Efficient Management of Water Resources for Improving the Livelihoods through Integrated Watershed Management Approach

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Abstract

Southwest China, administratively covering the provinces of Yunnan, Guizhou, Sichuan, Chongqing Municipality, and Tibet Autonomous Region is characterized by mountainous topography, multi-ethnic residents, and poor eco-environmental conditions. Except some parts of Sichuan province, the rest of the region consists of hills and mountains, which occupy more than 90 percent of the land area. Therefore, the cultivated land is very scarce. Most of the non-cultivated as well as cultivated lands are subject to severe soil erosion. Agriculture is a major dependency of livelihoods for the majority of the people in the region, especially in Yunnan, Guizhou and Sichuan provinces. The annual rainfall in this region varies from 1000 to 2000 mm and its distribution is erratic causing frequent droughts because most of the cropping is rain-fed. Agriculture is also the major source of revenues in the river valley areas in the southwest China, with a 44 percent of the social production values, and 54 percent of the Gross Domestic Product (GDP). Watershed management is one of the important schemes of the Chinese Government in the West Development Strategy. Economic development and improvement of eco-environmental conditions are two main goals of this strategy. The major constraints in this region are severe soil erosion, water scarcity for crop production and land degradation. The National Agricultural Research System (NARS) of China in recent years have developed and evaluated technologies like vegetation restoration, rain water harvesting, and control of soil erosion by different interventions in the research station to overcome the constraints. Since 2003 a collaborative project between International Crop Research Institute for Semi-Arid Tropics (ICRISAT) and Yunnan Academy of Agricultural Sciences (YAAS) and Guizhou Academy of Agricultural Sciences (GAAS), funded by Asian Development Bank (ADB), is being implemented in two benchmark watersheds representing two eco-regions, hot-arid valley region in Yunnan province and Karst region in Guizhou province. The major emphasis of this work is harvesting rainwater and its efficient use, control of soil erosion as also by various soil conservation measures in farmers' fields. As a part of integrated watershed management, many other interventions are being evaluated in order to improve the income of the farmers along with soil and water management interventions.

Introduction

Southwest China, administratively covering the provinces of Yunnan, Guizhou,

Sichuan, Chongqing Municipality, and Tibet Autonomous Region is characterized by mountainous topography, multi-ethnic residents, and poor eco-environmental conditions. Agriculture is a major source of livelihood for majority of the population in the region. Arid valley areas are the major agricultural areas in the region, especially in Yunnan, Guizhou and Sichuan provinces. Agriculture is also major source of revenue in the river valley areas in southwest China, with a 44 percent of the social production values, and 54 percent of the GDP. However, most of the agricultural activities in the arid river valleys are rainfed agriculture. Watershed management is one of the important schemes of Chinese Government in the West Development Strategy. Economic development and improvement of eco-environmental conditions are two main goals of the strategy.

Two eco-regions in the southwest China are described below representing hot-arid valley regions in Yunnan province as well as other similar areas of Jinshajiang river basin and the Karst region of Guizhou province, which are both within Yangtze River drainage area.

Yunnan province is characterized by large areas of hills and mountains. The total area of the province is 383,390 km^2 (84% are hills and mountains, 10% are undulating lands, 6% are flat and valley lands), with only 2.93 million ha of arable land, of which 0.95 million ha (32%) is paddy field, 1.98 million ha (68%) is upland; irrigated land is 1.18 million ha (44.6%) and rainfed area is 1.75 million ha (55.4%).

The average annual rainfall is about 1300 mm ranging from 500-2900 mm in different parts of the province, distributing 85-90 percent from May to October About 38.2 percent of the total area (146, 000 km^2) has erosion problem. The yearly erosion modules range from 5-180 t f ha^{-1}, mostly from 5 -50 t f ha^{-1}. Severe erosion mainly occurs during July to September.

Yunnan is an agricultural province where 87 percent of its population depends on agriculture. Farmers are small holder with about 0.07 ha farmland per capita, which makes about 0.28 ha per household and the land holding is always fragmented. The major crops of the province are rice, corn, wheat, beans, tobacco, sugarcane, potato, sweet potato, oil seed crops, tea, vegetables, fruits, etc. Diversified crop systems found in the province are rice-based system: rice-wheat, rice-beans; and tobacco-based system: tobacco-wheat, tobacco-faba bean or pea.

Guizhou province is located in the east slope of Yun-Gui plateau with a total population of 37 million. The average altitude is 1100 m asl. The total land area is 176,152 km^2 of which 97 percent is mountains and hills. It is characterized by sub-tropic monsoon climate with annual mean temperature of 14-16°C and the average precipitation of 1100-1300 mm. Abundant sunshine and rainfall provide suitable condition for various plants to grow in the province.

Soil erosion is the major problem in Guizhou province. About 41 km^2, accounting for 44 percent of the total territory of the province is eroded causing serious landslide and debris flow. Nearly 0.28 billion tonnes of soil flows down into Yangzte river and Zhujiang river and creating decline in reservoir capacity. Another result of soil erosion in this eco-region is stone exposure. In this province, around 73 percent of the total land are Karst areas with 23-thousand km^2 land with stone exposing.

The arable land in Guizhou province is more than 1.86 million ha. The arable land per capita is only 0.05 ha. The major crops of the province are rice, corn, wheat, beans, tobacco, potato, sweet potato, oilseed, tea, vegetables, fruits, etc.

The major constraints for agriculture production are:

- *Water scarcity:* Due to inadequate and erratic distribution of rainfall, frequent droughts occur.
- *Soil erosion:* A severe problem in both eco-regions leading to large gullies and 'earth forest' in Yunnan, and Karst exposure of large tracks of cultivated land in Guizhou
- *Degradation of land:* Mainly due to soil erosion and improper crop management.

A participatory integrated watershed management approach is being evaluated since 2003 with the collaboration of ICRISAT, YAAS and GAAS which is funded by ADB. The objectives of the approach are: (i) reducing soil erosion, (ii) rainwater harvesting and its efficient use; and (iii) improving crop management systems to sustain the present productivity in an efficient manner, in order to enhance the economic conditions of the farmers.

Previous Research

The Yunnan Academy of Agricultural Sciences (YAAS) and Guizhou Academy of Agricultural Sciences (GAAS) in recent years have conducted research to overcome the above constraints. Many interventions were developed and evaluated in the research station. Some examples of such work are:

1. Vegetation restoration in hot-arid valley regions:
   - Fruit production under supplemental irrigation condition, such as mango (*Mangifera indica*), litchi (*Litchi chinensis*), longgan (*Mimocarpus longgan*), jack fruit (*Artocarpus heterphyllus*), banana (*Musa nana*), papaya (*Carica papaya*), etc.
   - Participatory forest establishment for conservation of soil and water and/ or for fuel wood such as *Eucalypts camaldelensis, Leucaena lecocephala,* and native shrubs.
   - Rainfed high value woody species: tamarind (*Tamarindus indica*) and neem trees.
   - Participatory pastures restoring, such as tropical grasses, *Stylosanthes guianensis* and native grass species, etc., and livestock rearing.

   Results show that all these methods have good effect on increase of vegetative covers and promote diversification of crops production to generate higher incomes for the farmers. Use of agro-forestry to plant different fruit trees can improve 12-30 percent of water use efficiency, and increase income by US$ 150 per ha.

2. Technology of rainfall harvesting and its utilization in rainfed agriculture in hot-arid valley regions:
   - Establishing earthen moon ridge interditches with native grasses belt to harvest rainwater for rain-fed cash crop production. This technique can enhance soil moisture by 30-40 percent.
   - Constructing water cellar inside the fields to harvest run-off.
   - Using cement pitcher for pitcher irrigation. It can save 60-70 percent of water than flood irrigation.

3. Farming land construction of farm infrastructures and soil amelioration. The objectives of this intervention are to reduce soil erosion, improve soil moisture and soil fertility. Interventions include:
   - Terracing: This is a long-term measures to control soil erosion (supported by government).
   - Use of contour cropping to reduce soil and water loss.
   - Soil water conservation (mulching with litter, sand, plastic film, etc.).
   - Planting leguminous crops to improve soil fertility.

4. Select and use of drought resistant and/or high value species or varieties. These selections enable farmers' to have larger options to generate incomes from their lands.
   - Fast growing fuel wood trees, e.g, *Eucalypts camaldelensis*.
   - Industrial raw materials, such as medicinal plants and essential oil crops.
   - Fruits (high value, harvesting in winter), forages and off-season vegetables.

Approach

Participatory integrated watershed management approach is being adopted. Two benchmark watersheds to represent the above mentioned two eco-regions were identified. Xiaoxincun in Yuanmou county, Chuxiong prefecture of Yunnan province represents the hot-arid valley regions in Jinshajiang basin. Lucheba in Pingba county, Anshun prefecture of Guizhou province represents the Karst region. The brief descriptions of these two benchmark watersheds are given in Tables 1 and 2.

Table 1. Agriculture characteristics of two benchmark watersheds

	Xiaoxincun	Lucheba
Size (ha)	186.70	720.40
Population	316	1,350
Households	86	365
Land use system		
Cultivated lands	39.60	307.10
Paddy lands	5.20	102.20
Irrigated uplands	0.03	48.80
Rain-fed lands	34.10	156.10
Waste lands	133.40	17.42
Forest lands	11.30	390.40
Others	2.30	5.48
Cultivated lands holding (ha/hsd)	0.46	0.84
Major crops	Rice, watermelon, sweet potato corn/maize, groundnut, beans and chilli pepper	Rice, wheat, corn, soybean, rapeseed, sunflowers, vegetables
Cropping systems	Rice + vegetables, vegetable + maize, and/or fruits / maize sweet potato + seeds watermelon	Rice + rapeseed, corn + rapeseed or other oil seed soybean / corn, Rotation between vegetables, watermelon + rapeseed
Net income (USD/capita)	17.7	175.75

Table 2. Average yields of major crops in the benchmark watersheds (kg ha^{-1})

Crops	Xiaoxincun	Lucheba
Rice	6,000	6,000~7,500
Corn	3,000~4,500	5,000~7500
Sweet potato	12,000~15,000	—
Rapeseed	—	1,125~1,875
Watermelon	8,000~10,000	30,000~45,000
Seed-watermelon	750~1200 (seeds)	—
Potato	—	15,000~22,500
Groundnut	1,650~1,800	1,500~2,250
Sunflower	—	375 (intercropping)
Pigeon pea (pods)	450	—
Soybean (pods)	4,500~7,500	375 (intercropping)
Chinese cabbage	—	60,000~75,000
Tomato	70,000~90,000	45,000~75,000
Chilli pepper (fresh)	30,000~45,000	15,000~22,500
Beans	9,000~15,000	—
Onion	4,500~ 6,000	—

Xiaoxincun Watershed

Xiaoxincun watershed, a natural village of Jinlei village group, Julin town with the total area of about 186.7 ha is located in the middle-north of Yunnan Province belonging to Yuanmou County, Chuxiong Yi Minority Autonomous Prefecture.

Xiaoxincun watershed is about 1 km away from Longchuanjiang river, an important branch of Jinshajiang river, which is the first body-river of Yangtze river and passes through Yuanmou County in the north part from the west to the east. Qinlinghe river, the first order branch of Longchuanjiang river is also very close to the project watershed. Due to erosion, huge gullies have developed in the watershed. These gullies cover 71.45 percent of the total land area. According to statistics (1990), the average soil erosion modulus of Yuanmou was 43.33t ha^{-1} yr^{-1}, highest in Yunnan province.

Xiaoxincun watershed is a typical hot-arid valley area with slopy lands of hills and the altitude of 1068-1100 m asl. Due to fohen winds the climate is dry and hot with plentiful sunshine. During 1956-1990, the annual average temperature was about 21.9°C, annual mean rainfall 612.3 mm, annual mean evaporation 3600mm, average relative humidity 32 to 70 percent; and the average annual sunshine hours up to 2766. In the last 6 years (1997-2002), the annual average rainfall increased to 781mm.

Xiaoxincun is a new village, which emigrated from the semi-montane area in 1965 due to severe drought. All of the population which is Yi people is of 25 minorities in Yunnan Province.

As shown in Table 4, farmers' per capita net income in Xiaoxincun watershed is much lower than that of the farmers in the whole country and those settled in the irrigated-land areas. Moreover, of the total gross income of about 138 USD per capita, 46.4 percent come from off-farm work and open grazing livestock rearing.

Lucheba Watershed

Lucheba watershed is located in middle-low hilly areas, centre of Guizhou province and belongs to Karst landform. The average altitude is about 1350 m above sea level. The annual average precipitation is about 1200 mm and average temperature of 13.8°C. The soils in the watershed belong to yellow soil, paddy soil and limestone soil groups. The watershed is located near the branch of Yangtze river.

After the selection of these benchmark sites, participatory rural assessments (PRAs) were conducted at both the sites to identify and prioritize the constraints. Table 3 gives various constraints at both sites.

Table 3. Constraints for crop production at benchmark watersheds

Xiaoxincun	Lucheba
Soil erosion	Poor transportation
Low rainfall and water scarcity	Stone exposing (Krast)
Huge gullies, expanding	Water scarcity
Soil degradation	Small land holding
Small land holding	Low literacy
Low literacy	Poor income condition
Poor income condition	
Diseases and pests	

The income of farming households in these benchmark watershed are very low as compared with the national average, in spite of the fact that farmers are getting very high crop yields (Table 4). The agriculture output in the watersheds depends primarily on the holdings of irrigated land. Fox example, in Xiaoxincun watershed, paddy land holdings control the income of farming households because of the high profits of off-season vegetables grown in paddy lands in autumn and winter. The main reasons for low income are: (i) small land holdings, (ii) high inputs on fertilizer and farm chemicals to their crops, and (iii) undependable off-farm jobs. In order to improve the income of the poor farmers on sustainable basis, alternative options are needed like growing more of cash crops, such as vegetables, fruit crops, etc. Since most of the cultivated lands are rain-fed, more water is needed to grow alternative crop options. Therefore, rain water harvesting and its efficient utilization is a top priority. Secondly, in order to check the soil erosion and land degradation, interventions are needed. Both these can be achieved through an integrated watershed management.

Table 4. Gross incomes of farming households (USD/capita per annum)

Income	Xiaoxincun (Gross)	Lucheba (Gross)
Farming	73.8	137.2
Off-farming	30.5	18.3
Livestock raising	33.5	27.4
Total	137.8	182.9

Interventions

Xiaoxincun Watershed

Community groups and farmers activities: In August 2003, three community groups were set up, namely, scientific group, women group and leading people group, and each group composed of 5 members: 4 farmers and 1 researcher from the project.

In spite of various constraints to access all the farmers, farmers' activities at the level of community groups or households or individuals have been quite satisfactory from the beginning.

Rain water harvesting: With the participation of all the 86 households an agreement has been made to repair and make use of the existing three water tanks as well as the channel system to harvest the rainwater. The costs will be shared 50% each by farmers and the project. Channel system construction shall be completed in 3 months. The project will also facilitate to construct small water tanks in volunteer farmers' fields to use the harvested rainwater. In order to improve the water-use efficiency of harvested water, drip irrigation system will be evaluated in 10 farmers' fields.

Crop diversification: Crop diversification mainly focussed on home yard-horticulture. After more than 15 years of on-station research, jackfruit as a long-term profit crop and papaya as a short-term profit crop were planted in farm households. So far, three advantages have been supporting yard-horticulture in the watershed. Firstly, it can enhance the use-efficiency of water from open wells in farmers' yards. Wastewater from household activities was used in the yards, to irrigate the horticulture plants. Secondly, fruits, particularly short-term profit fruits can improve very quickly the nutrition level of the households, for example vitamins, and/or give more options to make marketing profits. Finally, yard-fruit-tree, especially, those arboreal trees like jackfruit in every household can provide shading for farmers' houses as well improve the environment of the village.

Crop variety evaluation: Major crops in the watershed are sweet potato and watermelon. The farmers have used very few varieties for long time causing crop degradation characterized by declined resistance to disease and pests, low yield and poor quality of the products, less marketing condition, and finally low income from farming. After three years of research in the station of ITSCC, new varieties of watermelon, muskmelon and sweet potato are introduced in farmers fields. In spite of the extreme drought conditions last year, the result showed good performance of all the sweet potato varieties. However, muskmelon and watermelon varieties did not perform well.

Integrated plant protection management: As previously mentioned, high cost of farm chemicals is one of the major reason for low income of the farm households. Crops resistance to disease and pests has declined in the watershed even in the whole

eco-region. Furthermore, frequent droughts exacerbate this problem. Integrated plant protection management (IPM) is adopted with bio-pesticides, e.g., tobacco waste extract is being evaluated on watermelon and rice on 20 farmer's fields covering an area of 0.67ha. It was used in rice with three methods: (i) put in with basal fertilizer; (ii) extracted and sprayed on crops; and (iii) dissolved at the entrance of water in paddy fields. Only basal fertilization with the wastes was tried on watermelon. The results from all trials of pests control on rice and watermelon are very encouraging. Rice paddy borer and rice hopper were completely under control. Damages by soil insects on watermelon such as cutworm, white grub, wireworm and ground beetle, etc. were reduced to the extent of about 50 percent. Encouraged by this performance, farmers want to try this pesticide also on their vegetable crops.

Also, 4 light-traps have been installed which cover 4 ha paddy lands used for vegetables production during autumn and winter. This method has been approved as an efficient countermeasure against insects in this eco-regional scale during the past three years.

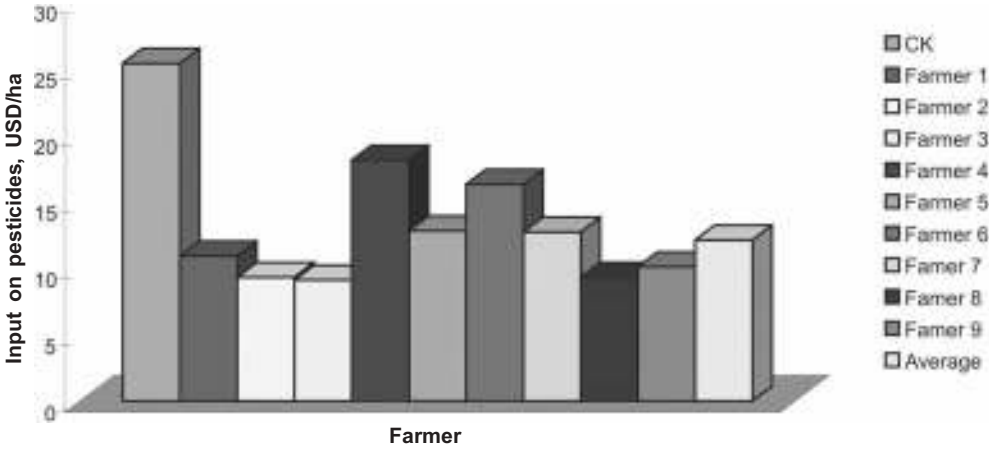

Figure 1. Input on pesticides for rice protection by using tobacco wastes bio-pesticides (USD/ha)

Forage crop evaluation: Overgrazing is considered by scientists and extension staff as the crucial factor contributing to land degradation and soil erosion in this eco-region. Stall-fed animal raised for land conservation was proposed and demonstrated by the project. Although this approach is gradually accepted by some households in the watershed but it gives rise to the shortage of appropriate forage supply. In the past five-year-on-station research and some extension cases several perennial forage species like *Panicum maximum* cv Reyan No 9, Neonotonia wightii spp. *Stylosanthes guianensis* cv Reyan 2, *Cajanus cajan* cv. spp. have been found to have good yield and quality. These species are major fodder resources in summer, autumn and winter, and annual *Medicago sativa* cv. sandili as an option of supplementary fodder in late winter and early spring have been planted in 5 farmers' fields. *Panicum* is also planted on hill slope to check soil erosion.

Gliricidia: Gliricidia was introduced into the watershed as an attempt mainly to provide more green manure to the degraded soils. Long-term surface soil loss, leaching, severe drought and continuous cropping result in severe soil degradation. *Gliricidia* was planted on farmers fields as field bunds and cross-slope intercropping. It was also planted on the sides of a live gully inside the farming field. The performance in all plots was very encouraging.

Training of farmers and leaders: Traditionally, cash crops especially fruit trees were not planted in the watershed due to the shortage of water. Since more open wells were constructed, some fruits and vegetables have been introduced into the watershed. *Zyziphus,* a popular fruit crop in places under appropriate irrigation condition in the eco-region has shown wonderful profit but nobody tried it in Xiaoxincun watershed till 2001. Two farmers grew this fruit crop on the irrigated upland and produced the pleasant results. Since 2003 about 20 farmers successively followed. However, their hopes are frustrated by high input, low yields and inferior quality of the fruit. Also, watermelon, especially, seeds watermelon has brought supportive income to the farmers in the past five years. But the profits have been declining due to disease and pests. In order to encourage these alternative crop options, the project took up the responsibility for training farmers and leaders on *Zyziphus* and watermelon crop management.

Lucheba Watershed

Drip irrigation: Besides introduction of forage crops (alfalfa, ryegrass, buckwheat) and providing balanced nutrition to all the crops, drip irrigation was demonstrated in Lucheba watershed. Several small size water tanks were constructed near farmlands to store water in dry season and harvest rainwater for supplementary irrigation. Each tank can store 3 cubic metres' water, which can be supplemented. About 2.5 ha of upland were protected against drought, that seriously affected yield of upland crops.

Road construction for transportation: Under the support from township government, a 4-metre wide, 1.7 km-long road was constructed for transportation to the market. Farmers put more hopes to the road construction for better movement and marketing of agricultural produce. Another road construction took place under the project support. It is about 1.5 km long, 4 metre wide connecting Zhangjiaba village to main highway (total is about 3.5 km). Cost of road construction was equally shared by farm households and the project.

Alley cropping: Alley cropping is a sustainable technology for sloping lands and was introduced by IWMI project and expanded at many places of Guizhou province. This technology could effectively control soil erosion and increase income on sloping land. After discussions, farmers selected the hedgerow crops themselves. Farmers preferred peach+ wild buckwheat or pear+ wild buckwheat. The fruit tree will have high income and the wild buckwheat is a good forage grass for raising

pigs. Total 261 peach and 259 pear trees have been planted and 49 kg of wild buckwheat seedlings were transplanted at the Liujiazai village of the watershed.

Farmers' training: Keeping in view the farmers interests, following three trainings were held at the watershed:

- 50 farmers were involved in the low-pollution vegetable production.
- 57 households participated in the training on solid-media rice seedling techniques. Due to serious drought last year, the water level at the reservoir declined and many farmers did not have enough water for rice seedling. Experts from GAAS suggested farmers to adopt this technology and about 15.6 percent of total households in the watershed accepted it. This technology was helpful not only in saving water at rice seedling stage, but also produced higher rice yield by avoiding cold weather effect at rice flowering stage (the disaster takes place every year and about 10-70 per cent of yield is lost).
- 100 farmers got trainings on technology of fruit tree plantation and management, contour alley fruit trees cropping, varieties selection, and other management technologies.
- 150 farmers took the courses on forage selection and planting. Most of the farmers showed great interest in selecting suitable varieties for their farmlands.

Author Index

Our vision is that in 2008, IWMI is a world-class knowledge resource center on water, food and environment. It generates knowledge on better water and land management in developing countries, through strategic research alliances with a set of core partners throughout Asia and Africa, and with advanced research institutes in developed countries.

This knowledge is held and maintained as global public goods for the benefit of mankind.

Watershed Management Challenges

Improved Productivity, Resources and Livelihoods

Edited by
Bharat R. Sharma, J.S. Samra, C.A. Scott and Suhas P. Wani

Watershed management has emerged as a potential concept, which harmonizes the use of natural resources for their long-term sustainability and optimal productivity. It has also been accepted as a sound development paradigm by the local governments and donor agencies for upliftment of the rural masses living in rainfed and fragile ecosystems. Though sound on hydrological and biophysical principles, the approach is confronted with several challenges related to equity, effective participation, scaling-up, water rights, conflict resolution, cost sharing and subsidies, public and private gains and crafting of suitable policies and institutions. This publication is an attempt to effectively address these and related issues from scientific, socio-economic, institutional and policy perspectives through integration of Indian and international knowledge and experience.

This book is also an attempt to broker the Indian and international experiences on watershed management to the researchers, policy makers, donors and program implementing agencies in the African continent. It will be of significant interest to those working in the areas of hydrology and engineering, land and water management, development studies, knowledge management, and policies and institutions.

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FUTURE HARVEST
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ISBN 92-9090-611 1