attributed to efficient management of rainwater and *in-situ* conservation, establishing water harvesting structures (WHS) and improved groundwater levels. Findings in most of the watershed sites reveal that open wells located near WHS have significantly higher water levels compared to those away from the WHS. Even after the rainy season, the water level in wells nearer to WHS sustained good groundwater yield.

In the various watersheds of India like Lalatora, treated area registered a groundwater level rise by 7.3 metres. At Bundi, the average rise was at 5.7 metres and the irrigated area increased from 207 to 343 hectares. In Kothapally watershed, the ground water level rise was at 4.2 metres in open wells (Figure 5). The various WHS resulted in an additional groundwater recharge per year of approximately 4,28,000 m^3 on the average. With this improvement in groundwater availability, the supply of clean drinking water was guaranteed. In Lucheba watershed, a drinking water project, which constitutes a water storage tank and pipelines to farm households, was a joint effort of the community and the watershed project. This solved the drinking water problem for 62 households and more than 300 livestock. Earlier, every farmer's household used to spend 2–3 hours per day in fetching drinking water. This was the main motivation for the excellent farmers' participation in the project. In Thanh Ha watershed, Vietnam collective pumping of well water and establishing efficient water distribution system enabled farmers' group to earn more income by growing watermelon with reduced drudgery for women who had to carry on head from a long distance, pumping of water from the river as a means to irrigate watermelon has provided maximum income for households (Wani et al., 2006a).

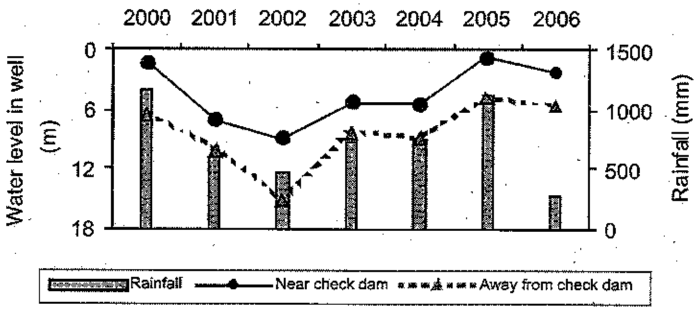
Figure 5
Impact of Watershed Interventions on Groundwater Levels at Two Benchmark Sites in India

Bundi Watershed, Rajasthan



Estimated additional groundwater recharge due to watershed interventions = 6,75,000 m^3 per year.

Adrasha Watershed, Andhra Pradesh



Estimated additional groundwater recharge due to watershed interventions = 4,27,800 m^3 per year.

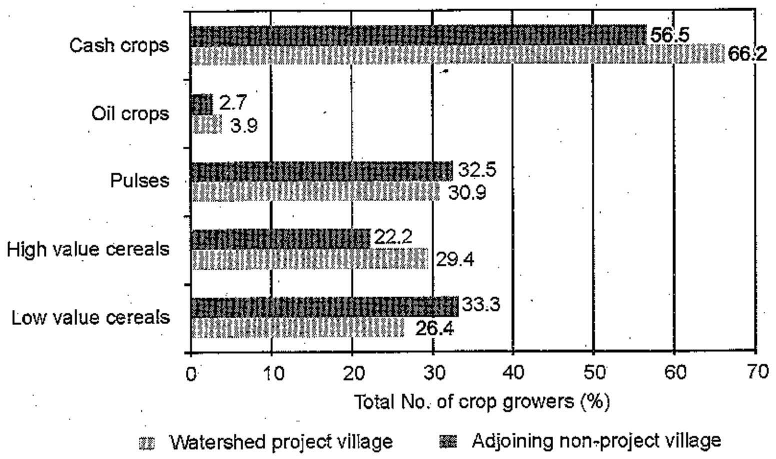
Diversification and marketable surplus: Improved water availability in the watershed not only resulted in increased crop productivity but significant shift in area under cultivation also took place towards high-value cereals, cash crops, vegetables, flowers and fruits, and areas under low-value cereals such as sorghum declined.

Watershed development resulted in increased number of farmers growing more commercial crops and high-value crops as compared to the farmers from the surrounding non-watershed villages (Figure 6).

Currently 100 farmers collectively send 10 tonnes fresh vegetables daily directly to retail vendors in Hyderabad and get Rs 2,000 more per tone than the prevailing wholesale price. Farmers in the developed watershed marketed more quantity as well as earned more income

Figure 6

Effect of Watershed Management on Commercialization of Production, Kothapally, AP



through sale of surplus produce (Figure 7). Watershed development farmers not only during normal rainfall year but also benefited during drought year. In fact, during drought year such as 2002, total amount as well as value (Rs 15,500) of produce marketed was significantly higher as compared to the non-project village (Rs 9,500) (Figure 8).

Sustaining development and protecting the environment are the two-pronged achievements of the watersheds. The effectiveness of improved watershed technologies was evident in reducing runoff volume, peak runoff rate and soil loss and improving ground water recharge. This is particularly significant in Tad Fa watershed where interventions such as contour cultivation at midslopes, vegetative bunds planted with *Vetiver*, fruit trees grown on steep slopes and relay cropping with rice bean reduced seasonal run off to less than half (194 mm) and soil loss less than one-seventh (4.21 t ha^{-1}) as compared to the conventional system (473 mm runoff and soil loss 31.2 t ha^{-1}). This holds true with peak runoff rate where the reduction is approximately one-third (Table 5). Similar results were reported from other watersheds.

Large numbers of fields (80–100%) in the SAT were found severely deficient in zinc, boron and sulphur along with nitrogen and phosphorus. Amendment of the deficient micro and secondary nutrients increased crop yields by 30 to 70 per cent resulting in overall increase in water and nutrient use efficiency (Rego et al., 2005). Crop rotation

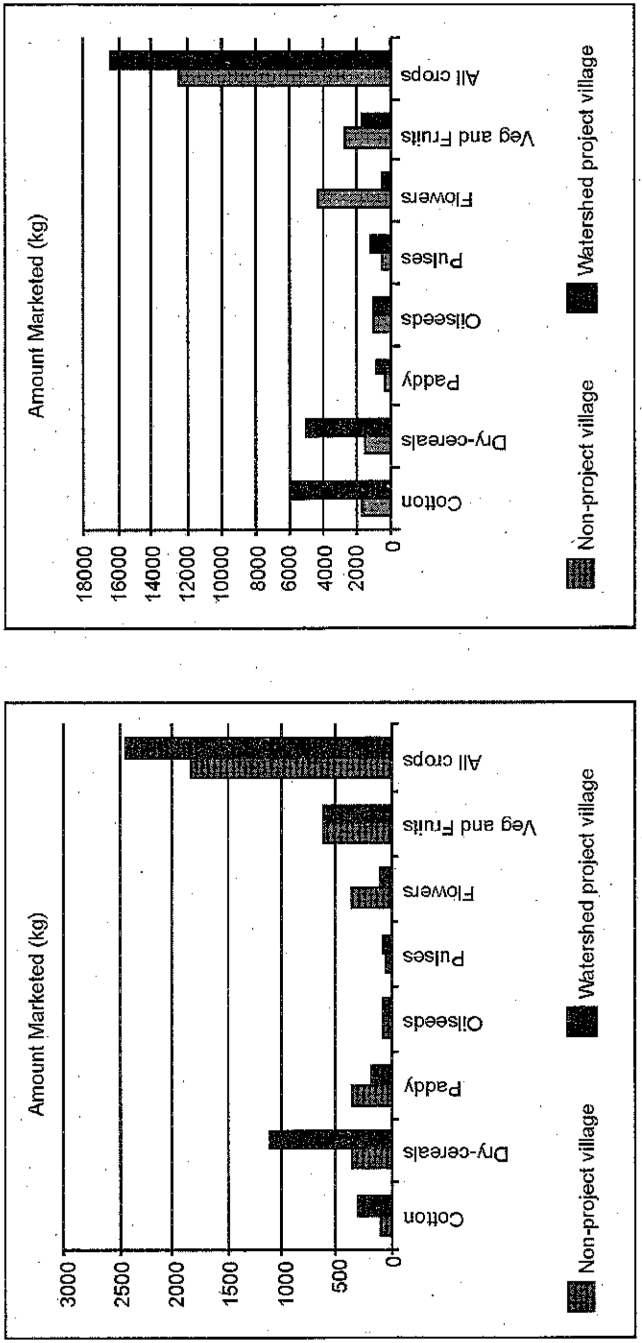
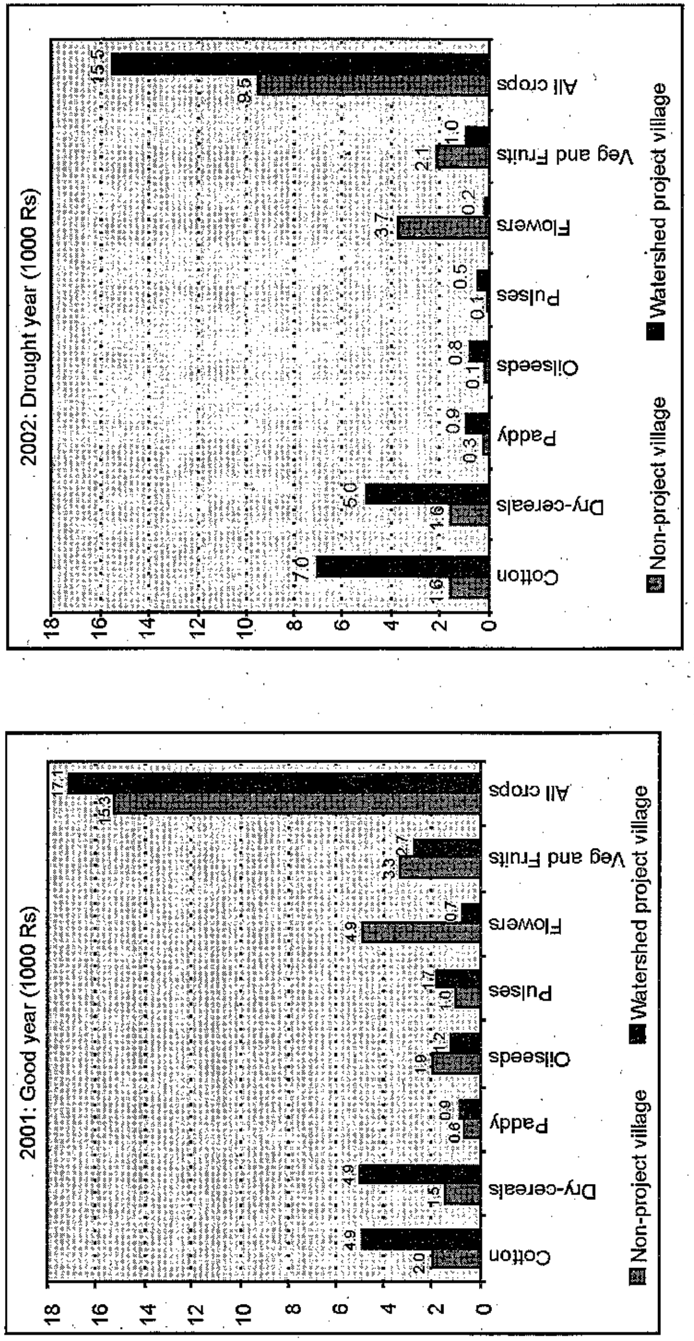


Figure 7

Effect of Watershed Management on Crop Commercialization, Kothapally, 2001–02

Figure 8

Effect of Watershed Management on Amount Marketed and Value in Good and Drought Year at Kothapally



using legumes in Wang Chai watershed substantially reduced nitrogen requirement for rainfed sugarcane. Introduction of integrated pest management (IPM) and improved cropping systems decreased the use of pesticides worth US$ 44–66 ha^{-1}. IPM practices, which brought into use local knowledge using insect traps of molasses, light traps and tobacco waste led, to extensive vegetable production in Xiaoxingcun (China) and Wang Chai (Thailand) watersheds.

Table 5

Seasonal Rainfall, Runoff and Soil Loss from Different Benchmark Watersheds in India and Thailand

Watershed	*Seasonal rainfall (mm)*	*Runoff (mm)*		*Soil loss (t ha^{-1})*	
		Treated	*Untreated*	*Treated*	*Untreated*
Tad Fa, Khon Kaen, NE Thailand	1284	194	473	4.21	31.2
Kothapally, Andhra Pradesh, India	743	44	67	0.82	1.90
Ringnodia, Madhya Pradesh, India	764	21	66	0.75	2.2
Lalatora, Madhya Pradesh, India	1046	70	273	0.63	3.2

Improved land and water management practices along with integrated nutrient management (INM), comprising of applications of inorganic fertilizers and organic amendments such as crop residues, vermicompost, farm manures, *Gliricidia* loppings as well as crop diversification with legumes, not only enhanced productivity but also improved soil quality. Increased carbon sequestration of 7.4 tonnes ha^{-1} in 24 years was observed with improved management options in a long-term watershed experiment at ICRISAT (Wani et al., 2003a). 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_2C) to the World Bank from their 4,500 *Pongamia* trees, seeds of which are collected for producing saplings for distribution/promotion of biodiesel plantation (D'Silva et al., 2004). Normalized difference vegetation index (NDVI) estimation from the satellite images showed that within four years, vegetation cover could increase by 35 per cent in Kothapally (Wani et al., 2003). The IGNRM options in the watersheds reduced loss of NO_3N in runoff water (8 vs 14 kg N ha^{-1}). Introduction of IPM in cotton and pigeonpea substantially reduced the number of chemical insecticide sprays during the season and use of pesticides reduced the pollution of water bodies with harmful chemicals. Reduced runoff and erosion reduced risk of downstream flooding and siltation of water bodies that directly improved environmental quality in the watersheds.

Conserving biodiversity in the watersheds was engendered through participatory NRM. The index of surface percentage of crops (ISPC), crop agro-biodiversity factor (CAF), and surface variability of main crops changed as a result of integrated watershed management (IWM) interventions. 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 hectares in 1998 to 100 hectares in 2002) to a maize/pigeonpea inter-crop system (40 hectares to 180 hectares), 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., 2005a). Similarly, rehabilitation of the common property resource land in Bundi watershed through the collective action of the community ensured the availability of fodder for all the households and income of US $1670 per year for the SHG through sale of grass to the surrounding villages. Above ground diversity of plants (54 plant species belonging to 35 families) as well as below ground diversity of micro organisms (21 bacterial isolates, 31 fungal species and 1.6 times higher biomass C) was evident in rehabilitated CPR as compared to the degraded CPR land (9 plant species, 18 bacterial isolates and 20 fungal isolates of which 75 per cent belong to *Aspergillus* sps.) (Dixit et al., 2005).

Harnessing gender power through integrated watershed approach was evident. Specific activities targeted for women and vulnerable groups enhanced their incomes as well as status in the society.

Enhancing partnerships and institutional innovations through the consortium approach was the major impetus for harnessing watershed's potential to reduce households' poverty. The underlying element of the consortium approach adapted in ICRISAT-led watersheds is engaging a range of actors with the locales (backdrop/setting) as the primary implementing unit. Complex issues were effectively addressed by the joint efforts of ICRISAT and with key partners, namely, the national agricultural research systems (NARS), non-government organizations (NGOs), government organizations (GOs), agricultural universities and other private interest groups with farm households as the key decision-makers. In SHGs, like village seedbanks, these were established not just to provide timely and quality seeds. These created the venue for receiving technical support and building the capacity of members like women for the management of conservation and livelihood development activities. Incorporating knowledge-based entry point in the approach led to the facilitation of rapport and at the same time enabled the community to take rational decisions for their own development. As demonstrated by ICRISAT, the strongest merit of consortium approach is in capacity building where farm households are not the sole beneficiaries. Researchers, development workers and students of various disciplines are also trained, and policy makers from the NARS sensitized on the entire gamut of watershed activities. Private-public partnership has provided the means for increased investments not only for enhancing productivity but also for building institutions as engines for people-led natural resource management.

Case on Women's Feat

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 eked her livelihood as a farm labour till she was introduced to vermicomposting; converting degradable garbage, weeds, and crop residues into valuable organic manure using worms. She earned US$ 36 month^{-1} from this activity. She has also inspired and trained 300 peers in 50 villages of Andhra Pradesh.

Subhadrah bai is key to the change in women's role and transformation of Powerguda (a tribal village) into one of self-sufficiency. She pioneered on integrated watershed management approach and biodiesel enterprise specifically *Pongamia*. With this, her women's group sold carbon credits to the World Bank and gained accolade worldwide.

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

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

From another aspect, the consortium approach has contributed to scaling through the nucleus-satellite scheme and building productive alliances for further research and technical backstopping. With cooperation, a balanced R&D was implemented rather than a 'purist model' of participation or blind adherence to government guidelines. A balanced R&D in watersheds has encouraged scientific debate and at the same time promoted development through tangible economic benefits

The contributions of other international agricultural research centres (IARCs) like the International Water Management Institute (IWMI), International Livestock Research Institute (ILRI) and World Wildlife Fund (WWF) have become allies because of common denominators like goal (poverty reduction) and subject (water resources). It must be reckoned that while centres have their own mandates, these will have to be addressed from a holistic perspective seeking the assistance and contributions of other centres—their technical expertise and findings. This not only maximized the use of resources but the problem situation in watersheds allowed for an integrated approach requiring the alliance of institutions and stakeholders. Similarly, the various networks like the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and Cereals and Legumes Asia Network (CLAN) have provided an added venue for exchange and collaboration. This led to a strong south-south partnership.

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