Research Report No. 61

ICRISAT Research Program
Resilient Dryland System

Improved Livelihoods and Water Productivity through Integrated Watershed Management – A Case Study from China

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International Crops Research Institute
for the Semi-Arid Tropics

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Abstract

ICRISAT in partnership with Guizhou Academy of Agricultural Sciences (GAAS), and Yunnan Academy of Agricultural Sciences (YAAS) implemented two benchmark watersheds namely Lucheba Watershed at Guizhou and Xiaoxincun watershed in Yunnan provinces for the ADB-ICRISAT project on "Improving Management of Natural Resources with Sustainable Rainfed Agriculture" during 2003-2006. Both the watersheds in China had vast untapped potential for enhancing agricultural productivity, however due to low adoption of improved management practices and lack of knowledge to the farmers, the yields till 2002 were low and natural resources like soil and water were prone to severe degradation. Through participatory management, the consortium embarked on implementing integrated watershed management program (IWMP) through improved rainwater management and harvesting, improved soil, crop and pest management options as well as income-generating microenterprises for the community members. The Lucheba benchmark watershed with 1284 mm amount of rainfall annually undertook two drinking water schemes for the villagers as an entry point activity by bringing spring water from hills by pipe to the village. Construction of 151 rainwater harvesting structures cum irrigation water storage tanks, plantation of 133,600 trees on 100 ha wasteland, construction of approach road and crop diversification with high-value vegetable crops in the watershed were undertaken by the community through IWMP. As a result, the family income in Lucheba watershed increased to US$ 2582 in 2007 against the baseline of US$ 973 per annum in 2002. In both the watersheds, empowerment of women was evident with improved livelihoods and incomes which they could spend. The IWMP interventions resulted in enhancing rainwater use efficiency along with the net incomes in Xiaoxincun watershed also. The vegetable growers association and the farmers groups in both the watersheds effectively implemented the watershed activities and successfully protected the natural resources by reducing the erosion using the biogas production from the pig excreta, avoiding cutting the trees for cooking, controlling soil erosion, enhancing water use efficiency and diversifying the crops and livelihood options.

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Suhas P Wani, TK Sreedevi, Raghavendrarao Sudi, Vamsidhar Reddy, Yin Dixin and Zhong Li

Our Partners

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Contents

Background

Dryland agriculture is prone to severe land degradation and particularly so, in steep slope areas as found in northeast Thailand, Vietnam and China. These areas are hot-spots of poverty, malnutrition, water scarcity and are also more vulnerable to impacts of climate change. Large potential of rain-fed agriculture remains untapped as the current crop yields on the farmers' fields are lower by two to five folds than the achievable yields. ICRISAT and its partners in Asia and other researchers in Africa have shown that potential of rain-fed areas can be unlocked by adopting integrated watershed management approach (Wani et al., 2002, 2003, 2009 and 2011 and Rockström et al., 2007).

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has developed a consortium model, which is farmer-centric, holistic and up-scalable one, by adopting the principle of convergence, collective action, capacity building and consortium. The Asian Development Bank (ADB) supported the development of pilot model in Kothapally in India during 1999-2002 through a project entitled "Improving Management of Natural Resources for Sustainable Rain-fed Agriculture". Based on the success of the project during the first phase, the ADB supported the scaling up of this project by establishing 25 benchmark watershed sites in India, Thailand, Vietnam and China. Under this project, two benchmark watersheds namely Lucheba watershed in Guizhou and Xiaoxincun watershed in Yunnan province (Figure 1 and Table 1) were established by adopting the principle of consortium in partnership with Guizhou Academy of Agricultural Sciences (GAAS) and Yunnan Academy of Agricultural Sciences (YAAS) under the umbrella of Chinese Academy of Agricultural Sciences (CAAS), Beijing. The project was implemented with a focus on reducing poverty and land degradation by adopting farmers' participatory watershed

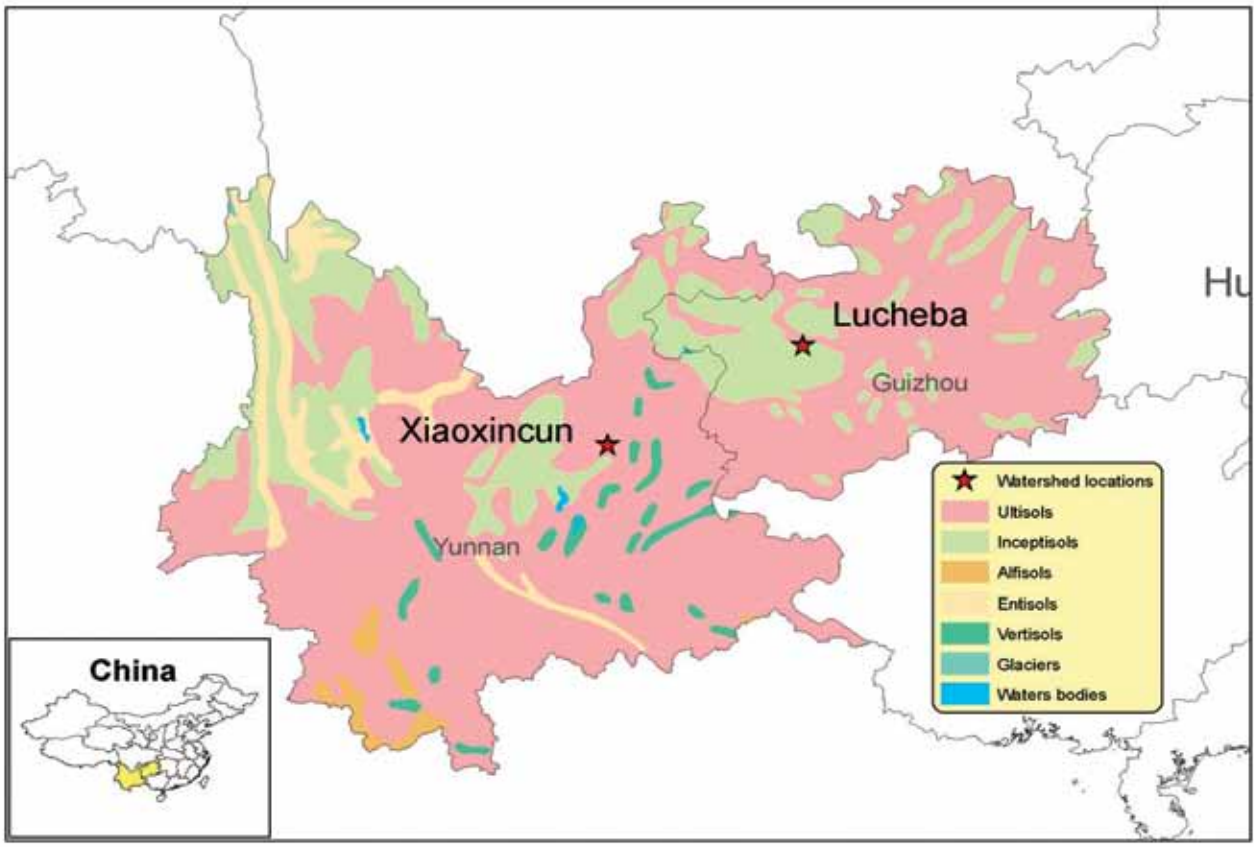

Figure 1. Location of benchmark watersheds and soils in China.

Table 1. Rainfall and other water balance parameters of two benchmark watersheds, China

Parameters	Lucheba	Xiaoxincun
Latitude	25°37' 7.03" N	26°57' 40.74" N
Longitude	103°12' 8.41" E	105°39' 24.22" E
Altitude (MSL, m)	1350	1100
Mean annual rainfall (mm)	1284	641
PET[1] (mm)	891	1464
AET[2] (mm)	831	641
WS[3] (mm)	384	Nil
WD[4] (mm)	60	815

1 PET – Potential Evapotranspiration
2 AET – Actual Evapotranspiration
3 WS – Water Surplus
4 WD – Water Deficit

management approach through the various interventions of integrated watershed management viz. in-situ- and ex-situ soil and water management, improved cropping systems, crop diversification, integrated nutrient management and integrated pest management practices along with other income-generating microenterprises, in partnership with National Agriculture Research Systems (NARSs) and local communities with active participation of farmers.

In this report, after the end of the project, the impact of various watershed management interventions are assessed by undertaking the detailed household survey as well as focus group discussions (FGDs) and the available data sets from various experiments conducted in the watersheds. The specific objectives of this study were:

- to assess on-site impacts of improved watershed management, in terms of increased productivity, water use efficiency, decreased degradation of natural resources, improved water availability and improved livelihoods of farmers
- to study institutional arrangements and collective action in the watershed projects for productivity enhancement and natural resources conservation and management

The multi-disciplinary team of scientists have undertaken the assessment and the findings of this study are reported in this report.

Data Sources and Methodology

Impact assessment of investment on watershed activities was carried out to examine the efficiency of economic returns, etc. This study is based on primary as well as secondary data collected from the watersheds. The primary data was collected through focussed group discussions (FGDs) as well as through stratified detailed household survey (Figure 2). For collecting primary data, a questionnaire was prepared and used. The team visited watershed and conducted meetings with farmers and had elaborate discussions followed by field visits to collect the basic information such as general agriculture, crops and productivity, surface- and groundwater and socio-economic data. The primary data was collected through investigation of farmers and pre-tested questionnaires and 30 households/farmers in each

Figure 2. Data collection for impact assessment at Xiaoxincun benchmark watershed in China.

watershed were selected by stratified random sampling method. The data were collected personally by administering the interview scheduled to the respondents and the objectives of the study were explained to the farmers before conducting survey. The secondary data were collected from various sources like progress reports and other sources. The storage capacity of water harvesting structures was quantified through detailed measurements and other financial details were collected from Project Implementing Agency (PIA). Thornthwaite's method was used to estimate the weekly water balance parameters like actual evapotranspiration, soil moisture, water surplus, water deficit and indices like moisture adequacy index and soil moisture index.

All the primary and secondary data collected for this study were first thoroughly checked for errors or discrepancy. The primary data were analyzed using statistical techniques such as percentage, regression, correlation and coefficient variance analysis.

Description of Benchmark Watersheds in China

The project has been implemented in a consortium mode by ICRISAT and Chinese partners - Integrated Rural Development Center of Guizhou Academy of Agricultural Sciences (GAAS), Guizhou and Tropical and Subtropical Cash Crops Research Institute of Yunnan Academy of Agricultural Sciences (YAAS), Kunming in two benchmark watersheds in China – Lucheba watershed in Guizhou province and Xiaoxincun watershed in Yunnan province, since 2003.

Lucheba Watershed

Lucheba watershed is located at latitude 25° 37′ 7.03″ N and longitude 103° 12′ 8.41″ E in the central region of Guizhou province, 75 km away from capital Guiyang. It belongs to Tianlong Township of Pingba County. The watershed is part of the Wujiang river basin. Its altitude is 1350 m above mean sea level with average rainfall of 1284 mm y^{-1}. The watershed comes under the climate of sub-tropic humid monsoon zone with hilly topography with an average temperature of 13.8°C and belongs to karst landform. The population is 1350 with 365 households dispersed and in 11 such natural villages (hamlets) are there on the township with six farmers village groups. The total area of the watershed is 721 ha, out of which 54%

is wasteland (390 ha). The per capita paddy land is 0.06 ha, upland 0.1 ha and garden land of 0.006 ha. Total paddy land is 78 ha out of which 60 ha is irrigated by reservoir constructed in 1970 and remaining is rain-fed. All the upland crops in 131 ha are rain-fed. Major crops are rice, corn, rape seed, soybean, sunflower, kidney bean, cabbage, watermelon and vegetables like tomato, pumpkin, chillies, eggplant, etc. Rice-rape seed, corn-rape seed were some of the major cropping systems as recorded in the baseline survey. Farmers apply huge quantities of FYM and chemical fertilizers for their crops.

Water Balance of Lucheba Watershed

Weekly water balance was computed with an average rainfall of 1284 mm, potential evapotranspiration (PET), actual evapotranspiration (AET), water surplus (WS) and water deficit (WD) were 891, 831, 384 and 60 mm respectively. The water balance study revealed that the watershed has lower annual PET values of 891 mm compared to annual rainfall of 1284 mm and also it records large water surplus, particularly during June and July with a quite good potential for water harvesting (Figure 3). The long-term rainfall data (45 years) annual rainfall varied from 920 mm to 1651 mm and the monthly rainfall above 100 mm was for six months (May- October) (Rao et al., 1999).

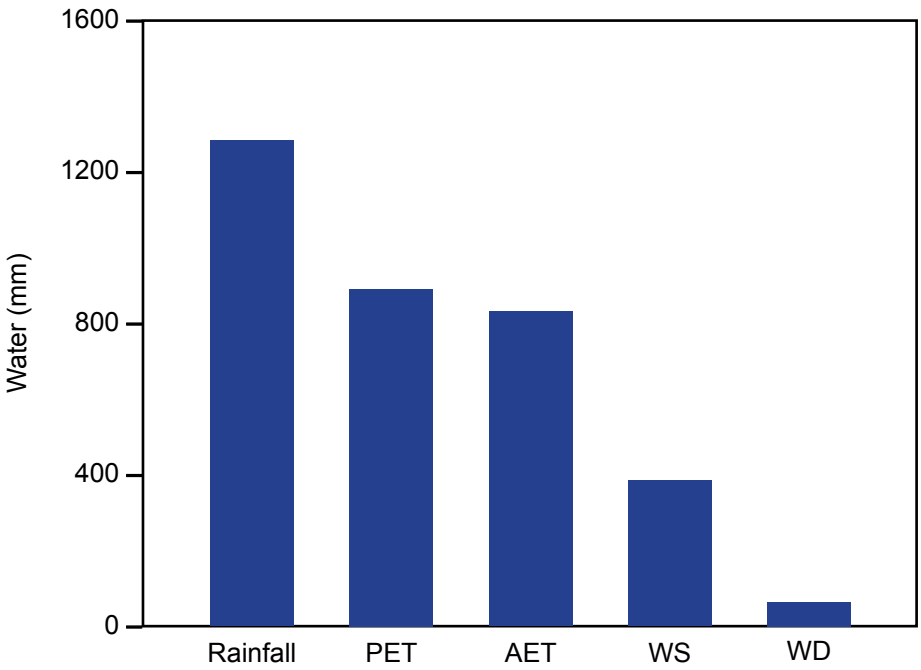

Figure 3. Water balance components of Lucheba watershed, China. (Source: Rao et al., 1999)

Major Constraints Perceived in the Watershed

Through FGDs and participatory rural appraisal (PRA) following constraints were highlighted by the community. Major constraints perceived by the community in the watershed for the increasing productivity and incomes were:

1. Soil erosion
2. Water scarcity

3. Low moisture retention capacity of soils
4. Low crop productivity
5. Fodder scarcity
6. Lack of proper infrastructure (viz. drinking water, accessibility, market)

Integrated Watershed Interventions

All the activities were undertaken in participatory mode with the community. The communities were involved from the beginning with constraint identification, prioritization of interventions, mode of implementation, monitoring and evaluation and impact assessment. For all the interventions in the watershed, the community contributed their share along with the government department and ADB-ICRISAT Project (Figure 4).

- As an entry point activity two drinking water schemes were completed by harvesting water from natural springs and brining it in villages through pipeline
- Construction of small masonry water tanks (cistern) (151 nos.) of 5 m^3 capacity for runoff water storage and used for irrigating vegetable and other crops.
- Cultivation on contour and across the slope
- Soil test-based balanced fertilization introduced and soils were found deficient in K
- Cost-effective pest control through integrated pest management (insecticidal lanterns)
- Forage grass production was taken up in 16 ha
- Afforestation in wastelands (100 ha)
- Establishment of 260 biogas plants in the village households reduced pressure on fuel wood to protect forest.
- Infrastructure development through roads construction in the villages was undertaken to link the villages to connect to main road to facilitate easy vegetable transportation
- Poultry farming, rabbit farms and livestock rearing
- Internet connectivity at community level
- Capacity building in improved farming and income-generating activities (IGAs)

Figure 4. Various interventions implemented in the watershed.

Results and Discussion

Impacts of Various Interventions

Land Use Pattern

The watershed interventions had clear impact on the land use pattern (Table 2). Average households land area with irrigation has increased substantially (94%) and rain-fed area reduced (34%). There is also significant increase in the area under horticulture and high-value crops like vegetable cultivation of average household due to improved water conservation measures along with other improved practices.

Table 2. Average households land use pattern during pre- and post-project.

	Area (ha)		
Land use pattern	Pre-project	Post-project	% change
Landholding per household	0.62	0.62	Nil
Rain-fed	0.44	0.29	-34
Irrigated	0.17	0.33	94
Vegetable crops	0.1	0.21	110
Horticulture	0.01	0.02	100
Forest	0.03	0.03	nil
Wasteland	0.02	0.02	nil

Water Productivity

The average cultivated area of households under different cropping pattern show that there is a drastic shift to the vegetable and high-value crops from the traditionally grown rice- and maize-rape seed system due to additional water availability owing to rainwater harvesting measures in the project ensuring higher income to the farmers. The average area under cultivation of rice, maize and peas has decreased by 18 and 38% respectively, while the area under cultivation of high-value crops like vegetables increased by two to six folds. The crops' yields also significantly increased in the range of 6-19% in rice and maize, while for different vegetables, the yields were 32– 673% (Table 3).

Table 3. The average crops yields and the cultivated area of households during Pre- and post-project period, Lucheba watershed.

	Pre-project				Post-project				Change (%)	
Crops	Yield (t ha^{-1})	SE	Area (ha)	SE	Yield (t ha^{-1})	SE	Area (ha)	SE	Yield (t ha^{-1})	Area (ha)
Rice	6.36	0.017	0.16	0.322	6.75	0.004	0.13	0.225	6	-18
Maize	5.89	0.047	0.354	0.342	7.03	0.036	0.22	0.293	19	-38
Tomato	4.50	0.004	0.006	3.147	34.77	0.010	0.04	7.358	673	582
Chilli	23.20	0.009	0.065	2.765	34.28	0.026	0.20	2.248	48	210
Cabbage	29.10	0.013	0.103	3.072	38.45	0.021	0.20	2.735	32	95

Table 4. Rainwater use efficiency of vegetable crops and watermelon during pre- and post-project in Lucheba watershed.

Crops	Pre-project period (2003)		Post-project period (2005)		Increase (%)
	Crop yield (t ha^{-1})	RWUE* (kg mm^{-1} ha^{-1})	Crop yield (kg ha^{-1})	RWUE* (kg mm^{-1} ha^{-1})	
Rice	6.36	4.95	6.75	5.26	6
Maize	5.89	4.59	7.03	5.48	19
Vegetables	36.9	28.8	41.9	32.6	13
Watermelon	11.3	8.8	29.3	22.8	161

* Rainwater use efficiency (kg mm^{-1} ha^{-1}) = Crop yield (kg ha^{-1})/mean annual rainfall (mm)

Rainwater use efficiency (RWUE) of rice, maize, vegetables and watermelon during pre- project were 4.95, 4.59, 28.8 and 8.8 kg mm^{-1} ha^{-1} while post-project are 5.26, 5.48, 32.6 and 22.8 kg mm^{-1} ha^{-1} respectively. The RWUE increased by 6-19% in cereals and vegetables and 161% in watermelon due to watershed interventions (Table 4).

To increase and sustain the yields of the high-value crops such as vegetables and fruit crop like watermelon, 151 small masonry water tanks with storage capacity of 5 m^3 were constructed. These tanks served as runoff harvesting and storage to provide supplemental irrigation during critical growth stages to field crops, mainly to vegetables and watermelon, reducing the risk of water stress due to erratic rainfall causing drastic reduction in yield and thus farmers were encouraged to go for high-value crops which involved high unit production cost compared to other annual crops. On an average a total of 37,750 m^3 (about 63 mm) of runoff water was harvested in these tanks. These tanks provided supplementary irrigation covering 60 ha benefiting 141 households. Substantial increase in the area under high-value crops were observed from the data — 40 ha in 2003 (vegetables 30 ha and watermelon 10 ha), while 113 ha in 2005 (vegetables 80 ha and watermelon 33 ha).

In three years (2003-2005), the net yield advantage and net monetary benefit per unit of water conserved for watermelon and vegetables were 287.3 and 78.7 kg mm^{-1} ha^{-1} respectively. Net monetary benefits for vegetables and watermelon were 147.1 and 83.4 RMB (US$ 18 and 10) mm^{-1} ha^{-1} respectively, which reflected a similar trend of net monetary advantage per unit area were 9253 and 5246 RMB (US$ 1,141 and 647) ha^{-1} respectively over three years due to availability of water during most critically required stage by these crops as a result of water harvesting tanks that facilitated the supplementary application of water (Table 5). The increase in the net returns of vegetable per unit of water per unit area was about 3.5 times in 2005 compared to 2003.

Li et al., (2000) reported that when sub-surface runoff storage tanks were used for supplemental irrigation with wheat crop grown in Gansu Province, China, water use efficiency on an average increased by 20% (10.3 kg mm^{-1} ha^{-1} with supplemental irrigation from 8.7 kg mm^{-1} ha^{-1} in rain-fed system), which consisted small masonry tanks of 10 – 60 m^3 capacity. The incremental water use efficiency ranged from 17-30 kg mm^{-1} ha^{-1}. Similar results were observed in maize with incremental water use efficiencies ranging from 15-62 kg mm^{-1} ha^{-1} of supplemental irrigation from runoff harvesting masonry tank system.

The benefit-cost ratios in vegetables and watermelon are shown in Table 6. Similar trend of benefit-cost (B:C) ratios are recorded during pre- and post-project period. The B:C ratios during pre-project for rice, maize, vegetables and watermelon were 1.77, 1.26, 1.40, 0.50 respectively and during post-project

Table 5. Effect of watershed interventions on crop yields per unit of water conserved at Lucheba watershed, China.

Crops	Net yield advantage (kg ha^{-1})	Yield advantage per unit of water conserved * (kg mm^{-1} ha^{-1})	Net monetary advantage (RMB ha^{-1})	Net monetary advantage per unit of water conserved# (RMB mm^{-1} ha^{-1})
Rice	390	6.2	535 (66) $	8.5 (1.1)
Maize	1140	18.2	1396 (172)	22.3 (2.8)
Vegetables	5000	78.7	9253 (1141)	147.1 (18.1)
Watermelon	18100	287.3	5246 (647)	83.4 (10.3)

*Yield advantage per unit of water conserved (kg mm^{-1} ha^{-1}) = Net increase in yield (kg ha^{-1})/ water conserved (mm)
Net monetary advantage per unit of water conserved (RMB mm^{-1} ha^{-1}) = Net benefit (RMB ha^{-1}) / water conserved (mm)
$ values in the parentheses are US $ (1US $=8.11 RMB)

Table 6. Effect of watershed interventions on benefit-cost ratio at Lucheba watershed, China.

	Pre-project		Post-project		
Crops	Yield (t ha^{-1})	B:C	Yield (t ha^{-1})	B:C	% increase in B:C
Rice	6.36	1.77	6.75	1.89	7
Maize	5.89	1.26	7.03	1.56	24
Vegetables	36.9	1.4	41.9	1.84	32
Watermelon	11.3	0.47	29.3	1.46	210

were 1.89, 1.56, 1.84, 1.46 respectively (Table 6). Higher B:C ratios were observed with vegetables than watermelon during both pre- and post-project period.

Crop Diversification

Watermelon Cultivation

Watermelon is main cash crop in the village, but the price varies depending on the weather at the time of selling. During 2003, watermelon was grown in 500 mu (33.3 ha) area. Due to very low market price, farmers incurred huge loss. In 2004, only 13.3 ha of watermelon was planted, but farmers had high returns due to good price in the market. During this year, the farmers harvested 450 t of watermelon with an income of 360,000 RMB. The price of the watermelon in 2005 was 800 RMB t^{-1}, which was higher than in 2003 (600 RMB t^{-1}). For the Liujiazhai farmers group, income from watermelon was estimated 6000 RMB per household, over 50% of this farmers' group income.

Vegetable Cultivation

Vegetables are also major crops in the village, because farmers could plant vegetables two or three times in same land, so the risk is lower than watermelon. Farmers can have high income from next vegetable planting even if the first vegetable crop had low price. Chilies, tomato, Chinese cabbage are the main crops

Table 7. Watermelon and vegetable development at Lucheba watershed in 2003 and 04.

	2003				2004			
Cash crops	Area (ha)	Total yield (t)	Yield price t^{-1} (RMB)	Total RMB (x1000)	Area (ha)	Total yield (t)	Yield price t^{-1} (RMB)	Total RMB (x1000)
Watermelon	20.0	500	600 (74)*	300 (37037)	13.3	450	800 (97)	360 (44390)
Cabbage	11.3	850	560 (69)	476 (58693)	22.0	1750	540 (67)	945 (116523)
Tomato	7.3	440	440 (54)	194 (2392)	6.0	360	600 (74)	216 (26634)
Chili	3.3	112.5	1300 (160)	146 (18003)	4.7	210	1100 (136)	231 (28483)
Others	3.3	155	1400 (172)	217 (26757)	4.7	220	1100 (136)	242 (29840)
All vegetables	25.3	1557.5	3700 (362)	1033 (127374)	37.3	2540		1634 (201480)
Total watermelon & vegetable	45.3	2057.5		2366 (291739)	58.7	2990		1994 (245869)

* values in parantheses are in US $

in the village. In 2003 total area under vegetable was 25.3 ha and in 2004 it was 37.3 ha (Table 7). Yield in 2004 was 2540 t with a total income of 1,634,000 RMB (US$ 2,01,480), respectively increased yield of 982.5 t (58.20%) and income of 601,150 RMB (US$ 74,125). It was estimated in the Baobaoshang farmers group that each household on an average had income of 10,000 RMB (US$ 1,233) of which 70% income came from vegetables cultivation. Although farmers were interested to grow vegetable in more area, often market fluctuations and market related information and service were a major limiting factors.

Participatory Sweet Potato Varietals Selection

A community sweet potato nursery had been established in a farmer's house garden. Several promising sweet potato cultivars were grown in the chosen farmer's field for the benefit of other farmers to evaluate and select improved suitable varieties. This activity ensured the availability of seed material to neighboring watersheds also. Fourteen farmers have simultaneously evaluated selected cultivars in 2005 through 'farmer-to-farmer' approach (Figure 5).

Horticultural Crops

Due to highly and fluctuating vegetable prices, farmers were encouraged to grow fruit crops and horticultural crops either as biennial crops or perennial crops on wastelands. Eighty-six farmers were encouraged to take-up home gardening of horticultural crops like jackfruit, papaya along with vegetables for sustained profits (Figure 6). Farmers were trained in nursery raising and other horticultural techniques. Thirty-five farmers were growing jujube fruit trees while 15 farmers grew papaya in the irrigated land during 2005.

Figure 5a. Community varietial nursery of sweet potato.

Figure 5b. Farmers field trials of sweet potato.

Figure 6a. Home garden with jack fruit, papaya and chili pepper.

Papaya

Figure 6b. Crop diversification horticultural crops.

Income-generating Livelihood Activities

Forage Production and Livestock Development

Qualitative and quantitative enhancements in fodder productivity were contemplated through introduction of *Panicum, Stylosanthas*, rye grass and pigeonpea (Figures 7 and 8). Twenty-six farmers demonstrated productivity of seven species of fodder. Fodder productivity and palatability as animal feed was also evaluated. Farmers considered *Panicum maximum* as the most acceptable species of fodder followed by Italian rye grass (*Lolium multiflorum)* for animals from their evaluation.

Figure 7. Farmer grown Panicum on upland instead of sweet potato.

Figure 8. Farmer is cutting and collecting rye grass.

Due to increased water availability, area under the forage production and its yield has increased substantially. Forage production in alley cropping was introduced on slopping land to control soil erosion while providing most needed forage for pigs raising, which provides additional income to farmers. Prior to 2003, negligible area was under cultivation of forage grass in the watershed, depriving the animal husbandry activities. From an area of 8.4 ha with a yield of 36.9 t ha^{-1} in 2003 to 15.7 ha with an yield of 41.9 t ha^{-1} in 2004-05, reflected an increase of area by 100% and forage yield by 32% in three years.

The increase in forage production has enhanced the livestock development activities in the watershed. It is quite evident from the data reported by Animal Husbandry Office of Lucheba watershed (Table 8). The increase in the number of animals shown in the Table 8 was the population at the end of year, but in some cases like pigs, baby pigs would have been sold in two months and fat pigs in five months, which were not included in the Table 8. It clearly indicates the drastic increase in chicken (115%) and pigs (99%) during the project period.

Figure 9 shows the four promising species grown as percent of total forage area under cultivation in 2005.

Some interested farmers volunteered to grow pigeonpea (*Cajanus cajan)*, *Neonotonia wightii* and stylo (*Stylosanthes guianensis*) on their own to assess value of these fodder crops. One farmer experimented growing rye grass in the fall and *Medicago sativa* in the winter on irrigated land for year-round forage production as supplementary to feed rabbits. Some farmers have grown pigeonpea as a fence crop and also to provide protein rich nutritive fodder along with forage grasses.

Table 8. Livestock development at Lucheba watershed, 2003-2005.

	Livestock population (No.)		
Livestock	2003	2005	Increase (%)
Cattle	195	217	11.2
Pigs	512	1017	98.6
Chicken	738	1589	115.3
Duck	251	301	19.9
Goose	120	136	13.3

(Source: Animal Husbandry Office, Tianlong Township)

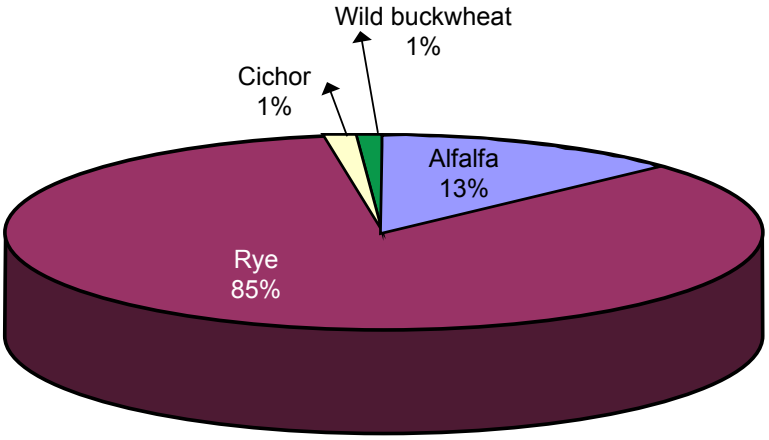

Figure 9. Forage grasses grown in at Lucheba watershed, China, 2005.

Poultry Farming

Increased water availability in the watershed villages enabled the farmers to grow two to three vegetable crops in a year. With vegetables, farmers' incomes tripled (3000 RMB to 10,000 RMB y^{-1}) and the farmers invested in poultry farming which has pulled the family out of poverty (see Box 1)

Box 1: Mrs. Song Pangying in Lucheba becomes a micro-entrepreneur

Mrs. Song Pangying is the wife of Mr. Peng who has 1 ha land in the watershed. Before watershed development Mr. and Mrs. Peng's family had income of 3,000 RMB (US$ 478) per year from the land. However, with increased water availability, family started growing three crops of vegetables in a year. With increased income to 10,000 RMB (US$ 1594) per year, family started investing in poultry farming. Now Mrs. Song Pangying is running a small shop in another nearby village. She comes home once in a week. She is earning 30,000 RMB (US$ 4780) per year. Although, all the money is held jointly in family she spends about 33% on her own. She works for 17 hr where as Mr. Peng works for 8-12 hr, clearly indicating increased workload on her.

Mrs. Song's daughter in law Mrs. Caiyang Ju, elder son's wife is 22 years old and has completed middle level high school and can converse a little in English. She cooks for the family and takes care of house in the absence of her mother in law. She feeds the animals and also does house work. She does not hold any money with her but she can spend the jointly held money in the family. She plans to expand vegetable cultivation to earn more income for the family to have better life.

In the family they do discuss about ways to increase family income? She said "Prior to biogas plant we used coal for cooking but it used to be a costly affair and gas is very cheap for us". (However, she does not find any time saving due to biogas but it is clean and she has no clue about the adverse impacts of coal burning on environment).

Even with increased workload Mrs. Song and Caiyang Ju are happy with increased family incomes.

Rabbit Farming

One trained farmer runs a rabbit farm in the area. Rabbit farming includes trials on stall-feeding techniques and skill development on rearing new exotic rabbit breeds (Figures 10 and 11). Most importantly this farm was developed as the community rabbit-breeding center, to further provide animals on loan scheme initiative with micro credit. Approximately 27 m^2 stalls with 72 cages was built to house 31 quality New Zealand breeds and 16 quality indigenous breeds in July 2005.

Controlled stall feeding of rabbits, goats and cattle

Stall-feeding is adopted with an objective of reducing uncontrolled open grazing by goats and cattle, so as to reduce land degradation from cultivable area and wastelands. To evaluate economic advantages of stall feeding, livestock stall-feeding was encouraged for instant-profits. Pigs - the most popular livestock was also being evaluated with stall-feeding and increased economic benefits by reducing wastage of grain (Figure 12).

A small intervention called pig rearing bank was started by working team in Mashangchong group, Lucheba Village in September, 2004. Twenty five farmers' households [(total 40 in the farmers group) were involved. The fund from farmers and project (both contributed 50% each, total is 10,000 RMB (US$ 1,233] was deposited to the pig-feeding bank. In the first round, each of the 10 farmers' households (out of 25 households) had a fund of 1,000 RMB (US$ 123). This amount was enough to buy 3-5 young pigs. After five months, the borrowed money plus interest was returned to the management group

Figure 10. Introduced New Zealand rabbit as the start-up capital of community micro credit scheme.

Figure 11. Cages for rabbit breeding use.

Partly stall feeding cattles

Stall feeding of pigs in piggery

Figure 12. Stall feeding of livestock for enhanced benefit.

(committee) and another ten farmers received the funds, after another five months, the remaining five farmers and additional another five farmers were randomly selected from 20 farmers for providing the loan. After 15 months the project fund became 13,100 RMB (US$ 1,615), which was managed by the village management committee. This project was developed after PRA and farmers showed keen interest and active participation. Farmers selected the project, it was managed by them and they had set up the farmers' management committee and played major roles in the project period. Every farmer's household had direct net benefit of 900-1,500 RMB (US$ 185) from this micro enterprise. It also encouraged farmers to grow grass in their farmland, that greatly increased the number of animal raising. The number of pigs increased from 17 to 52 in first round of the ten farmers, that is almost three times than in 2003 (Table 9).

Table 9. The pig rearing by Mashangchong farmers group, Lucheba watershed in China during 2003–2004.

Farmer	No. of pigs		% increase
	2003	2004	
Pen Xuegan	5	7	40
Pen Guangsheng	2	5	150
Pen Fayou	2	7	250
Pen Fade	0	3	100
Yang Xuxue	1	5	400
Cheng Qiaogui	2	5	150
Cheng Degui	3	12	300
Shi Hongfa	0	3	100
Cheng Zhuwen	2	5	150
Total	17	52	205

Box 2: Mrs. Wang Xianhui, Women Group Leader in Lucheba Says Our Village Environment is Cleaner than in the Cities

During the FGD in Lucheba Watershed women came forth happily to discuss with the project team. With the initial introductory discussions when the team asked them about the watershed activities and the impacts they can feel themselves, the members were very enthusiastic and indicated the impacts in their own words:

- On an average all families' incomes increased by 1,200 RMB per year.
- Mrs. Wang Xianhui, group leader stated, "I wanted to go to city for better income but now I don't want to go to city as we all are having better income in the village itself. Moreover, in a village environment is better and cleaner than the city."
- When men stated that workload on women has increased *substantially*, women said " We are happy as our family incomes have also increased substantially and we need to learn new methods more to earn additional income. With increased incomes whole family is happy.
- They wish to provide better opportunities for their children to learn and have better life. At present 33% women had no formal education where as 66% had middle level and elementary levels education (33% each).
- Women stated that they wish to invest their additional income in better water use system and roads.
- Collective action in the village has increased immensely for men as well as women members. Women in the village meet together to organize festivals. Discuss how to maintain village traditions? How to enhance use of new technologies? They do undertake excursions, group singing etc. which serves as good social bonding.
- They feel, diversification with fruit trees in this region will benefit them more.

Box 3: Mr. Yang, Village Chief of Lucheba Proudly Reels out the Watershed Benefits

During the FGD with a group of 30 farmers at Lucheba team introduced and enquired about the watershed project interventions as well as the benefits what the community sees. Mr. Yang, Village Chief stated that:

- In all 1,347 population is residing in 43 Km^2 area with 340 households in 6 village farmers groups (11 natural villages) have benefited immensely in terms of improved life quality, environment, increased incomes (300 RMB per capita per year).
- Well trained farmers with new technologies (e.g. improved water use technologies, planting methods, growing vegetables and fodder, soil conservation etc.) are able to cope up now better to any adverse situation as low market prices for the water melon during last year.
- The change in the village which has happened is that farmers have started growing vegetables instead of rice; animals are fed with fodder than corn; farmers harvest water and are much concerned with efficient use of water.
- The project has introduced water harvesting, soil conservation, fodder and vegetables cultivation.
- In the opinion of men workload on women is almost doubled due to vegetables cultivation.
- Farmers are diversifying their enterprises for example Mr. Cai Bepi Gui one of the vegetable growing farmers has recently purchased a transport vehicle to transport vegetables to a nearby market. His vehicle has costed him 13000 RMB.
- The irrigation project is benefiting 260 farmers, 67 households to move out of poverty by growing vegetables.

Box 4: Improved Livelihoods of Luchea Watersheds

Mr. Peng Fay Ou, a normal farmer with 1 ha landholding in Lucheba watershed in China, has seven members in the family and was earning 3000 RMB per year. However, with the watershed project interventions his agricultural income has been raised by three folds to 10000 RMB per year and it is largely due to growing vegetables thrice in a year using the harvested rainwater. The way Mr. Peng Fay has moved out of the poverty leveraging the allied sector activities through increased income is exemplary. He is having 200 chicks and plans to sell these when they are 70-days old. He is expecting 30 RMB per bird and total income of 6,000 RMB. He has 2 female pigs, 7 male pigs and 15 piglets which he sold at 1,500 RMB. He also has one buffalo. His income has increased to 4,000-5,000 RMB 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 project activities.

Mr. Chen Shao Bao is another enterprising farmer who has 1,500 chicks in his unit for the first time. He said “income from pigs was less and they decided to invest more in poultry to earn more income. From pigs he got 10,000 RMB total income whereas by investing 4,000 RMB in chicks he will get 7,000 RMB net income in less time. He plans to have 20 days cycle for the poultry. His mother Liu Yun Zhen helps him taking care of the poultry. His family is a joint family with eight members. Similarly, there are 10 other farmers who are rearing poultry in this group of 44 farmers.

Eco-friendly Alternate Energy Sources

Biogas Production Units

Livestock rearing in the watershed was accepted not only by the farmers but also by the local government with its encouragement for safe disposal and efficient utilization of animal litter. In 2005, this watershed village was presented as the model village for biogass (methane) production and utilization in the country. Biogas production encouraged farmers to use night soil, cattle and pig waste and rural wastes for the production of dependable alternative source of energy, besides improving the quality of manure. Gas production helped reducing energy costs and bush cutting for firewood in the villages. The substantial increase in the animal population was attributed to increased forage production which was instrumental in promoting the biogas plants for daily energy need for cooking and lighting in the watershed villages (Table 10 and Figure 13). Biogas provided safe, clean and low-cost energy while protecting the forest wood and coal as their fuel need and farm yard manure requirement on the farm. The survey revealed that 260 biogas plants were constructed in the watershed, and in 2009 and 2011, that is about 80% of households used biogas energy for domestic use viz. cooking and lighting in the watershed. A biogas tank of 8 m^3 provided enough energy for a family of six with litter of four pigs. Increased availability of fodder also increased the number of pigs facilitating farmers to have their own biogas plants. On an average farmers use to spend about 690 RMB (US$ 85) per annum per household (at the rate of 2.5 – 3.0 t y^{-1} coal use costing 250 RMB (US$ 31) t^{-1}) on purchase of coal, where as now, by installing the biogas plants farmers saved this money on coal in addition to firewood.

Table 10. Various energy sources utilized during Pre-and post-project for domestic purposes by household in Lucheba watershed.

	% of household using	
Source	Pre-project	Post-project
Biogas	3.3	69.9 (255nos.)
LPG	nil	6.70
Electricity*	39.3	51 (106)
Fire wood	53 (204)	23(32)
Coal**	69.8 (269)	25.9 (100)
Solar	nil	2 (7 nos.)

*values in parentheses are electricity consumption in kw h^{-1} $month^{-1}$
**values in parentheses are quantity used in kg $month^{-1}$

Solar Energy

Seven solar water heaters were installed in the watershed villages as alternate eco-friendly energy sources for domestic use that reduces the pressure on the use of fire wood or electricity (Figure 14).

The usage of electricity has increased due the subsidy offered by government (earlier cost of electricity was 1 RMB $unit^{-1}$ and reduced to 0.5 RMB $unit^{-1}$ presently).

Figure 13. Biogas used for cooking and lighting in Lucheba watershed, China.

Figure 14. Solar water heaters installed in the watershed farmers houses.

Development of wastelands in the Lucheba watershed, Guizhou province, China

Afforestation of 53.3 ha of wasteland was developed in the watershed by forest department in consultation with the community. About 133,600 of fir and cyprus trees were planted in the watershed during the year. The survival ratio was below 60%, in most of the area, except in the Liujiazhai farmers group where the survival ratio was more than 80%. This was mainly due to the better support from the community.

Household Income and Dietary Pattern

The increase in the average household net income from farm, non-farm and livestock were 237, 133 and 89% respectively, while the increase in the total income during post-project was 166% compared to their pre-project household income (Table 11).

The increase in the household income had positive impact on the dietary pattern (Table 12). There was significant improvement in the consumption pattern of different diet viz. meat, fish, vegetable and milk, while in case of cereals consumption it was same, which indicated the affordability of households in addition of nutrient value to their diet.

Affordability due to increased households' income reflected in the living standard in terms of the possession of household equipments and transport vehicles of farmers in the watershed village (Table 13 and 14).

Equity, Empowerment and Gender Issues

The detailed household survey revealed that the literacy status of women in the Lucheba watershed grew with 29% had primary school education, 61% had senior and junior high school education and 10% were illiterate. More than 90% of families were nuclear families. Women's role in decision-making in household related issues was found to be 29% while for men it was 71% in the watershed villages/hamlets. About 86% of women expressed that they were involved in the watershed project activities right from initial stage of planning to at all stages of activities in the project, while 13% women were involved partly. More than 90% of women played decision making role for the project activities and same proportion of women attended meetings regularly. Large proportion of women farmers (77%) observed that the watershed development has improved the household welfare in terms of living standard, economic affordability in acquiring household items, children education and health, etc. The household survey data revealed that the 86% of women farmers felt that their responsibility in the household and farming activities increased and 90% expressed that they are now financially independent and that the household income has increased. Large number of women (86%) stated that their voice is heard more now. Majority of women realize that the improved watershed interventions have empowered the folks in terms of knowledge, financial and social status. But at the same time, they (86%) also felt that there is a need to motivate men to accept their role in watershed activities.

Table 11. Average household income per annum, Lucheba watershed.

	Pre-project				Post-project			
Parameters	Input	SE	Net income (RMB)	SE	Input	SE	Net income (RMB)	SE
Farm	2762	992.5	3183 (393)*	1078.7	5104	805.2	10723 (1322)	475.5
Non-farm	2100	2468.4	3000 (370)	3503.7	3767	1355.5	7000 (863)	844.7
Livestock	2353	1362.2	1700 (210)	893.7	4889	1543.3	3218 (397)	736.1
Total	7215		7883 (973)		13760		20941 (2582)	

* values in the parentheses are US $

Table 12. Impact of increased income on dietary pattern of farmers, Lucheba watershed.

	Pre-project		Post-project	
Diet	Consumption (kg/HH/month)	% of HH	Consumption (kg/HH/month)	% of HH
Meat	3.75 (±0.31)*	100	7.91 (±0.44)	100
Fish	1.5 (±0.29)	13	2.9 (±0.13)	57
Veg	33.7 (±2.01)	100	47.8 (±2.31)	100
Cereals	44.5 (±2.40)	100	43.3 (±1.80)	100
Milk	0	0	33.3 (±1.82)	Few HH
Milk product	0	0	60	Few HH

* Values in the parentheses are SEM

Table 13. Possession of household items, Lucheba watershed.

	Pre-project	Post-project
Household items	% of HH having	% of HH having
TV	23.4	110
Dish antenna	0	90
Water heater	0	23.3
Fridge	0	26.7
Fan	0	33.3
Washing machine	13.3	76.7
Other	0	36.7

Table 14. Transport vehicles in the Lucheba watershed.

Transport vehicle	% of HH	% of HH
Lorry	0	6.7
Goods wagon	0	0
Cars	0	3.3
MC	33.3	73.3
Auto	0	3.3

Infrastructure Development through Collective Action

Participatory Drinking Water Project in Lucheba Watershed, Guizhou Province, China

Water harvesting projects for drinking water using spring water to provide clean and sufficient water were implemented with two farmers' groups viz. Liujiazhai farmers group and Zhangjiaba farmers group in the watershed (Figure 15).

Liujiazhai Farmers Group: The Liujiazhai drinking water project includes one 122 m^3 water storage tank and three km length of pipeline to supply water from tank to farmers' houses. The project was completed in October 2005. The financial support was obtained from five sources, i.e., 10,170 RMB (US$ 1,254) from individual farmers, 1060 RMB (US$ 131) from the community forest income, 10000 RMB (US$ 1,233) from private donors outside the village, 12,000 RMB (US$ 1,480) from project and 6,687 RMB from other sources of individual and government support. About 1,100 labor days were needed to complete the construction. This was done by the group farmers (equivalent of 22,000 RMB =US$ 2,713). The project met the water requirement for 65 farmers' households, that includes 268 farmers and more than 300 animals.

Zhangjiaba Farmers' group: Zhangjiaba farmers' group had a meeting along with two government extension officials on 19 December 2004. A decision was taken in the meeting that to execute a drinking water

Figure 15. Drinking water supply initiative through community collective action.

Figure 16 to 17. Village roads constructed from project support with collective action.

project with the support of the watershed project. A Farmers committee was formed to lead the project. Execution of the drinking water project began on 23 December 2004 and it was completed on 23 February 2005. This project had very active farmers' participation. Farmers in the age group of 10 to 60 years were mobilized to join the project, some farmers worked over 15 hours per day, without any pay, even in cold winter and rains. One water tank of 37.5 m^3 capacity at the top of hill and 1400 meter of pipeline from the tank on hill to the village was completed. It has solved the problem of drinking water for 62 households and more than 300 animals in the village. Earlier every farmer's household used to spend 2–3 hours per day for fetching drinking water. The drudgery of fetching water was the main motivation for the excellent farmers participation in the project.

For achieving high quality of construction farmers set up four sub-groups for division of labor and selected one leader for each sub-group. The first sub-group was given responsibility to construct the base of water tank, second for carrying the construction materials from foot to the top of the hill, third for laying pipes and fourth sub-group for the construction of water tank. After the completion of the project, regulations for the water supply project management were discussed. One farmer was assigned to operate and manage the water supply under overall guidance of the farmers' management group. It was decided that every farmer of the village would contribute 2 RMB per month as a salary for the farmer who operates the water supply system.

Village Roads Construction

Road connecting villages to outside is a key for developing village economy. During the project, construction of one-village road through collective action of the villagers in Baobaoshang, which is 1 km long and 3 m wide was done. In 2004 a 4-m wide, 1.7 km long village road was constructed through collective action with government support (Figure 16 & 17).

Some of the highlights of the road project are:

The total cost of the project was about 24,135 RMB (US$ 2976), out of which 5,975 RMB (US$ 737) came from the farmers contribution, 6,000 RMB (US$ 740) came from the project and 12,160 RMB (US$ 1,499) of farmers labor (608 labor-day in total) of the financial support from the watershed project was 24.86% of the total project cost, which served as a catalyst and facilitated to mobilize other investments. Farmers were the main contributor for accomplishment of the project.

Xiaoxincun Watershed in Yunnan Province

Xiaoxincun watershed, a natural village of Jinlei village group, Julin town, is situated in the mid-north of Yunnan province, belonging to Yuanmou county, Chuxiong Yi tribe that is one of the 25 ethnic groups in Yunnan province, which is located at latitude 26° 57′ 40.74″ N and longitude 105° 39′ 8.41″ E. It is 180 km away from Kunming, the capital of Yunnan province. It is a typical hot-arid valley area with mild slope of hills with the altitude of 1100 m above sea level near the Longchuanjiang River. It is representative of the Xerothermic valley region in China with hot wet summer and warm dry winter seasonal climate.

The total land area is 186.7 ha. Due to erosion many gullies have developed accounting for 71.5% of the total land area. The total population in the watershed is 316, consisting 194 males and 112 females. There are 86 households. Out of 186.7 ha total land, only 39.6 ha is being cultivated. Out of this cultivated area 89.6% is rain-fed with a cultivable land holding of 0.13 ha per person, however 0.44 ha per person of wasteland is available. Only 5.2 ha is irrigated and 0.33 ha seasonally irrigated. Wasteland accounts for 133.4 ha, forest 11.3 ha and other 2.3 ha.

Figure 18. Severe soil erosion in Xiaoxincun watershed, China.

Major crops/cropping systems are rice–vegetable (broad bean, chillies), corn, groundnut, sweet potato and watermelon. The major constraints for crop production are lack of water due to low and erratic rainfall and frequent droughts. Soil erosion is equally a major problem as meager natural soil resource is already dwindling (Figure 18). Farmers in the watershed are resource poor and per capita income was less than US$ 17 compared to per capita of income of the country US$ 45.

Rainfall and Water Balance of Xiaoxincun Watershed

The average (1956–1990) rainfall was 612 mm but recent average (1997–2002) is 781 mm. Rainfall analysis indicated that Xiaoxincun has a low annual rainfall of about 61 mm distributed in about 50 rainy days (day receiving at least 2.5 mm). In the past 45 years, large variation in the annual rainfall is observed. Annual rainfall varied from 473 mm to 917 mm at Xiaoxincun watershed. Above 100 mm rainfall per month is received at Xiaoxincun during the three-month period June to August. Weekly water balance was computed with an average rainfall of 641 mm, and potential evapotranspiration (PET), actual evapotranspiration (AET), water surplus (WS) and water deficit (WD) were 1,464, 641, nil and 815 mm respectively. Xiaoxincun experiences high annual PET of about 1,464 mm compared to the rainfall of 641 mm with large water deficit. Xiaoxincun experiences very little water surplus for a short-duration in the rainy season (Figure 19) (Kesava Rao et al., 2012).

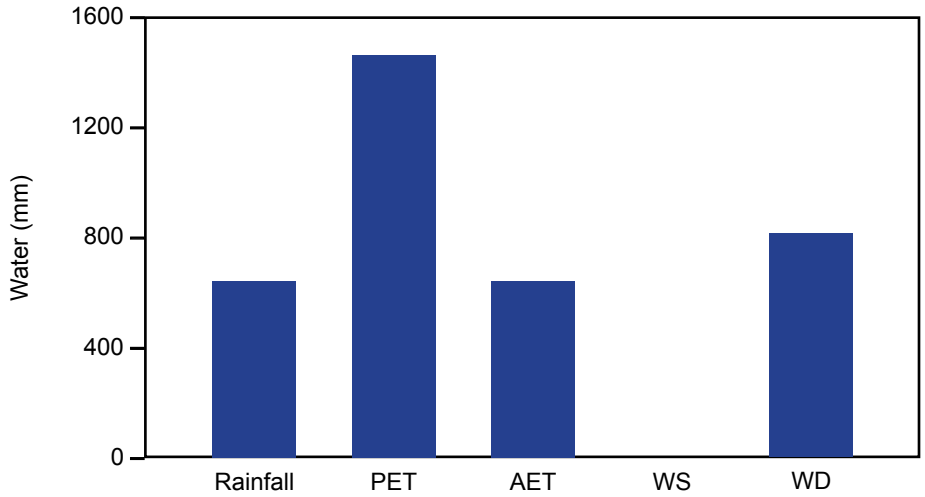

Figure 19. Water balance components of Xiaoxincun watershed, China.

Variability in the Length of Growing Period at Xiaoxincun Watershed, China

Weekly Index of Moisture Adequacy (ratio of actual evapotranspiration to potential evapotranspiration) was used to determine the beginning and end of crop-growing season and delineating the length of rain-fed crop-growing period at Xiaoxincun. Figure 20 shows the variability in the growing period along with weekly dry and wet spells during the crop-growing period at Xiaoxincun watershed. Beginning and end of crop-growing season varied greatly at Xiaoxincun in the last 48 years. Generally, the growing season starts by 10th June and an end by 10th December, thus the Length of Growing Period (LGP) is about 180 days (Figure 20). In the year 1960, though the season started by 24th June, it ended very early by 23rd September, making this year with the shortest LGP of about 90 days, which is half of the normal LGP. Longest LGP of about 290 days was experienced in the year 2001 and 2002, when the season started as early as 13th May and extended till the end of December. The earliest beginning of the season (1st May) was recorded in the year 1968. It is observed that there is more year-to-year variation in the beginning compared to the end. Probability analysis indicated that at 75% probability (in 3 out of 4 years), the growing season begins by 25th June and ends by 25th November with a total LGP of about 150 days (ICRISAT, 2006).

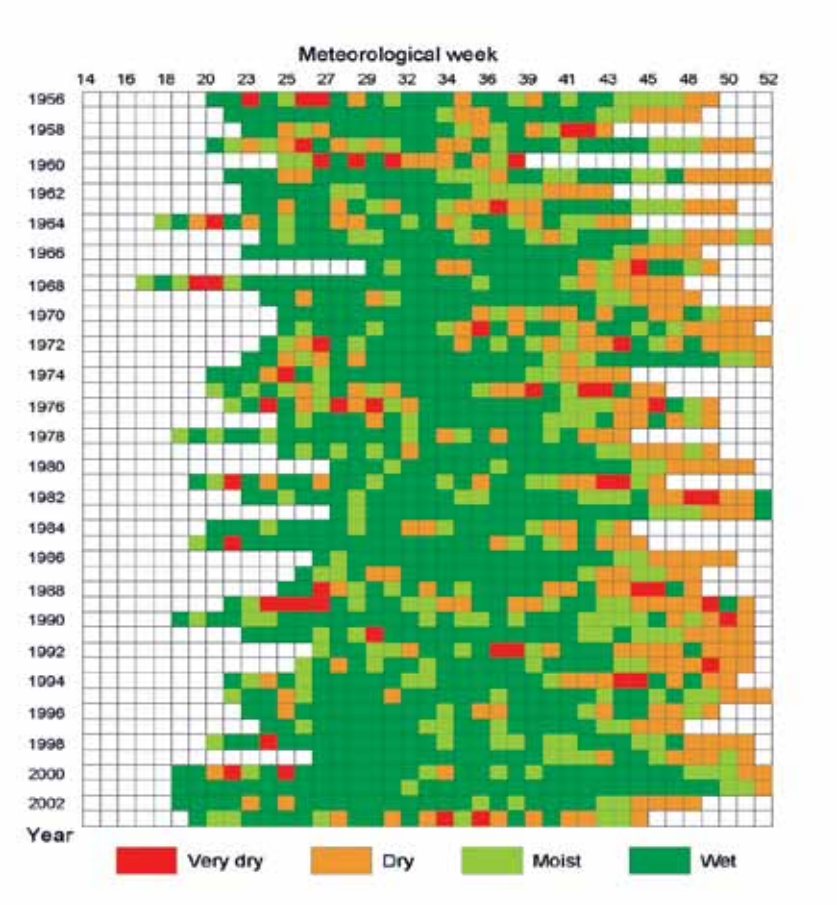

Figure 20. Variability in the crop-growing period at Xiaoxincun, China. (Source: Rao et al., 1999)

Constraints

The major constraints to productivity are as follows.

- High soil erosion, soil degradation
- Low and erratic rainfall; leading to severe water scarcity and low crop yields
- Small landholding
- Low income
- Low literacy level

Integrated Watershed Interventions

Rainwater harvesting and erosion control measures such as check dams and earthen tanks, repair and desilting of water channel and rejuvenating of existing tanks (Figure 21) were undertaken.

Check dam

Water harvesting structure

Gliricidia on field bund

Contour cultivation

Figure 21. Various interventions at Xiaoxincun watershed, China.

- Community mobilization and entry point activity
- Installation of irrigation pipes: Longchuanjiang river water pumped to existing cement tank (600 m^3 storage capacity) located on the hillock, and provide water through 460 m length pipe line was installed collectively by farmers.
- Cultivation of fields across the slope as generally farmers were cultivating along the slope.
- Planted N_2-fixing G*liricidia* on bunds as shrubs to protect field bunds and generate N-rich organic matter for application in fields.
- Soil test-based balanced fertilization introduced

Family Size and Landholding

The interviews with 30 households/farmers revealed that the average family size is 4.43 and average landholding was 0.13 ha (Table 14).

Table 14. Family size and status of land holdings of sample households

	Average	Minimum	Maximum	S.D.	CV (%)
Family size	4.43	2	6	1.22	27.58
Land holding (ha)	0.13	0.05	0.22	0.057	39.80

N= 30

Educational Status

The level of education of the people in the watershed village is a major indicator of any development project. The education level of farmers depend on affordability which is again a function of economic and social status of farmers. In this watershed, about 57% of households have received elementary education, 10-13% have middle and high school education and 20% are illiterate (Table 15).

Table 15. Educational status of sample households

Education level	Percentage (%)
Elementary education	57
Senior middle school	10
Junior high school	13
Illiterates	20

N= 30

Decision-Making Status

The survey data shows that the men (60%) played important role in decision making, followed by women (40%) pertaining to children schooling, choice of crops to be grown, marriage, celebration of festival other domestic expenditure, etc., in the family.

Improved Soil Conservation

As observed during the baseline survey severe land degradation due to water erosion has resulted in large gullies which are widening year after year. In order to minimize soil erosion and runoff loss, the project demonstrated the soil and water conservation measures such as contour cultivation, field bunding and planting of *Glyricidia* (N_2-fixing tree) as shrub to protect bunds as well as generate N-rich organic matter to apply in fields. More than 60 per cent of land in the watershed is cultivated now across the slope and fields are bunded by the farmers. All farmers in the watershed have planted *Glyricidia* seedlings on their field bunds.

Box 5: Xiaoxincun Watershed Impact as Felt and Observed by the Community

Fifty five farmers dominated by 44 women community members attended the focused group discussion and from their words following impacts associated with watershed project interventions harnessed by the community members were recorded.

- Community hall constructed with the partial support from the project is found very useful by the women group for conducting group meetings, to undertake cultural activities, collective activities and festival celebrations, to discuss issues of how to enhance incomes for their families?
- Fodder and forage initiative has helped 26 families in the village and biogas initiative has benefited 83 families. Prior to project no one used to grow fodder plots in the village as well as no one had biogas plant.
- Prior to project 20 mules were there and now 50+ mules are there in the village.
- New knowledge (rainwater harvesting, kitchen garden, forage cultivation, improved cultivation methods) is perceived by the community as important gain from the project.
- Family incomes are increased and in most cases doubled during the project. Increased incomes are spent on food items, children education as well as purchasing of luxury items for family.
- Increased family incomes did not end up in alcohol consumption as there is not much difference for alcohol consumption in the village before and after the project.
- Women control money in the family. They are also decision makers in the family; in most cases they discuss things together and then take decision and money is also held together.
- Men use their portion to spend for smoking and drinking.
- Children get educated up to primary level and boys and girls are treated uniformly. However boys are preferred in the family although boys have to give gifts to girls' family at marriage.
- Families are prepared to spend increased incomes for the elderly members in the families.
- Prior to biogas plant villagers were using fire wood and electricity for cooking and they had to spend at least 2 h for collection every day. Since 2005 due to biogas plants they do not cut trees or use electricity for cooking. There is also saving time (2hr) which they spend now on productive farm work (80%) and 20% on child care. For biogas plant, pig and human excreta are used as feed stock

and slurry is used as manure in fields. The benefits from the biogas plant are ascribed as sparing of trees from cutting for fire wood, reduction in drudgery for women, clean environment, saved time and also resulted in good health.

- In village tuberculosis cases are there and other health issues are joint pains, gall bladder stone, coughing. Villagers are not aware about relationship between smoking and TB.
- In village non-farm activities are limited to cycle repair and shoe repairing services. Farmers still have water shortage and they are trying to mobilize government help to lift water from river which is estimated to cost 300,000 RMB and government can contribute 90,000 RMB.
- Kitchen garden is also very preferred activity in the village. Almost each house has a small kitchen garden where they grow fruit trees such as papaya, jack fruits, lemon, longoan. Ninety per cent of the produce from the kitchen garden is sent to market and 10% is consumed in the family.
- Community's aspirations are to have drinking water supply in the village, diversification of crops and water saving technologies. There is no school in the village and kids have to go 1 km away and market place is 4 km from the village.

Impact of Watershed Interventions on Rainwater Use Efficiency

The net storage capacity of five water harvesting structure (WHS) is 37626 m^3, which contributed as effective water conservation considering percolation/seepage is about 51 mm or 7.9% of mean annual rainfall of 641 mm. The WHS have played a crucial role in increasing and stabilizing agricultural productivity by increasing RWUE and livelihoods of farmers in the watershed.

Rainwater use efficiency of some of the major crops rice, maize, groundnut, watermelon and sweet potato during pre-project was 9.5, 7.0, 2.2, 16.4 and 30.4 kg mm^{-1} ha^{-1} while post-project increased to 11.2, 8.1, 2.8, 19.5 and 35.5 kg mm^{-1} ha^{-1} respectively. The RWUE increased in the range of 15 – 29%. Sweet potato had the highest RWUE both during pre- and post-project period compared to other crops and followed by rice, maize and groundnut. While the highest per cent increase of RWUE during pre- and post-project was recorded in groundnut (29%), followed by watermelon (19%), rice (18%), maize (16%) and sweet potato (15%) (Table 16).

Table 16. Rainwater use efficiency of vegetable crops and watermelon during pre- and post-project in Xiaoxincun watershed.

	Pre-project period		Post-project period		
Crops	Crop yield (kg ha^{-1})	RWUE* (kg mm^{-1} ha^{-1})	Crop yield (kg ha^{-1})	RWUE* (kg mm^{-1} ha^{-1})	Increase (%)
Rice	5800	9.5	6300	11.2	18
Maize	4500	7.0	5200	8.1	16
Groundnut	1400	2.2	1800	2.8	29
Watermelon	10500	16.4	12500	19.5	19
Sweet potato	19500	30.4	22500	35.1	15

* RWUE (kg mm^{-1} ha^{-1}) = Crop yield (kg ha^{-1}) / mean annual rainfall (mm)

Impact of Watershed Interventions on Monetary Benefit

The net yield advantage for crops viz. rice, maize, groundnut, watermelon and sweet potato were 9.8, 13.7, 7.8, 39.2 and 58.8 kg mm^{-1} ha^{-1} respectively. The net monetary benefit per unit of water conserved were in the order of watermelon, sweet potato, groundnut, maize and rice with 57.7, 43.3, 38.5, 18.9 and 14.4 RMB mm^{-1} ha^{-1} respectively, whereas the net monetary advantage per unit area was in the order of watermelon, sweet potato, maize, rice and groundnut with 2800, 2250, 800, 550 and 300 RMB ha^{-1} respectively due to increased availability of water attributed to the water harvesting structures and irrigation facility created through pumping of river water to tank and supplied through pipeline that facilitated the supplementary application of water. Among five crops shown in the Table 17, watermelon was most efficient and beneficial in terms of production and economics aspect followed by sweet potato, groundnut, maize and rice.

Table 17. Effect of watershed interventions on crop yields per unit of water conserved at Xiaoxincun watershed.

Crops	Net increase in yield (kg ha^{-1})	Yield per unit of water conserved* (kg mm^{-1} ha^{-1})	Net increased benefit (RMB ha^{-1})	Net benefit per unit of water conserved# (RMB mm^{-1} ha^{-1})
Rice	500	9.8	550 (68)$	14.4 (1.8)
Maize	700	13.7	800 (99)	18.9 (2.3)
Groundnut	400	7.8	300 (37)	38.5 (4.7)
Watermelon	2000	39.2	2800 (345)	57.7 (7.1)
Sweet potato	3000	58.8	2250 (277)	43.3 (5.3)

* Yield per unit of water conserved (kg ha^{-1} mm^{-1}) = Net increase in yield (kg ha^{-1}) / water conserved (mm)
# Net benefit per unit of water conserved (RMB ha^{-1} mm^{-1}) = Net benefit (RMB ha^{-1}) / water conserved (mm)
$ Values in parentheses are US $

Impact of Watershed Interventions on Cost-Benefit Ratio

The benefit-cost (B:C) ratios shown in Table 18 show similar trend of benefit-cost ratios during pre- and post-project period for different crops. Amongst the crops grown watermelon showed highest B:C ratio. The B:C ratios during pre-project were in the order of watermelon (3.4), sweet potato (2.5), groundnut (1.8), maize (1.9) and rice (1.9) and during post-project are 3.9, 3.0, 2.2, 2.2 and 2.0 respectively (Table 18). Higher B:C ratios were observed with watermelon and sweet potato during both pre- and post-project period.

Table 18. Effect of watershed interventions on benefit-cost ratio at Xiaoxincun watershed.

	Pre-project			Post-project		
Crops	Yield (kg ha^{-1})	Net income (RMB ha^{-1})	B:C	Yield (kg ha^{-1})	Net income (RMB ha^{-1})	B:C
Rice	5800	5700 (703)$	1.9	6300	6250 (771)	2.0
Maize	4500	4100 (506)	1.9	5200	4980 (614)	2.2
Groundnut	1400	4500 (555)	1.8	1800	6200 (765)	2.2
Sweet potato	16500	10425 (1287)	2.5	22500	12675 (1564)	3.0
Watermelon	10500	12150 (1500)	3.4	12500	14950 (1845)	3.9

$ Values in parentheses are US $

Impact of Watershed Interventions on Groundwater

Various soil and water conservation measures and water harvesting structures in the watershed have significant influence on groundwater in the watershed. The mean groundwater level from surface in wells, those used for irrigation, which are located in the lower part of watershed on toposequence before watershed interventions were 13.9 m while after watershed interventions it was 10.1 m. The annual mean groundwater level rose by 3.8 m due to watershed intervention, whereas the wells located in the middle part of watershed on toposequence, those used for drinking/domestic purposes, the increase in water level was 1.4 m (Figure 22).

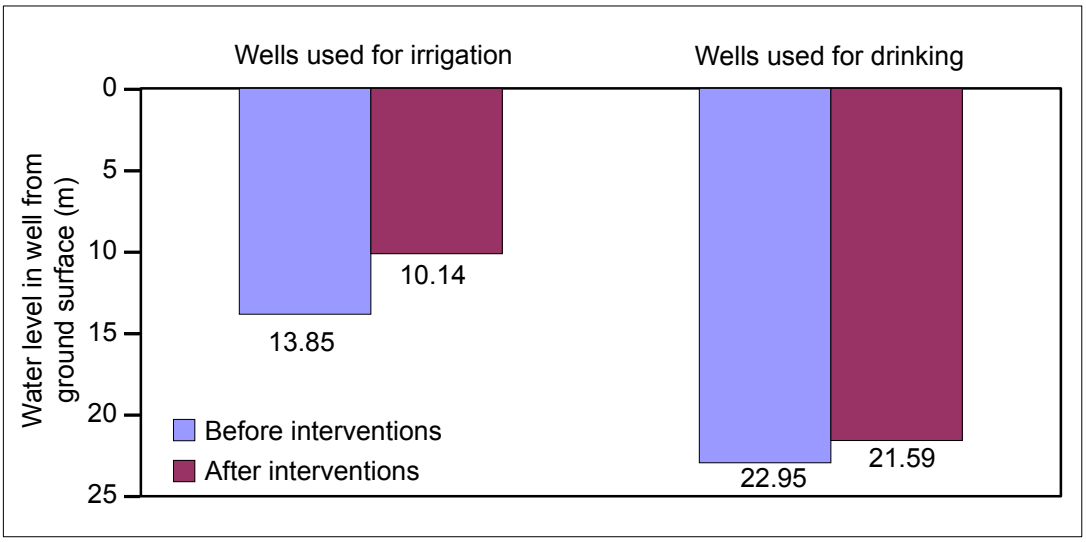

Figure 22. Impact of water harvesting structures on groundwater level, Xiaoxincun watershed, China.

The location of wells on toposequence had significant influence on water level in wells (Figure 23). The wells located at lower reach (valley) of watershed had water at shallow depth compared to the wells located at middle part of watershed.

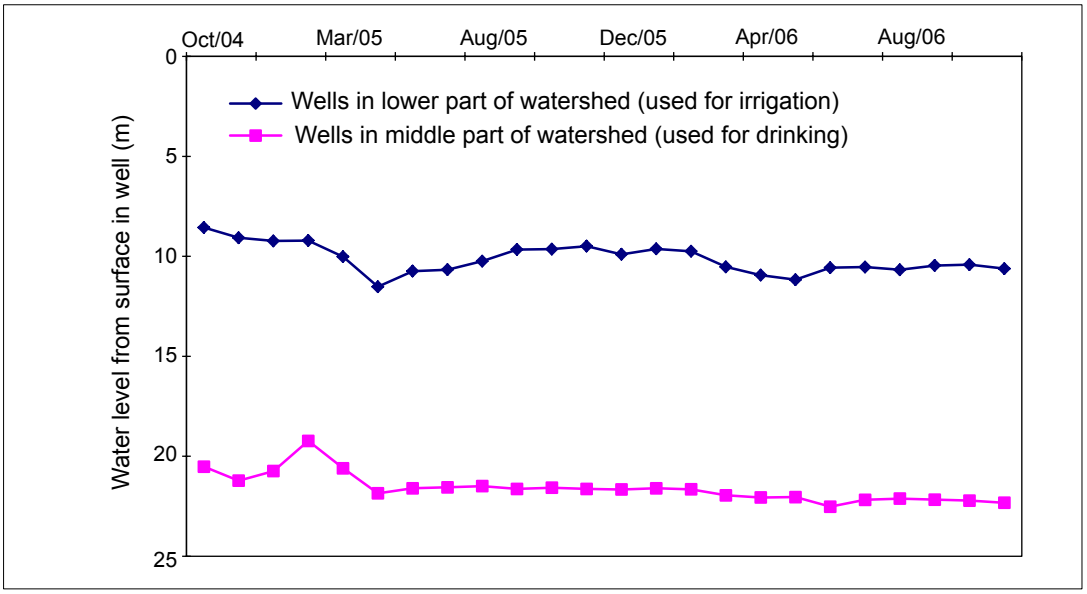

Figure 23. Effect of location of wells on toposequence on groundwater level, Xiaoxincun watershed, China (2004-2006).

Participation of Households in Various Activities

Table 19 describes that the per cent of households involved in different watershed intervention activities, such as about 73% households are involved in the vegetable cultivation, 70% in biogas, 77% livestock rearing, 47% cash crop cultivation and 17% in other crops.

Table 19. Participation of respondents in different activities

Vegetable cultivation (%)	Biogass (%)	Livestock rearing (%)	Cash crops (%)	Other crops (%)
73.3	70	76.7	46.7	16.7

(N= 30)

Source of Information & Knowledge about Specific Activities

Different sources of information that farmers get are shown in Table 8. The major source of information to the farmers is watershed project staff (Table 20).

Table 20. Sources of knowledge about specific activities.

Different sources	Percentage (%)
From villagers	10.00
From project staff	50.00
Guideline of projects	13.33
From publicity	3.33
Other sources	23.34

(N=30)

Participation of farmers in the Project Activities

About 70–83% of respondents said that they take active participation in the most of the project activities (performance of work, involvement in initial stage of project and meetings) which ranged from 27 to 83 per cent, however, possess less participation in decision-making (27%), indicated that more efforts are needed to improve community participation and targeted capacity building activities are needed (Table 21).

Table 21. Participation in the project at different stages

	Percentage (%)
Involvement in the project at initial (planning) stage	70.00
Participation in decision making	26.67
Attendance of meeting	70.00
Performance of allocated works	83.33

Motivational Factor for Active Participation in the Project

Farmers agree that the major motivating factor for the active participation in the watershed project was to improve their family income through increased productivity and livelihoods options (Table 22).

Table 22. Motivational factors for participation in watershed activities.

	Percentage (%)
Economic Benefit	53.33
Urge to lead development village	30.00
Others	16.67

Women Participation in Household and Livelihood Activities.

The impact of watershed technology was clearly seen in the increased activity of women in livestock rearing and reduced women drudgery in household work (Table 23). Increased participation of women in income-generating activities benefitted them and reduced drudgery of collecting firewood and water.

Table 23. Participation of women in household and livelihood activities.

Parameters	Before project (%)	After project (%)
Household work	96.67	86.67
Livestock rearing	63.33	66.67
Planting in rainy season	63.33	63.33
Any other	23.33	NA

Perception of Women on Different Parameters

About 63.33% of respondents expressed that the responsibilities or participation of women in household and other livelihood activities have increased after the inception of watershed project, while about 37% said there was no change. Also 67 per cent women of respondents indicated that there was increase in household income, cooperation from other family members and financial independence of women (Table 24). This shows that the watershed project not only improved the productivity and economic benefits but also improved the social status of women and vulnerable groups in the watershed village.

Impact of Technology Interventions on Income and Health

The survey show that there is a good trend that most of the households are able to increase their spending on better food, health, education, agriculture and other good purposes and savings too due to improved household income (Table 25).

Acquisition of Assets

As there is increase in household income due to the increased productivity and livelihood opportunities impacted by the various watershed interventions, the affordability of farmers to acquire the necessary assets has also improved viz. motorcycles and color TVs, etc. (Table 26).

Table 24. Perception of women on different parameters.

Parameters	Respondents' perception (%)	
	Increased	No change
Responsibilities of women after watershed project	63	37
Support from the family		
a. Husband	90	-
b. Son	3	-
c. Self	7	-
Sharing responsibility	43	57
Feeling independence	63	37
Opinion in public	63	37
Cooperation from fellow colleagues	97	3
Requirement of opposite sex for better coordination	90	10
Household income	67	33

Table 25. Average additional amount (RMB per month) spent on food, health and Education.

	Average additional amount spent (Yuan RMB)
Food	12.70
Health	6.52
Education of children	12.31
Cloths and other amenities	15.07
Investment in agriculture	11.08
Savings	5.44

Table 26. Acquisition of Assets during intervention of watershed programme

	Before Watershed	After Watershed
Bullocks (Average number)	1	1
Land (acre)	1.45	1.45
Bicycle (%)	50	26.67
Motorcycle (%)	-	26.67
Color TV (%)	73.33	80.00

Role of Institutional Arrangements and Social Organizations in the Integrated Watershed Management in China

A study was undertaken to investigate the role of institutional arrangements and social organizations in the benchmark watersheds in China with specific objectives of –

- To study institutional arrangements and collective action in the watershed projects for productivity enhancement and natural resources conservation and management;
- To document contribution of the project activities on livelihoods of households and the community.

Some of the key findings of the institutional arrangements and associated impacts in the benchmark watersheds in China are described here.

The Consortium Approach – Convergence of Efforts

The consortium team comprising various institutions / apex bodies (viz. YAAS in Yunnan and GAAS in Guizhou) in each of the provinces resulted in convergence of activities of different programs in the project. For instance, in Lucheba watershed, project interventions such as two drinking water initiatives in Zhangjiaba and Liujiazai hamlets and a 14 km long village approach road were taken up by converging resources from different departments along with project finances. Village approach roads were constructed in Lucheba watershed. These new roads have played crucial role in connecting villagers for transporting products to markets. Financial resources were pooled from different departments along with the project money to take up this work. The local authorities actively supported the drinking water initiative and village approach road initiative of Lucheba watershed. Activities concerning fodder species evaluation and integrated pest management (IPM) and other components were contributed by different departments. It was observed during the study that most of the project activities were planned in line with the policies of the local administration. The activities that are being promoted by the local authorities find their place and got emphasized in the project. The biogas initiative in Xiaoxincun and Lucheba watersheds, vegetable and livestock farmers associations in Lucheba watershed are being promoted actively in respective areas. The rye grass planting was initiated by the Animal Husbandry Office of Tianlong township in 2003, which was subsequently tried in the watershed project and promoted once farmers realised its usefulness.

It was observed that the nature of expertise of project implementing agency (PIA) was reflected in the type of activities taken up in the project. In Lucheba watershed, typically, the activities taken up through the project show increasing orientation towards rural development activities such as drinking water issues, rural roads, etc. In this watershed the PIA (Integrated Rural Development Centre, Guizhou) has its mandate on integrated rural development. This is partly because there is convergence of resources from the project implementing agency (PIA) in the project. In case of Xiaoxincun watershed, the project activities show their orientation towards on-farm developmental research activities, which is the mandate of the PIA, the Kunming Tropical and Subtropical Cash Crops Research Institute. During semi-structured interviews with staff of partner organisations, it was evident that they do not differentiate between this project and other activities of their institute.

Institutional Arrangements and Social Organizations

At the watershed level, the social organization is simple but effective in the local socio-political context. A few leading people of the village were selected by the project staff (and farmers) to form the village

representative group. The program activities were taken up through this group. One researcher, who is the fulltime staff of the PIA allocated for the project, was the contact person in the field for the project. However, it was observed that in case of Lucheba watershed, personnel from local agriculture bureau were actively involved in the project at the watershed level. In Xiaoxincun watershed, one village representative group is organized at the village level but in Lucheba watershed, six groups were organized, as six hamlets inhabited the watershed. There exists a strong two-way relationship between the researcher and the village representative group. Village representative group meets based on requirement, mostly summoned by the researcher. Researcher regularly visits the village and meets project farmers individually. Meetings are called for when necessary, which is not frequent. In Xiaoxincun watershed, the agriculture bureau is not at all involved in the project. The researcher collected and maintained all the data, such as biophysical and socioeconomic. Researcher was the main contact point for ICRISAT to communicate project progress, monitor the project activities and collect data for processing. However, senior staff of YAAS and GAAS coordinated. They are essentially present in all the programme activities such as meetings, field days, etc. Information sharing with villagers mostly during field days and other important meetings were organised during the project period. However, there was a great amount of sharing of information involuntarily between farmers. Apart from this there were no specific efforts in the project to upscale the best-bet practices to farmers in the community or farmers in the neighbouring villages. However, formation of farmers' associations in Lucheba watershed was found to be a very useful strategy to upscale the research outcomes to the larger community (Figure 24).

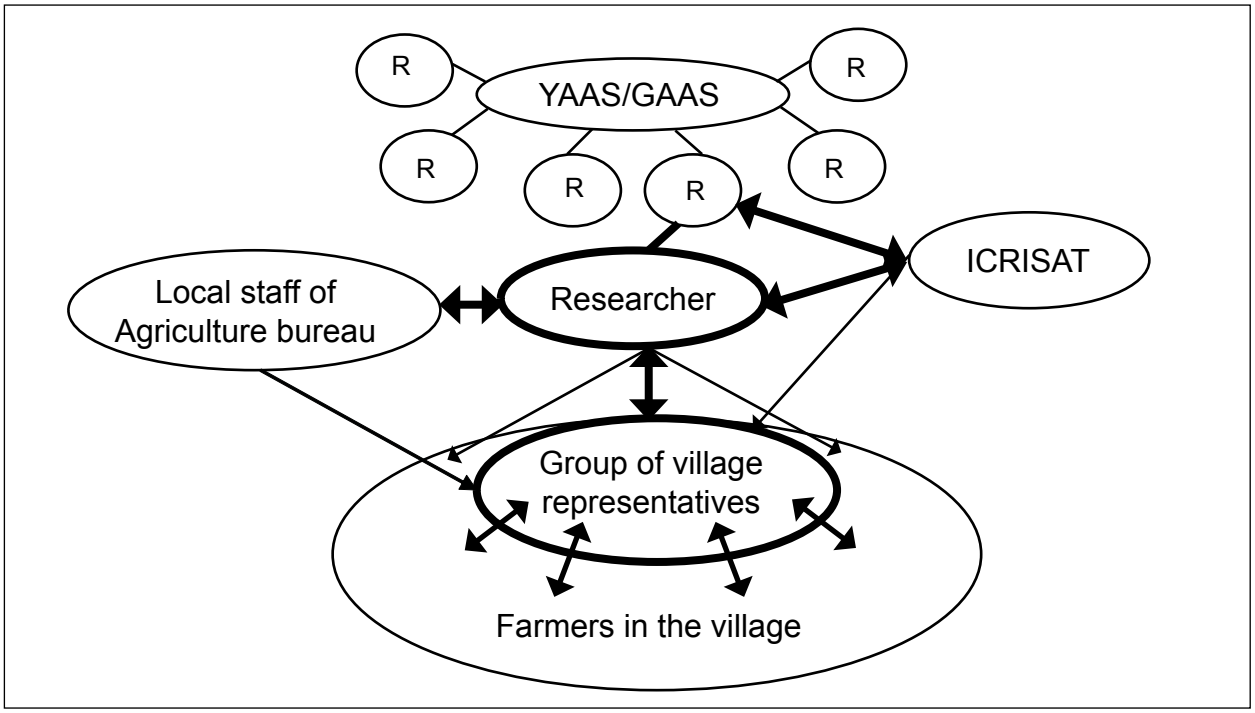

Figure 24. Organisational linkages observed in the two benchmark watersheds in China. (Thicker lines indicate higher role in the programme. Arrows show information flows.)

However, during the stakeholder linkage analysis exercises, it was observed that there is potential to link up with many relevant agencies to enhance the impact of integrated watershed technologies. It was interesting to observe that in the Xiaoxincun watershed, *Gliricidia* plantation that was tried through the project was found useful in avoiding enlargement of gullies when planted on ridges. But they couldn't extend the area due to lack of plant material. It was observed during the field visit that Jatropha was growing wildly in the watershed area and project staff were not aware of its usefulness. It was agreed by the project staff that for scaling up the process and best bet practices, there is a need to involve other relevant organisations such as Agriculture Bureau for transmitting the learnings to wider section of stakeholders and local agriculture university for participating in the programme through taking learnings from the project as feedback for relevant incorporations into its curriculum and also contribute in the project through local technical expertise.

Community Groups in Xiaoxincun Watershed

In the Xiaoxincun watershed the villagers are organized into different functional groups such as village representative group, women associations and informal farmers' group, operating for many years (Table 27). In all these groups no regular meetings were held but they follow minimum rules and regulations of functioning, jointly agreed by the members. From the activities and functioning of the groups, it is evident that the emphasis on social organization appears to be insufficient in this watershed. These groups possess the characteristics of functional groups (group of farmers who come together voluntarily for a specific function) and show no sign of sustainability in the post-project phase undertaken by the members.

Table 27. Different community groups in Xiaoxincun watersheds.

Group	When formed	No. of members	No. of meetings held in a year
Village representative group	2004	9	10
Women association	1990	60	2-4
Informal farmers' group	-	All	10

Farmers' Cooperative Associations in Lucheba Watershed

In case of Lucheba watershed, social organization received better attention, as seen from the interventions. This fact was reflected in formation and functioning of farmers' groups in each of the six hamlets of the watershed. These groups showed essential characteristics of collective action such as regular meetings, functional leader in each of the groups and joint activities by the group members. The project activities taken up in the watershed such as drinking water initiative, village approach road construction and farmers' associations were based on strong social organization. From the functioning of these groups it can be inferred that these groups exhibit features of sustainability.

Two farmers' cooperative associations with a focus on livestock development in their respective hamlets and one farmer's cooperative association with focus on vegetable cultivation are formed during the project period (Table 28). These groups were found to be active. Facilitation of these associations has significant impact on the livelihoods of the watershed community. These associations promoted –

Table 28. Various of farmers associations in Lucheba watershed.

Farmers association	Formed during	Members in the beginning	Current members
Fruit and vegetable farmers association, Lucheba village	2003	141 (47)*	294 (90)
Livestock farmers association, Mashangchong village	2004	25 (63)	44 (100)
Livestock farmers association, Zhangjiaba village	2005	21 (33)	32 (50)

* values in parentheses are of percent of total households

- increased production by large number of farmers taking up specific project initiatives,
- increased productivity by following improved production practices,
- improved efficiency through market linkage for the their produce by collective action

and as a result there is increase in the net income leading to better living conditions, which is evident from the socio economic data.

The Fruit and Vegetable Farmers Association, Lucheba Village

The fruit and vegetable farmers association has helped promote vegetable cultivation in the area. Number of vegetable farmers increased from 147 households (i.e. 47% of the total households in the watershed) in 2003 to 294 households (about 90% of the total households in the watershed) in 2006. Correspondingly the area under vegetables in the watershed increased from 30 ha in 2003 to 120 ha in 2006. The survey data revealed that the net income in the watershed (only from increased vegetable cultivation) has risen from RMB 415,400 (US$ 51,220.71) during 2003 to RMB 1,580,600 (US$ 194,895.19) during 2005. The partners attribute this significant change to formation of the farmers association. They said it was possible through:

- introduction of new suitable high-yielding vegetable varieties for demonstration such as kidney bean from Thailand, hybrid chilly from Hunnan province, etc;
- promoting IPM techniques such as biocide lanterns, etc;
- water management through small water tanks (cisterns);
- promoting Chinese cabbage in collaboration with Bureau of Science and Technology of Pingba county;
- integrated nutrient management for balanced nutrition; use of liquid residue from biogas plants, promoted by the Bureau of Agriculture of Pingba county;
- collective action for market linkage through the association.

The association has envisioned expanding the vegetable area in the nearby areas, introducing new and high-income vegetable varieties, setting up a brand/ trademark for vegetables produced in the watershed and also to establish a whole sale vegetable market at Lucheba village.

In Lucheba watershed farmers have moved from paddy to vegetables. This has resulted in increased incomes. The increase in per capita income from 1600 RMB in 2003 to 2600 RMB at the end of 2005 (Source project documents) is a clear indicator of this fact. About 40 new houses were constructed and over 100 motor cycles (both two wheelers and three wheelers) were purchased by the farmers in the past three years. Farmers expressed that the increased incomes was due to agriculture intensification with high-value vegetable crops and the government policy of relieving farmers from paying land/agriculture tax. However, this intensification through vegetable crops has reduced area under food crops. Farmers analyzed that, before the project they were producing 100% of the food they need in their farms, while now they are purchasing about 80% of the food items from the market. But it does not bother them as their incomes have increased to buy the required food grains.

The Livestock Farmers' Cooperative Association, Mashangchong Village

With an aim to improve pig production in the village, the farmers' association was formed. In the beginning 25 households became members of the association. By 2005, all the households of the hamlet (44 households) joined the association. The project has contributed RMB 11,000 (US$ 1,356) as seed money while the farmers matched with RMB 13,800 (US$ 1,702) contribution to take the amount to RMB 24,800 (US$ 3,058). After the money was pooled it was distributed at the rate of RMB 1,000 per household for pig rearing. They used that money for the purchase of baby pigs, female pigs and feed. After five months they returned the money with interest to the group. In the next rotation, the amount was given to needy farmers and the process continued. They have completed five rotations of the money and the fund has increased to over RMB 30,000 (US$ 3,699). Total number of pigs in 2003 was 343 while that number has increased to 616 by 2006. This increase has been completely attributed to the farmers association. Partners also told that increased fodder production through wild buckwheat plantation in hedgerows has supported this increase in number of animals. This increase in number of pigs has a positive impact on the availability raw material required for the biogas plants, which is a positive cycle of sustainable production.

The Livestock Farmers' Cooperative Association, Zhangjiaba Village

Impressed by the success in the Mashangchong village, farmers' association was formed on similar lines with initial 21 households. The initial fund was RMB 12,300 (US$ 1,517) of which RMB 6000 (US$ 740) was contributed by the project. Two rotations of the credit have been completed and the fund has risen to RMB 14,883 (US$ 1,835). The group members told that the total number of pigs has increased from 30 to 151. Members are very happy with their progress and are enthusiastically looking into the future.

Conclusions

The rain-fed agriculture in China had a vast untapped potential and to bridge the yield gap between current farmers yields and the achievable potential yields. ICRISAT-led consortium identified integrated watershed management approach for reducing the poverty and minimizing land degradation (ICRISAT, 2006).

Two benchmark sites namely Lucheba watershed, a part of Wujiang river basin located at latitude 25° 37′ 7.03″ N and longitude 103° 12′ 8.41″ E in the central region of Guizhou, 75 km away from capital city Guiyang in Tianlong township of Pingba County, Guizhou province. The Xiaoxincun watershed in Julin

town is situated in the mid-north of Yunnan province, belonging to Yuanmou county in Yunnan province were selected as the benchmark sites for ADB-ICRISAT collaboration project.

- At Lucheba benchmark watershed baseline data collection revealed paucity/scarcity of drinking water for the villagers, severe problems of soil erosion, water scarcity, low crop productivity and were also highlighted by the community.
- As an entry point activity, two drinking water schemes were implemented by harvesting water from natural springs and transport it through pipes in the villages.
- Construction of small masonry water tanks (cistern) (151 nos.) of 5 m^3 capacity each for rainwater storage as well as for irrigation water storage were constructed.
- Farmers diversified from their existing maize, paddy and rape seed system to high-value crops like vegetables and fruits along with forage grass production during the project period with the technical support from the ICRISAT-led consortium.
- Contour plantation, soil test-based fertilizer applications, cost-effective integrated pest management and plantation of 133,600 fir and cyprus trees were planted in 100 ha degraded lands.
- Through income-generating activities such as livestock rearing, poultry, pigs rearing and rabbit farming were undertaken by the farmers groups using the revolving fund.
- Villagers undertook construction of approach road from village to the main highway as well as interconnecting roads in the villages with the help of resources from local governments, project and their own contribution in order to access the market for vegetables produced.
- Community distant information center (internet based) was established by the government to benefit the farmers
- The area under high-value vegetables increased from 10 ha in 2002 to 37 ha in 2004, producing 2,540 t with a total income of US$ 201,480. The per household income was around US$ 1,433 annually of which 70% came from vegetable cultivation
- Livestock rearing, rabbit farming and pig farms enhanced the incomes of the families as well as enabled the farmers to construct a biogas plants in each house reducing the pressure for fuel wood on forests.
- The impact of integrated watershed management was in terms of increased family incomes as indicated above along with US$ 2,581 against US$ 973 per annum
- Significant increase in meat consumption as well as vegetable consumption was recorded with marginal decline in cereal consumption
- Empowerment of women was evident in the village with improved livelihoods and income which they could spend. Women farmers (77%) felt at their household welfare is improved through the project in terms of living standard, economic affordability in acquiring household items, children education and health
- Ninety per cent of the women felt now that they are financially independent and equal per centage felt that they have a voice in the decision making process in the house now. However, 86% of the women felt that there is need to motivate men to accept their role in watershed activities.
- Xiaoxincun benchmark watershed in Yuanmou county, Yunnan province also reported rice-vegetables, corn, groundnut, sweet potato and watermelon as the main crops with a per capita income of US$ 17 in the baseline survey. Soil erosion and water scarcity were identified as a major constraints.

- Rainwater harvesting and erosion control measures through contour cultivation, field bunding and planting of *Glyricidia*, rainwater harvesting structures, rejuvenation of existing tanks along with transportation of the water through pipes to the fields were undertaken. Soil test-based fertilizer use of local techniques for pest control like tobacco waste in irrigation water for pest control, light traps for pests control; crop diversification and income-generating activities through the women groups were undertaken.
- IWMP interventions resulted in enhancing rainwater use efficiency as well as increasing net incomes for the farmers for example, rice cultivation benefitted farmers for US$ 503 before project interventions which increased to US$ 771 during the post-project evaluation. Similarly, increased benefits were observed in case of maize, groundnut, sweet potato and watermelon.
- IWMP also impacted groundwater availability by raising the groundwater table by 1.4 to 3.8 m.
- Seventy per cent of population women involved in vegetable cultivation, biogas activities, livestock rearing in the watershed program
- Fifty three per cent of the population felt that economic benefit were the main motivational factor for their participation where as 30% of the population felt that urge to lead development in the village was motivational factor for them to participate in the project activities.
- IWMP benefited the women in the watersheds who perceived that the responsibilities of women increased with the project activities and 67% women recorded increased household incomes as well as cooperation from other family members and financial independence as a direct benefit for themselves.
- Along with the increased income, the household spent additional amount on clothes, education of children, food, health and investment in agriculture along with savings also and acquired some assets like motorbikes and TVs.
- The institutional arrangements in the watersheds were mainly through the farmers groups and farmers associations for vegetable and fruit growers with technical support from the provincial agriculture academy who ensured convergence of project activities with government programs to harness the synergies of development to benefit the farmers.

References

ICRISAT. 2006. Participatory Watershed Management for Reducing Poverty and Land Degradation in SAT Asia. TA Completion Report, Global Theme on Agro ecosystems, ICRISAT, Patancheru, 502 324, Andhra Pradesh, India (Limited distribution).

Kesava Rao AVR, Wani SP, Singh P, Srinivas K and **Srinivasa Rao Ch.** 2012. Water requirement and use by Jatropha curcas in a semi-arid tropical location. Biomass and Bioenergy 39. 175-181 pp.

Li FS, Cook GT, Geballe WR and **Burch Jr.** 2000. Rainwater harvesting agriculture: An integrated system for water management on rain-fed land in China's semi-arid area. AMBIO 29(8): 477-483.

Rao GGSN, Kesava Rao AVR, Ramakrishna YS and **Victor US.** 1999. Resource characterization of drylands: climate. In: Fifty years of dryland agricultural research in India. Ed. H.P. Singh, Y.S.Ramakrishna, K.L.Sharma and B. Venkateswaralu, 24 – 40. Hyderabad, India: CRIDA.

Rockström J, Hatibu N, Oweis T et al. 2007. Managing water in rain-fed agriculture. In Water for food, water for life: A comprehensive assessment of water management in agriculture, ed. D. Molden, 315–348. London: Earthscan and Colombo, Srilanka: International Water Management Institute (IWMI).

Wani SP, Pathak P, Tam HM, Ramakrishna A, Singh P and **Sreedevi TK.** 2002. Integrated watershed management for minimizing land degradation and sustaining productivity in Asia. In: Integrated Land Management in the Dry Areas. (Zafar Adeel Ed.). Proceedings of a Joint UNU-CAS International Workshop, 8-13 September 2001, Beijing, China, United Nations University, Tokyo, Japan. 207-230 pp.

Wani SP, Sreedevi TK, Pathak P, Rego TJ, Ranga Rao GV, Jangawad LS, Pardhasaradhi G and **Shailaja R Iyer.** 2003. Minimizing Land Degradation and Sustaining Productivity by Integrated Water Management: Adarsha Watershed, Kothapally, India. In Integrated Watershed Management for Land and Water Conservation and Sustainable Agricultural Production in Asia. (eds. Wani SP, A.R. Maglinao, A. Ramakrishna and T.J. Rego). Proceedings of the ADB-ICRISAT-IWMI Project Review and Planning Meeting, Hanoi, Vietnam, 10-14 Dec 2001. Patancheru, 502 325, Andhra Pradesh, India: ICRISAT. 79-96 pp.

Wani SP, Rockström J, Venkateswarlu B and **Singh AK.** 2011. New Paradigm to UnlockthePotential of Rain-fed Agriculture in the Semi-arid Tropics. World Soil Resources and Food Security. (Eds. Rattan Lal and BA Stewart). Advances in Soil Science.CRC Press. 419-469 pp.

Wani SP, Pathak P, Sreedevi TK, Singh H P and **Singh P.** 2003. Efficient management of rainwater for increased crop productivity and groundwater recharge in Asia. In: Kijne, w, Barker R, and Molden D (Eds.) Water Productivity in Agriculture: Limits and Opportunities for Improvement. CAB International. 199-215 pp.

Wani SP, Sreedevi TK, Rockström J and **Ramakrishna YS.** 2009. Rain-fed agriculture - Past trend and future prospects. In: (eds. Wani SP, Rockström J and Oweis T) Rain-fed agriculture: Unlocking the Potential. Comprehensive Assessment of Water Management in Agriculture Series. CAB International, Wallingford, UK. 1-35 pp.

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ICRISAT Science with a human face

International Crops Research Institute for the Semi-Arid Tropics

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ICRISAT is a member of the CGIAR Consortium

The **International Crops Research Institute for the Semi-Arid Tropics** (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, of whom 644 million are the poorest of the poor. ICRISAT innovations help the dryland poor move from poverty to prosperity by harnessing markets while managing risks – a strategy called Inclusive Market-Oriented Development (IMOD).

ICRISAT is headquartered in Patancheru near Hyderabad, Andhra Pradesh, India, with two regional hubs and five country offices in sub-Saharan Africa. It is a member of the CGIAR Consortium. CGIAR is a global research partnership for a food secure future.

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