5 Sustainable mountain agriculture through integrated and science-based watershed management: A case study

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5.1 Introduction

Agriculture in mountain areas is essential for the world's food security. Mountains account for one quarter of the world's land surface and are home to 12 percent of its population. More vitally, 50 percent of the world's population depend on the water and ecosystem services that mountains provide. Mountain areas are characterized by topography of variable altitudes and variable climatic conditions and so are major reservoirs of global biodiversity.

Mountain ecosystems are largely fragile and rainfed, and are a high-risk environment throughout the year. Mountain systems are extremely vulnerable to climate variability and the implications of climate change. People who live in mountain regions are often amongst the poorest and most food insecure people in the world due to the harsh conditions of the terrain, poor infrastructure development, lack of services and general isolation. However, mountain regions are increasingly popular tourist destinations worldwide attracting over 50 million visitors annually which can provide the opportunity to popularise FSF and also create additional income for the locals.

Achieving Zero Hunger for a world population that is expected to pass the 9 billion mark by 2050 is a major challenge. Moreover, ensuring that nutrition is balanced is also important, especially when both malnutrition and obesity are growing concerns globally as a result of poor or unhealthy diets.

As a natural resource, our water supply is finite and circulates through the water cycle in a process of evaporation, transpiration and precipitation driven mainly by various climatic and land management factors (Falkenmark, 1997). Of the 1 385.5 million km^3 of water available on earth, 97.3 percent is salt water in oceans with only 2.7 percent fresh water, which is the lifeline of the biosphere, where forest, woodlands, wetlands, grasslands and croplands are the major outputs (Shiklomanov, 1993; Postel *et al*., 1996; Rockström *et al*., 1999). Of the annual precipitation (110 305 km^3), only about 35 percent (38 230 km^3) returns to the ocean surface as run off, while the remaining 65 percent is converted into water vapour. The availability of water resources per capita will decline as the world population keeps growing. For example, per capita water availability in India decreased from 5 177 m^3 in 1951 to 1 820 m^3 in 2001 due to the increase in population from 361 million in 1951 to 1.02 billion in 2001. This population increase is expected to continue, with a rise to 1.39 billion by 2025 and 1.64 billion by 2050, with a corresponding decrease in per capita water availability of 1 341 m^3 by 2025 and 1 140 m^3 by 2050, respectively. Although mountains provide fresh water resources to 50 percent of the world's population, people living in mountain regions face water scarcity during the dry months of the year. This contributes to both food insecurity and poverty. But poverty and food insecurity also exist in mountain areas where there is high precipitation. This is because of poor agricultural productivity, a lack of infrastructure and little development due to the twin challenges of topography and isolation. This is in line with the well-established nexus between hunger, water scarcity and poverty worldwide (Falkenmark, 1986). Adopting a science-based holistic integrated watershed approach is vital for addressing the major challenges of water scarcity, poverty and hunger in mountain regions (Wani *et al*., 2018).

Table 5.1 Details of case watershed sites in China and Thailand

Site	Region	Geographic position	Number of families	Rainfall (mm)	Soil type	Major crops/ cropping systems
Xiaoxincun	Yunnan, China	25° 36′ 14″ N/ 103° 13′ 12″ E	86	640	Ultisols, Inceptisols	Rice, vegetables (broad bean, chilli, corn, groundnut, sweet potato, watermelon
Lucheba	Guizhou, China	26° 35′ N/ 106° 43′ E	365	1 284	Ultisols, Inceptisols	Cabbage, corn, kidney bean, rape, rice, soybean, sunflower, watermelon and vegetables (chillies, eggplant, pumpkin, tomato, etc.)
Tad Fa	Khon Kaen, Thailand	15° 30′ N/ 101° 30′ – 140° 30′ E	358	1 300	Ustults	Bamboo, maize, vegetables, plantation, tamarind
Wang Chai	Khon Kaen, Thailand	16° 30′ N/ 102° 47′ E	358	1 171	Ustults	Paddy, groundnut, soybean, sugarcane, cassava, cowpea, fruits vegetables

5.2 Characterization of case studies of watershed areas in China and Thailand

The details of sites of farmer participatory watershed management initiatives managed and implemented by an ICRISAT-led consortium in China and Thailand are shown in Table 5.1.

The major constraints for crop and food production are lack of water due to low and erratic rainfall, and severe land degradation from soil erosion causing large gullies and water run-off due to steep slopes that results in frequent droughts. Farmers living in the watersheds, therefore, may be resource poor and not have the knowledge to take on new and emerging challenges.

5.3 Participatory, integrated and consortium approaches for watershed management

An ICRISAT-led consortium undertook comprehensive assessments of watershed programmes in India and the meta-analysis of 636 watershed case studies from different agro-eco regions. The findings revealed that watershed programmes were silently revolutionizing rainfed areas and were economically remunerative for farmers. Some 99 percent of these programmes showed a benefit-cost ratio of 2:1 with an internal rate of return of 27.2 percent (Joshi *et al*., 2008). These programmes benefited farmers by increasing irrigated areas by 51.5 percent, improving cropping intensity by 35 percent, and reducing soil loss to 1.1 tonnes/ha^{-1} and runoff by 45 percent. There was also an improvement in the availability of groundwater. However, about 62 percent of the case studies showed a below average performance (Figure 5.1). Better performances of watersheds were realized in the rainfall regime of 700–1 000 mm. This indicates a need to develop technologies suited to areas with a rainfall regime of less than 700 mm and more than 1 000 mm.

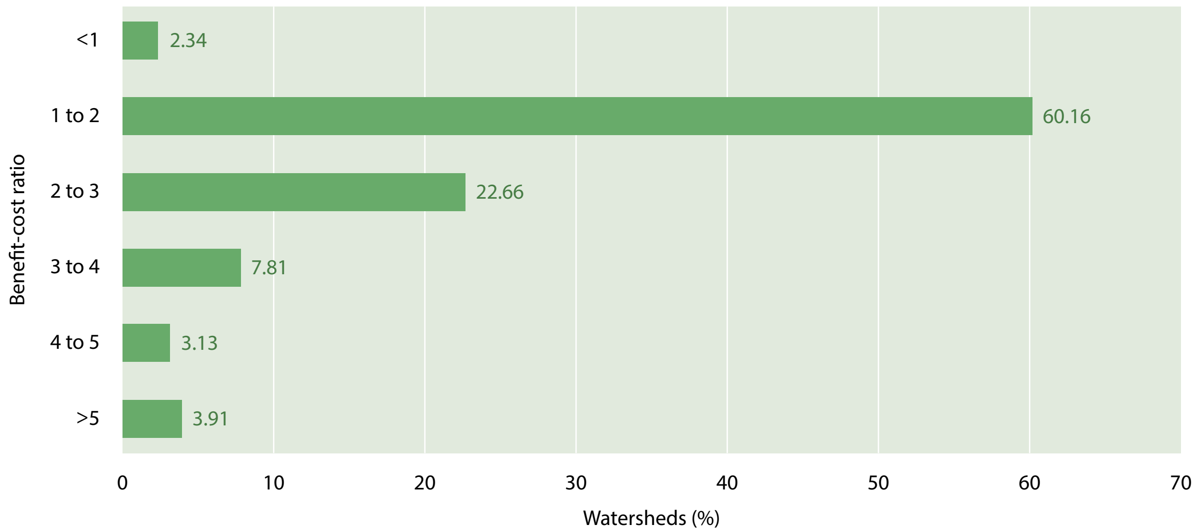
The results of the meta-analysis regression indicated that the benefits of watershed programmes vary depending upon the location, rainfall quantity and intensity, rainfall patterns, and the implementing agency. It is also important to emphasize that the status of the target population and people's participation play a deterministic role in the performance and efficiency of such watershed programmes (Joshi *et al*., 2008).

5.3.1 Integrated watershed management to enhance productivity and resilience

Watersheds are not only hydrological units but also connect upstream and downstream areas while providing life support to rural populations by making people, crops and animals an integral part of the watershed system. The activities of people, such as growing crops and raising livestock can affect the productive status of watersheds. Water scarcity (drought) due to land degradation can be addressed through a system of integrated watershed management.

A new generation of watershed development programmes has been implemented with the larger aim of addressing issues of food security, equity, poverty, severe land degradation and water scarcity in dryland areas. This new approach is people-centric and integrated for achieving Zero Hunger and improved

Figure 5.1 Meta-analysis of watershed programmes in India based on economic parameters



Source: Joshi *et al.*, 2008

livelihoods through sustainable management of natural resources. These recent watershed initiatives have been looking beyond soil and water conservation into a range of activities from productivity and profitability enhancement to interventions in agriculture, including both agronomic and horticultural crops, and animal husbandry. They also involve community organization and gender equity to build climate resilience (Wani *et al.*, 2002, 2003 and 2007a). This more holistic approach requires optimal contribution from people of different disciplinary backgrounds to create a demand for multi-stakeholder watershed development programmes.

In Asia, ICRISAT in partnership with national agricultural research systems, non-governmental organizations (NGOs) and the private sector have developed and evaluated an innovative farmers participatory integrated watershed consortium model aimed at increasing agricultural productivity and eventually improving rural livelihoods (Wani *et al.*, 2003, Wani *et al.*, 2014). The conventional watershed approach was compartmental, structure-driven and lacked an effective strategy for efficient use of resources. Though watersheds served as the entry point, a paradigm shift was needed from these traditional structure-driven watershed programmes to a holistic systems approach to improve livelihoods, help alleviate poverty and to achieve food security through increased agricultural productivity using environment-friendly resource management practices (Wani *et al.*, 2003, 2008a, 2014). Watershed management should also lead to exploring multiple livelihood interventions (Wani *et al.*, 2006, 2007a, 2008a), which allows the new community watershed management model to fit into the livelihood framework as a tool to assist in the sustainable development of rural livelihoods (Wani *et al.*, 2008).

The ICRISAT consortium model for community watershed management adopted the principles of convergence, cooperation, collective action, and capacity building (termed the 4Cs). Technical backstopping came from a consortium of institutions to address the issues of equity, efficiency, economics and the environment (termed the 4Es) (Wani *et al.*, 2008b). Later, Innovations, Integration, Inclusivity and Intensification (termed the 4Is) were added thereby leading to the development of the 4 ICEs model (Wani *et al.*, 2018b). The new integrated community watershed model provides technological options for management of surface water harvesting and waterway systems, *in-situ* conservation of rainwater for recharging groundwater, and supplemental irrigation. It also provides for the appropriate management of nutrients and soils, crop production technology and appropriate farming systems with income-generating micro-enterprises for improving livelihoods while protecting the environment (Wani *et al.*, 2002, 2007a, 2007b; Sreedevi *et al.*, 2004).

To achieve equity for small farmers, a focus on demand-driven low-cost technologies with built-in tangible economic benefits comprises an integral component of participatory watershed management. This helps to ensure increased and effective individual participation. In a survey undertaken in watersheds in China and Thailand, 70 percent of the local people were involved from the initial stage. The same high

Figure 5.2a Water balance in Tad Fa watershed in Thailand: data for the wet year of 2000 (left); data for the dry year of 2001 (right).

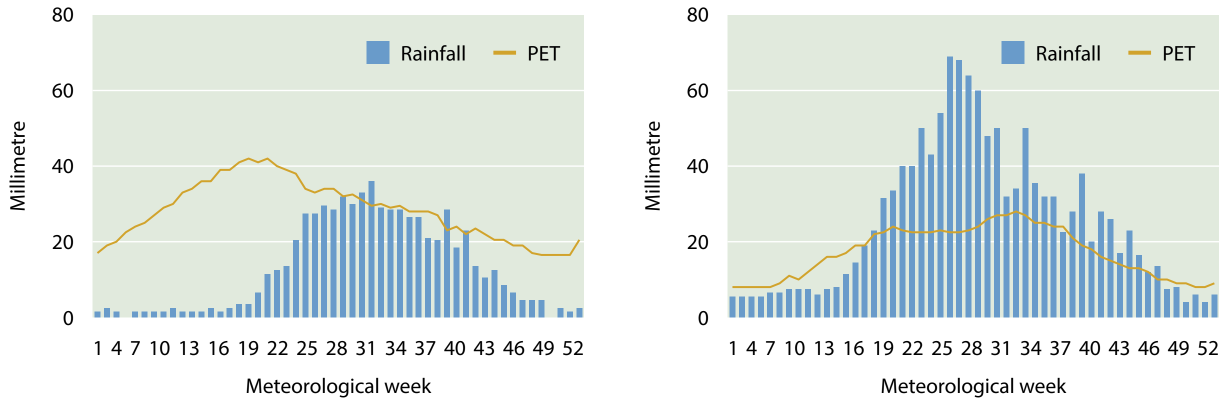
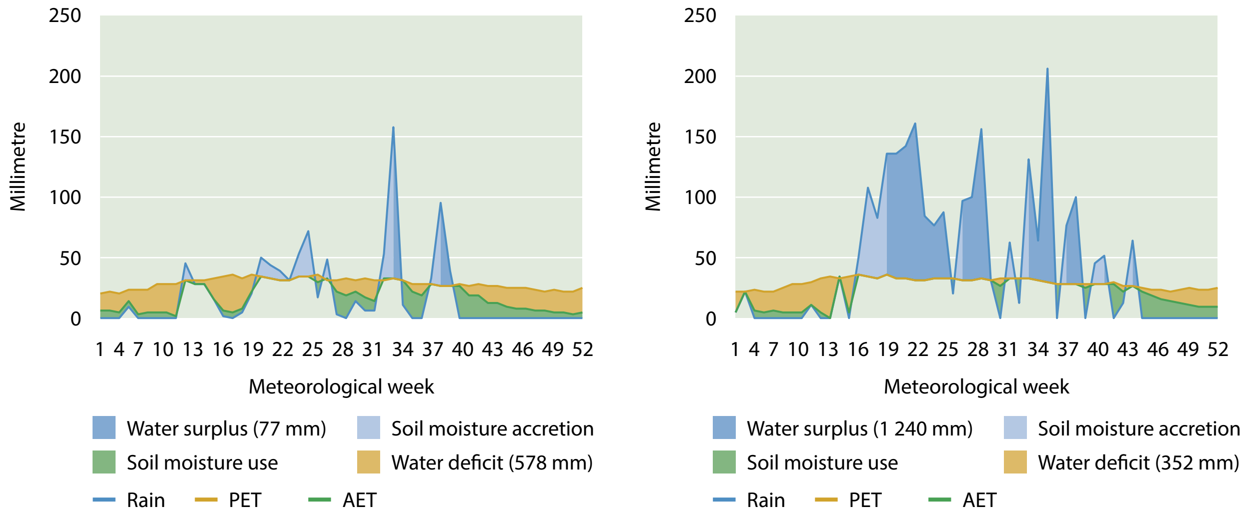


Figure 5.2b Water balance in the Xiaoxincun (left); and Lucheba (right) watersheds in China



Source: Wani *et al.*, 2012

percentage of the population attended all meetings. Twenty-seven percent of the population were involved in decision-making, and 83 percent were involved in carrying out allocated tasks. Empowerment, involvement and ownership of the local communities in decision-making and the execution of tasks were the main reasons behind the success of the watershed management interventions. The ownership and important benefits to the communities helped to institutionalize watershed management to ensure that users would be willing pay for the interventions. This introduces the sustainability component in watershed management, allowing it to continue when the external aid, used to initiate watershed programmes, is phased out.

A consortium of multidisciplinary experts from different institutions supported farmers in taking forward the watershed management programmes at study sites in China and Thailand. In the case of the watersheds in China (at Xiaoxincun and Lucheba), the consortium was made up of experts from the Integrated Rural Development Centre (IRDC) of Guizhou Academy of Agricultural Sciences (GAAS), Guizhou; the Tropical and Subtropical Cash Crops Research Institute of Yunnan Academy of Agricultural Sciences (YAAS), Kunming; and ICRISAT, Patancheru. For watersheds in Thailand (at Tad Fa and Wang Chai), the consortium was comprised of experts from the Royal Thai Department of Agriculture, Royal Thai Department of Land Development, Khon Kaen University and ICRISAT.

5.3.2 Water budgeting to plan a water management strategy

Before a water management strategy can be put in place, a water budgeting or a water balance of the identified watershed area has to be undertaken to assess the occurrence of dry spells, as well as excess water available for harvesting based on the rainfall, soil moisture/water status and potential evapo-transpiration (PET) of the area.

Table 5.2 The impact of improved watershed management in reducing runoff water

Country	Study site	Rainfall (mm)	Runoff (mm)	Runoff as percentage of rainfall
China	Xiaoxincun	344	24.3	7.1
India	Kothapally	743	44.0	7.8
Thailand	Tad Fa	1 284	169.0	13.2
	Wang Chai	940	210.0	22.3

Water balance/budgeting in the potential watershed areas can differ drastically during wetter and drier years as compared to years where rainfall patterns are more normal. The process can be further affected by climate change, even when the total rainfall quantity has not been affected. This is because the change in rainfall distribution or the number of rainy days and the rainfall intensity affects the water balance of the watershed. The watershed interventions under discussion were planned based on the previous 30 years of average rainfall quantity and intensity. There is an urgent need to consider the growing impacts of climate change on rainfall quantity and intensity, rainfall distribution, and the occurrence of dry spells during the crop-growing season for planning water management strategies in the watershed. It is no longer possible to take a business-as-usual approach due to the serious implications of climate change, more specifically the increase in the number of days when rainfall intensity is high and the decrease in the total number of rainy days causing more dry spells during the crop-growing season (Rao *et al*., 2016).

In the Tad Fa watershed in Thailand, more rainfall than the potential PET was observed from the first week of April until the last week of October during the wet year of 2000 (Figure 5.2a left). Although, there were weeks when rainfall was less than the PET, as the soil was fully saturated by the last week of April, a water surplus (1 240 mm) was available for managing efficiently. However, a 352 mm annual water deficit was experienced during the dry period of the year. During 2001, a dry year, rainfall surpassed PET from the last week of April and this continued up to the middle of September (Figure 5.2a, right), resulting in a small (77 mm) water surplus over two weeks and a considerable annual water deficit of 578 mm.

In China, the Xiaoxincun watershed showed a high annual PET of about 1 464 mm compared to rainfall of 640 mm, with a large water deficit (Figure 5.2b left). The Xiaoxincun watershed in Yunnan province experienced very little water surplus for a short duration in the rainy season only, suggesting that *in-situ* rainwater conservation measures would be economically more rewarding and investments in *ex situ* rainwater harvesting could be moderate in benefits. However, another watershed in a nearby province Guizhou showed a lower annual PET of 891 mm with 1 284 mm annual rainfall. This resulted in a large (384 mm) water surplus, particularly during June and July (Figure 5.2b, right).

Such studies on distribution of various water balance components reveal uneven distribution of rainfall during the year and suggest the need to adopt measures for efficiently harnessing and conserving surplus water during rainy periods to counter water deficits,

Figure 5.3 Various interventions implemented in the watershed

Table 5.3 Changes in area and yield of major crops before and after watershed management in the Lucheba watershed in China

Crops and cropping system (intercrop or sole crop)	**Before**		**After**	
	Area (ha)	**Yield** (kg/ha)	**Area** (ha)	**Yield** (kg/ha)
Corn (intercrop)	3.230	29 563	0	0
Corn (sole crop)	1.840	24 918	0	0
Rice (sole crop)	5.113	29 782	0	0
Cabbage	0	0	4.00	363 549
Tomato (sole crop)	0	0	3.40	640 880
Pepper (sole crop)	0	0	2.04	281 690
Cucumber	0	0	0.66	443 147
Chilli (sole crop)	0	0	1.40	299 786

particularly during dry periods of the year or in a dry year itself. Improved watershed management can be achieved by constructing water harvesting structures, contour cultivation across slopes, the planting of *Gliricidia* on bunds (embankments), ensuring less exposed soil erosion through increased cropping intensity, increased use of organic manures, and better crop growth due to adoption of new varieties aimed at offering more balanced nutrition. All these practices would restrict the free flow of water, leading to more infiltration and reduce runoff in comparison to the rainfall received (Table 5.2), as generally more than 30 percent of rainfall is lost as runoff. The reduced runoff infiltrated into the soil would augment green water sources in rainfed agriculture. Green water sources are vital for food production with almost three times more green water being used than blue (5 000 *versus* 1 800 km^3 y^{-1}), (Karlberg *et al*., 2009). Soil erosion, which is a major environmental problem particularly in Yunnan province of southwest China and other parts of the semi-arid tropics (SAT), including the benchmark site Tad Fa in northeast Thailand, will decrease due to improved watershed management measures that would restrict displacement of soil particles and loss thanks to the reduced water runoff.

5.3.3 Impacts of integrated watershed management in the Lucheba watershed in China

In the Lucheba watershed in China, land-use patterns at the household level changed favourably after improved irrigation resulted in a 94 percent increase in irrigated areas and a 34 percent reduction in rain-fed areas (Wani *et al*., 2013). The area under high-value horticultural crops, such as vegetables, increased significantly for the average household due to more effective water conservation measures and other improved management practices.

Crop Production System: The impact of watershed development on crop production system and related components was assessed in the Lucheba watershed in China through participatory rapid rural appraisals (PRRA).

Figure 5.4 Community and farming nursery of sweet potatos

Table 5.4 Changes in crop production system and field inputs and outputs in 2003 and 2012 in the Lucheba watershed in China

S. Number	Indications	2003	2012
1	Cropping system		
	a. Summer	Rice, maize	Vegetables – Chinese cabbage chilli, tomato
	b. Winter	Rapeseed	Vegetables – Chinese cabbage
2	Cropping intensity (%)	100 – 150	300
3	Irrigation area	Largely rain-fed	Total irrigated
4	Use of improved seeds	Partial	Total cropped area under high-yielding varieties (HYVs)/hybrid
5	Fertilizer use (tonne)	Yes	Yes
	Nitrogen (N)	21.3	78.0
	Phosphorus (P)	5.8	4.2
	Potassium (K)	8.8	10.0
6	Use of agriculture. Plastic films	Nil	15 000 kg
7	Mulch film	Nil	14 800 kg
8	Area under mulch film	Nil	7 500 mu
10	Area ploughed by tractor	Nil	3 500 mu
14	Net income	CNY 1 057 per ha	CNY 3 680 per mu
15	Fuel availability	Forest based	Liquid petroleum gas and electric
16		Wood, bio-gas	Cooking modes
17	Drinking water	Acute shortage	Adequate and reliable water availability
18	Migration from village	Important part of livelihood	Nil, due to crop diversification being higher Opportunity cost for labours

Source: RRA-July 14, 2013

Box 5.1 The Lucheba watershed at glance: 2012

The total area of the Lucheba watershed is 7.2 square km and it has a total population of 1 370, of whom 860 are labourers. There are 11 villages at 1 340 m above sea level and six Farmers Groups. Arable land accounts for 3 350 mu (1 ha = 15 mu) of which 3 300 mu is irrigated and 50 mu is now dry land. Forest coverage is 43.8 percent. Thirty-five farmers have become trainers and instruct other farmers, and 85 farmers having earned the title of Farmer Technician. Vegetables are grown on 10 000 mu, three times the amount grown on total irrigated land in 2002. Annually 30 600 tonnes of produce is sold, with a product gross value of CNY 36.8 million and a net per capita income of CNY 6 800 in 2011 and CNY 8 100 in 2012, which is an increase of 19 percent in per capita income within one year. In 2012 chillies were grown on 1 500 mu, tomatoes on 500 mu, Chinese cabbage on 1 000 mu and beans, eggplants (*brinjal*), etc. on 300 mu.

The benchmark crops before starting the project were corn, kidney bean rapeseed, rice, soybean and sunflower. But after watershed implementation cabbage, watermelon and other vegetables such as chilli, eggplant, pumpkin, and tomato are being cultivated with improved agronomical practices and using hybrid seeds. A major shift in crop area and yield levels at the household level can is shown in Table 5.3. The area under maize, peas and rice cultivation decreased by 18 and 38 percent, respectively, in favour of the increased area under high-value horticultural crops such as vegetables which increased by two to six times (Wani *et al*., 2013). Similarly, after watershed management, yield levels of field crops increased in the range of 6 to 19 percent for maize and rice, while for different vegetables the increase in productivity was in

Box 5.2 The improving prosperity and livelihood of Mr Yixianyou in the Lucheba in China through integrated watershed development

Back in 2002, Mr Yi and Mrs Liu Rui and their son Mr Liu Yong made a living by cultivating 1.3 ha of agricultural land in the Lucheba village of Kieanong Township in Pingba County of Guizhau Province in southern China. Mr Li and Mrs Liu Rui used to grow maize and millet, and struggled to produce sufficient food for their family's food security. The son, Yong migrated to work in the city as a construction worker when he had completed high school. Their family income in 2002 was around CNT 3 500 per annum (a per capita income of CNY 1 200 per year). They were living in an old house in the village and were looking for way to move out of poverty.

In 2013 researchers visited Mr Yi and his family, and were greeted with the sight of their grandson playing with a remote control car in the courtyard of the family's gated, two-storey house. Mr Yi was in the house, sitting on a comfortable sofa and taking part in a meeting involving ten farmers of his group who were discussing an impact assessment of ICRISAT-Asian Development Bank (ADB) project on integrated watershed. The house was well designed and constructed, with a fully equipped kitchen that included and induction plate on a cooking platform and an excellent set of utensils and crockery. In the adjoining room was a 36-inch LED TV with a dish antenna and DVD player, as well as a music system, a refrigerator and water purifier supplying cold and hot water. In the main hall, the researchers spoke to Mrs Liu Rui with Dr Hao Wieping from the Chinese Academy of Agricultural Sciences (CAAS) acting as a translator.

Mrs Liu said, "Our annual income is about 50 000 to 60 000 (CNY) (USD 8 333 to 10 000) and we don't want to go to city at all to make a living. We enjoy our life here. In fact, our son who had worked in the city earlier has come back and joined the family to farm. "This house is for their son with Mr Yi and Mrs Liu Rui having a separate house in the village but the whole family stays together. Eight years ago they constructed the first floor of this house on land that is their ancestral property. Five years later, they decided to add a second floor and spent about CNY 200 000 (USD 33 330) on construction. Mrs Liu said, "we used to grow corn and millet but since 2003 we slowly moved into growing vegetables and now we only grow vegetables. It pays well and four years ago we purchased a fridge for the house, and two years ago we bought a car. First we purchased a motorcycle and small tractor (power tiller) for cultivating our land, then we acquired a small truck for vegetable produce transportation." She very humbly pointed to all their assets in the shade of the courtyard.

Mrs Liu's main concern was that there is little extra labour in the village and all the fieldwork is done by family members only. So their son has also joined them along with their daughter in-law. They had spent about CNY 50 000 (USD 8 330) on gifts to the bride on the occasion of their son's marriage. Researchers asked Mrs Liu about financial loans, and she was adamant that the family hadn't taken any out. In response to the inquiry as to whether they can get additional land for cultivation in the village, she said, "No land is available here now for leasing or purchasing." When asked about the family bank balance, Mrs Liu gave an estimate of CNY 20 000 to 30 000 (USD 3 330 to 5 000). Her first priority for investment is house construction for the whole family then saving funds for risk reserves for years of bad agriculture. She said, "We are a middle class family in the village and there are at least 200 families who have similar living standards."

By now Mr Yi had finished his meeting with the farmer's group members and joined the discussion. To validate what they had heard from his wife about the income and his investment priorities, researchers made enquiries. Mr Yi said that his first priority was his grandson's education and investment in the business such as transportation, as other needs for housing and household appliances had now been met. The total income from agriculture for their family is about CNY 70 000 to 80 000 (USD 11 660 to 13 330) per annum and net income or profit is CNY 30 000 to 40 000 (USD 5 000 to 6 660) per annum. Mr Yi said the family had a current bank balance of CNY 40 000 (USD 6 660) higher than his wife's estimate of CNY 20 000 to 30 000.

the range of 32 to 673 percent. The similar yield levels of farmers are a clear indication of a significant contribution of well-designed technical and extension support services to farmers in the Lucheba watershed. The rapid rural appraisal (RRA) and focus group discussions (FGDs) also backed this evidence.

Farmers do apply considerable quantities of chemical fertilizers and pesticides to their crops. To conserve soil moisture, a large quantity of plastic mulch film is used to cover most of the cropped area. This is a recent innovation in production systems (Figure 5.4), in addition to the use of tractors for ploughing. All these practices in the post-watershed period have increased land productivity, total production and have boosted the sale of farm produce. This has led to increased village income and has reduced migration significantly. Another impact of conserving soil moisture by the use of plastic mulch has been an increase in the availability of irrigation and drinking water. A sizable reduction in the livestock population has been observed by the villagers, except for backyard poultry raised for home consumption (Table 5.4).

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Table 5.5 Impact of watershed management interventions on forage production development in the Lucheba watershed in China

Year	Area under forage (ha)	Yield (t ha^{-1})	RWUE (CNY mm^{-1} ha^{-1})	Net monetary return (CNY ha^{-1})	Benefit-cost ratio
2003	8.4	36.9	28.8	13 220	1.4
2005	15.7	41.9	32.6	22 473	1.8

5.3.4 Forage production and animal-based livelihoods

Increased water availability as a result of effective watershed management has enabled farmers to increase not only cropping intensity, but also diversification of their land-use production systems involving horticultural or forage crop on sloping lands. In the study site at the Lucheba watershed, the area under forage production increased by 87 percent, from 8.4 ha in 2003 to 15.7 ha in 2005 (Table 5.5), which resulted in two major benefits: arresting soil erosion on sloping lands and increasing forage supplies for a livestock-based production system. The maximum area under forage crops was under rye (85 percent), followed by alfalfa (13 percent). Livestock including ruminants are important components of mixed crops-livestock farming systems that can provide an alternative source of income to improve livelihoods. Mixed farming systems also improve resilience to commodity price volatility and impacts of climate change. The holistic watershed management interventions substantially increased the livestock population and agriculture productivity at the Lucheba watershed. The substantial increase in animal population also proved instrumental in promoting biogas plants for to meet the daily energy needs of households in watershed areas. Construction of biogas plants in the Lucheba watershed area has increased, and now more they meet the energy needs of more than 230 homes in the village. By switching over to biogas plants to meet domestic energy requirements, one household saved about CNY 690 (USD 87) per annum because there was no longer a need to purchase coal, and saved 3–4 hours a day of hard work for women per day as they no longer needed to collect fuel wood from the forest. So the biogas initiative is also helping to conserve local forests and woodlands.

5.3.5 Input utilization, output and income patterns in crop production

The introduction and cultivation of high-value vegetable crops in the Lucheba watershed in China, has greatly increased the need for labour, machinery and animal power in comparison to more traditionally grown field crops like rice and corn. Similarly, the use of fertilizers and pesticides for plant protection is much higher for vegetable crops compared to field crops (Table 5.6), and

Table 5.6 Various inputs used in in the production of different crops during 2012 in the Lucheba watershed in China

Inputs	Crop type					
	Corn	Rice	Cabbage	Pepper	Tomato	Chillies
Working Power						
Human labour (person days/ha)	121.0	235.0	157.0	186.0	356.0	196.0
Machinery (hours/ha)	6.6	13.2	15.5	16.3	16.3	16.9
Animal power (hours/ha)	36.4	51.6	15.8	23.5	14.3	22.5
Fertilizer (kg/ha)						
Nitrogen (N)	838	1 073	1 044	1 479	1 268	1 050
Phosphorus (P)	987	1 561	1 512	1 897	2 325	1 425
Potassium (K)	280	289	372	525	864	211
Other (specify)						
Pesticides for plant protection (litre/ha)	3.9	3.6	5.1	7.1	14.2	9.7
Seed (kg/ha)	30.0	20.0	0.6	0.5	0.2	0.6

Table 5.7 Cost of inputs, yield levels and net returns in different crops produced during 2012 in the Lucheba watershed in China

Inputs	Crop type					
	Corn	Rice	Cabbage	Pepper	Tomato	Chilli
A Cost of inputs (CNY/ha)						
1 Labour						
Human	700	583	1 610	1 856	1 674	1 342
Machine	277	245	500	504	507	501
Animal	676	203	450	450	450	0
2 Irrigation	436	0	29	28	24	20
3 Fertilizer and pesticides	2 447	1 664	4 486	7 639	12 192	2 613
4 Seed	445	468	270	1 767	2 578	1 967
B Yield (kg/ha)	6 248	5 394	59 114	31 431	56 228	31 583
C Farm gate price (CNY/kg)	1.5	1.2	0.8	2.0	1.6	2.0
D Gross value of output (CNY)	9 372.0	6 472.8	47 291.2	62 862.0	89 964.8	63 166.0
E Net return (CNY/ha)	4 391	3 310	39 946	50 618	72 540	56 723

Table 5.8 Benefit-cost ratio of the production of different crops in 2012 in the Lucheba watershed in China

Particulars	Before	After
Rice	1.77	1.9
Maize/corn	1.26	2.0
Vegetables*	1.40	5.5
Watermelon	0.47	–
Pepper	–	5.1
Chilli	–	9.8

* Tomatoes, brinjal (egg plant), okra, etc.

has been rising since the initial phase of the watershed management development (Zhong Li *et al*., 2005). Such an increase, particularly in the use of pesticides, must be monitored to assess the impact on the environment and human health, and to ensure sustainable and environmentally friendly agronomic practices. Farmers are using highly productive hybrid seeds for all the crops grown, and more than 60 percent of farmers attributed the adoption of new technology to the timely availability of hybrid seeds. Net returns from all vegetable crops are several times higher than for corn and rice (Table 5.7). Also, for chillies, cabbage, tomatoes and peppers, cost-benefit ratios are 1:9.8, 1:6.4, 1:5.2 and 1:5.1, respectively, which compares favourably with rice and corn's cost-benefit ratio of 1:1.9 and 1:2.0, respectively (Table 5.8).

5.3.6 Emerging market patterns

After watershed interventions, which resulted in a marketable surplus production of high-value vegetables, a mixed marketing pattern has emerged that is very different from the self-marketing method used in the past. Before effective watershed management, farmers were selling their produce of corn and rice in the village themselves. But the cultivation of vegetables has created new marketing channels and types of markets in the village (Table 5.9). Collective marketing through farmers' village associations (FVA) and middle men or agents are now major methods of selling produce – largely to semi-organized and unregulated markets using the Internet. It is important to note that with these Internet marketing facilities and assistance from FVAs, nearly 73.3 percent, 66.7 percent, 40.0 percent and

Table 5.9 Marketing patterns in 2012 in the Lucheba watershed in China

Name of the crop	Marketing mode (%)				Market type (%)			Total quantity sold (q)	Selling price (CNY/Kg)	Farmers who sold their production at expected price (%)	What marketing support will help you realize maximum revenue?
	Self	Collective	Middle men	Contract	Organized	Semi-organized	Unregulated				
Cabbage	0.0	40.0	56.7	0.0	0.0	63.3	63.3	4 033	0.8	66.7	Contract System
Pepper	0.0	40.0	20.0	0.0	0.0	60.0	60.0	537	1.9	40.0	
Tomato	0.0	40.0	56.7	0.0	0.0	60.0	60.0	1 821	1.6	73.3	
Corn	76.7	0.0	0.0	0.0	0.0	0.0	63.3	200	1.4	53.3	
Rice	76.7	0.0	0.0	0.0	0.0	0.0	63.3	198	1.6	4.8	
Chilli	0.0	63.0	36.7	0.0	0.0	60.0	0.0	399	2.7	36.7	

Table 5.10 Employment and income from farm and non-farm activities before and after the watershed management project in the Lucheba watershed in China

Sources	Units	Before project		After project		Percentage change	
		Number of units	Per unit cost	Number of units	Per unit cost	Number of units	Per unit cost
Casual village labour (farm work)	Work days	230	110.0	330	200	43.47	81.81
Casual village labour (non-farm work)	Days	1 330	677.5	300	990	-77.40	46.12
Income from migration	Work days	250	50.0	200	100	-20.00	100.00
Remittances (sent from family and relatives)		–	–	–	–	–	–
Sale from common property resources (CPRs)		–	–	–	–	–	–
Business net income (shops, trade, tailor, etc.)		–	–	–	–	–	–
Part-time job		–	–	–	–	–	–

Sale of CPRs includes firewood, fruits, etc.

Table 5.11 Gross income of farming households before and after the watershed management project in the Lucheba watershed in China

S. Number	Source of income	Before (CNY)	After (CNY)	Percentage change (%)
1	Crop	95 500	279 129	192
2	Livestock	51 000	0[1]	-100
3	Non-farm	90 000	33 000	-63
	Total	236 500	312 129	32

36.7 percent of farmers producing tomatoes, cabbage, pepper and chillies, respectively, sold their produce at expected prices. However, in cases of rice and corn, 4.8 percent and 53.3 percent of farmers, respectively, received the expected price for their marketable surplus production. To minimize market risks, most of the sample farmers said they would prefer to carry out transactions using the new marketing systems (Table 5.9).

5.3.7 Employment and income from farm and non-farm activities

Integrated watershed management at Lucheba significantly improved food security and enhanced family incomes as was observed through tangible impact indictors of farm-based employment and income (Table 5.10 and 5.11). Diversification, using high-value vegetable crops, increased numbers of causal labour workdays by 43.47 percent with the labour force earning an increase of 81.81 percent. On the other hand, casual labour employment opportunities for non-farm activities fell by 77.4 percent, but earnings still rose 46.12 percent largely due to the increase in wages for non-farm activities in recent years. At the same time, migration reduced by 20 percent (Table 5.9). Farm income from crops, (largely vegetables), has increased by 192.30 percent whereas income from livestock and non-farm activities reduced by 100 percent and 63.3 percent respectively in the post watershed programme. Total income at the household level increased by 32 percent (Table 5.11). In Lucheba, per capita income in 2012 increased from CNY 6 800 per year in 2011 to CNY 8 100 per year, which was double the provincial average per capita income.

5.4 Conclusion and recommendations

An integrated watershed management approach has proved successful in improving the livelihoods of mountain people and providing better food security while ensuring sustainable environmental services and building the resilience of the food systems. If such systems are implemented on a wider scale, they could go a long way to helping achieve the target of Zero Hunger in mountainous regions.

Building integrated watershed systems through efficient rainwater management has enabled sustainable intensification of farming through diversification of systems with high-value crops. In addition, collective planning and new marketing methods using information-technology enabled services have benefitted small farmers, giving them improved scale of operation and better negotiating power with the market.

The success of the integrated watershed management and a value-chain approach is evident in Lucheba watershed where:

- By adopting an integrated watershed management approach through collectivization using a Farmers Association, water scarcity was overcome and enabled crop diversification with high-value crops.
- Per capita income (CNY 8 100 per year in 2012) was double the provincial per capita income.
- Cropping intensity increased 300 percent as the water availability was improved through *in-situ* and *ex-situ* management of rainwater in the watershed areas.
- High-value crops such as vegetables replaced the previously grown crops of rapeseed, rice and maize.
- A net present value (NPV) of USD 14.7 million was made over 10 years with an investment of USD 4.5 million.
- Many Future Smart Foods (FSF), which are climate resilient, locally grown, nutritious and are also good for the planet, can be grown in mountain areas, improving food security and helping to meet Zero Hunger.

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