6 Managing Scarce Water Resources – China

General Information

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- **Implementation Period:** Five years (January 2000 to December 2004)

- **Costs:** The cost of this project (excluding indirect local costs) was $5.27 million. Funds were provided by a CAREERI grant for technical assistance and procurement ($1.52 million), a national grant ($2.06 million), international collaboration ($0.31 million) and other associated CAREERI projects ($1.38 million).
Researchers at the Cold and Arid Regions Environmental and Engineering Research Institute (CAREERI) have implemented integrated river-basin management strategies in arid inland river basins of northwest China using the Heihe River Basin as a case study.

The Heihe River Basin, which spans the border between Qinghai and Gansu provinces and the Inner Mongolia Autonomous Region, covers an area of nearly 130,000 square kilometres, making it the second largest inland river basin in the arid area of northwest China. The basin includes three major topographic landscapes: the Qilian Mountains in the upper reaches, the Hexi Corridor in the middle reaches and the Alxa highlands in the lower reaches. The Qilian Mountains, where rainfall is highest, are the catchment or run-off-producing areas while the basins, which receive less frequent precipitation, are run-off-absorbing areas. Because they differ greatly in economic structure and water-use practices, the three provinces served by the Heihe River Basin face serious water conflicts and benefit-sharing is complex.

At the government level, a Master Plan for the Heihe River Basin (MPHRB), the aim of which was to allow an adequate volume of water to reach the lower parts of the river, was initiated in 1992 and revised in 1997 and 2000. A basin-wide management organization, the Heihe River Basin Administrative Bureau, was established in 2000 and is responsible for the management of water resources in the basin and the implementation, operation and maintenance of large-scale water projects. However, the complex problems in the area – including providing access to irrigation water for a large number of farmers – could not be solved solely through government intervention and focusing on water issues alone. Therefore CAREERI, in association with local governments and communities, implemented an integrated project incorporating water, ecological and economic aspects on a river-basin scale in the Heihe River Basin.

In this project, intensive water-saving measures were tested in the middle basin in order to increase water productivity, that is, to gain greater benefits per drop of water used. The use of water-rights cards and water tickets by farmers and other stakeholders was piloted in the irrigation districts. At the community level, the establishment of an association for water users and improved price transparency reduced farmer conflicts and promoted the protection of irrigation facilities.

To sustain the increased river discharge required to maintain the fragile ecology of the lower river basin, many activities such as the production of cash crops, stall-feeding of livestock and ecotourism have been demonstrated and extended as new income-generating alternatives for local farmers and Mongolian herders. Moreover, an integrated mountain-valley-oasis system on a river-basin scale, including stall-feeding, deferring grazing, fodder production and the processing of agricultural products,
has been initiated and demonstrated to maximize regional resources.

Particular successes were achieved in persuading communities to participate in water-saving schemes, increasing incomes and rehabilitating the ecology of the basin. Efforts to establish close collaboration among research institutes, local government and communities were also successful. The project also promoted research-based solutions to critical problems that were demonstrated and extended in practice by involving and training local government and community representatives. In turn, their capacity to develop their local environment on a sustainable basis has been improved.

**BACKGROUND AND JUSTIFICATION**

Arid and semi-arid areas cover 30 per cent of the total land area of the world and sustain more than 10 per cent of the global population. About one third of the total area of China consists of arid inland river basins. During recent decades, water shortages caused by rapid population growth and the development of irrigated agriculture have resulted in the drying up of tributaries and terminal lakes, the shrinking of natural oases, biodiversity loss, salinization of soils and desertification. Man-made oases in the lower reaches are shrinking and degrading. Human activities have significantly changed the distribution and allocation of limited water resources, the most crucial problem in an inland river basin being water-use competition between the upper, middle and lower reaches of the river. Currently, about 20 million people in the arid northwest region of China face drinking-water shortages often because of the uneven distribution of available water resources.

The Heihe River Basin is a typical inland river basin in the arid zone of northwestern China. It covers an area of approximately 130,000 square kilometres (fig. 1) and three distinct geographical zones. Its upper reaches are located in the southern Qilian Mountains in the boundary district of Gansu and Qinghai provinces, where the altitude is mainly between 2,000 and 5,000 metres above sea level and rainfall ranges between 250 and 500 millimetres per year. Zhangye, a city of more than

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**Figure 1**  |  Location and landscape of the Heihe River Basin in China.
1 million inhabitants, is located in its middle reaches – also known as the Hexi Corridor – which has an elevation of between 1,000 and 2,000 metres above sea level and receives between 100 and 250 millimetres of rainfall per year. Irrigated crops are widespread in this zone. The lower reaches of the river, in the north, are located in Inner Mongolia and are characterized by low rainfall (less than 50 millimetres per year) and the evaporation and seepage of surface water.

The middle zone of the Heihe River Basin, the Hexi Corridor, is one of the major grain-producing regions of China. Ninety per cent of the irrigated farmland and more than 85 per cent of the total population of the river basin are located in this zone, which accounts for 68.1 per cent of the total water demand of the basin. The area of irrigated farmland is divided into six large-scale irrigation districts, which have an average size of 32,000 hectares and are managed by an average of 170,000 farmers.

Although water is scarce, wastage rates are high in most irrigation districts. Canals are the main method for transferring water, with flood irrigation being the predominant practice and more efficient irrigation systems, such as sprinklers and drip irrigation, rarely used. The cost of water used for irrigation is determined according to the plot area owned by the farmer rather than the volume of water used so there is no incentive for farmers to save water. The average irrigation quota of 10,000 cubic metres per hectare is 40 per cent higher than the national average.

The expansion of man-made oases in the middle reaches of the basin has dramatically reduced river discharge towards the lower reaches. River discharge into the natural Ejina Oasis, for example, decreased from more than 500 million to 600 million cubic metres per year to 300 million to 400 million cubic metres per year during the 1990s. As a result, when compared with measurements made during the 1980s, the area of natural forest has decreased by 343 square kilometres, degraded grassland has increased by 3,948 square kilometres, desertified land has expanded by 405 square kilometres, and salinized land has increased by 835 square kilometres. In addition, the two terminal lakes in the desert have dried up. A consequence of this environmental degradation is that the natural oasis has been shrinking and indigenous tree and shrub species such as Populus diversifolia and Tamarix ramosissima have been lost.

While the lower Heihe River Basin faces ecological degradation and desertification, the issues faced in the middle basin revolve around conflicts of water demand and supply while the management challenges facing the upper basin include the reduction of forest cover and rangeland degradation. Only if these issues are studied on a basin-wide scale, beginning with an integrated river-basin management system and coordinating the relationships between water availability, ecology and economy, can there be sustainable development in the Heihe River Basin.

To address these issues, the Heihe
River Basin Administrative Bureau was set up in January 2000, with responsibility for management and coordination of the water resources in the basin. However, the two provinces and the Inner Mongolia Autonomous Region, across which the Heihe River flows, differ greatly in the structure of their economies and water-use practices. Thus, the Heihe River Basin Administrative Bureau must address a complex set of water-conflict and benefit-sharing issues.

In August 2001, the five-year Master Plan for the Heihe River Basin was officially ratified. The goal of this Master Plan is to ensure that the lower reaches of the river basin receive 950 million cubic metres of water per year when the water discharge at Yingluoxia Dam reaches 1,580 million cubic metres per year. Through the efforts of the Heihe River Basin Administrative Bureau and local governments over the past five years, the Master Plan target has been generally achieved (table 1). Its implementation, however, enforced a reduction in water withdrawal in the middle river basin by 23 per cent relative to earlier water use, resulting in 40,000 hectares of cropland becoming water-stressed in 2002.

To improve water productivity, ecological sustainability and economic performance in the whole basin, an integrated river-basin management project was implemented on the basin scale led by CAREERI in association with local governments and communities. The overall objective of the project was the mitigation of ecological degradation and alleviation of poverty in the Heihe River Basin through the implementation of environmental interventions.

**Table 1 | River discharge at Yingluoxia Dam and Zhengyixia Dam**

<table>
<thead>
<tr>
<th>Year and Target</th>
<th>Yingluoxia Dam</th>
<th>Zhengyixia Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>1,310</td>
<td>638</td>
</tr>
<tr>
<td>2002</td>
<td>1,589</td>
<td>1,027</td>
</tr>
<tr>
<td>2003</td>
<td>1,903</td>
<td>1,256</td>
</tr>
<tr>
<td>2004</td>
<td>1,498</td>
<td>855</td>
</tr>
<tr>
<td>2005</td>
<td>1,777</td>
<td>1,049</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>1,615</strong></td>
<td><strong>965</strong></td>
</tr>
<tr>
<td><strong>MPHRB target</strong></td>
<td><strong>1,580</strong></td>
<td><strong>950</strong></td>
</tr>
</tbody>
</table>

MPHRB = Master Plan for the Heihe River Basin

*The Yingluoxia Dam is located near the entry point of the middle Heihe River Basin and the Zhengyixia Dam is situated near the exit point of the middle Heihe River Basin (which is also the entry point into the lower Heihe River Basin).*

**Description**

The key strategies for the implementation of integrated river-basin management in the Heihe River Basin were to employ the mountain-valley-oasis system in the entire basin, to reduce agricultural water consumption in the middle basin, and to demonstrate new income alternatives and maintain an adequate flow of water to sustain the environment of the lower basin.

On a river-basin scale, an integrated mountain-valley-oasis system has been developed that includes stall-feeding, deferring grazing, fodder production and
processing of agricultural products. Stall-feeding is at the centre of the system.

The expansion of irrigated farmland in the middle river basin has caused water shortages and ecological degradation in the Heihe River Basin. Since agriculture is the largest consumer of water in the middle river basin (accounting for about 90 per cent of total consumption), in order to carry out an integrated river-basin management approach, it is essential to reduce agricultural water consumption in this area. Four critical steps were identified for improving water productivity in the irrigation districts:

- improve the rate at which rain or irrigation water is transferred into the soil so that it can be used by crops;
- increase the ratio of water consumption by crops to the soil water content, i.e., the efficiency with which growing crops use water to increase their biomass. This can be achieved by improving soil structure, developing water-saving irrigation scheduling and optimizing water allocation in irrigated areas;
- improve crop biomass production, particularly by introducing or breeding new varieties with a lower water requirement and higher yields; and
- improve the output benefit of the produced biomass, including both economic and ecological benefits. This step is primarily market-driven and is achieved by reallocating water to higher-priority uses.

On the basis of these four steps and local irrigation practices, intensive water-saving measures were implemented in the middle basin. In contrast to water-saving measures employed in the past, which had tended to promote technological solutions developed by universities and research institutes rather than technologies and practices appropriate for low-income farmers, the CAREERI project team worked closely with local governments and communities to develop and demonstrate practical water-saving measures using systematic and integrated approaches. The water-saving measures studied and demonstrated in Pinchuan Irrigation District of Linze County, part of the project area, included optimizing flood irrigation as well as irrigation scheduling (technical measures), demonstrating the use of water-rights cards and water tickets; and establishing a water users association (WUA) and adjustment of the agricultural sector (non-technical measures).

In the lower river basin, it is important to restrict further development of irrigated farmland and maintain adequate environmental flow. Therefore, while emphasis has been placed on rehabilitation of the degraded ecological environment, growth of cotton and hami melon, stall-feeding and eco-tourism have been implemented as examples of alternative sources of income for local farmers and Mongolian herders. These activities were identified in community meetings and demonstrated at the village level.
A MOUNTAIN-VALLEY-OASIS SYSTEM

The Master Plan for the Heihe River Basin is an example of an integrated system at the river-basin scale that takes into account the whole system from mountain to valley to oasis. The overall development of the strategy involves different management regimes in the different zones.

Traditionally, most people in the Heihe River Basin are engaged in three types of economic activity: grazing livestock in the mountainous areas, small-scale intensive agriculture in the valley areas and large-scale extensive agriculture in oases. The absence of any coordinated management of these areas has led to the degradation of grassland areas in the mountains caused by over-grazing; poor returns for farmers in the valley areas; and high water consumption in the oases.

In order to integrate regional resources and maximize economic benefit, an integrated mountain-valley-oasis system has been developed. The system includes coupling the production of grazing livestock in the mountainous areas, fodder production and stall-feeding in the valley areas, and production and processing of high-quality fodder (alfalfa) in the oases (table 2). To assist with these changes, private companies have been established locally or introduced from outside the region to sign contracts with stall-feeding households so that market risks caused by changing practices are reduced.

<table>
<thead>
<tr>
<th>Model</th>
<th>Main Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountain-valley-oasis development</td>
<td>Links production of grazing livestock in mountain areas, fodder production and stall-feeding in valley areas, and fodder production and processing in oases. The core of this system is stall-feeding, which involves the intensive breeding and feeding of sheep and cows.</td>
</tr>
<tr>
<td>Cooperative</td>
<td>Association that performs market surveys and helps farmers and herders to sell their products.</td>
</tr>
<tr>
<td>Contract between farmers and companies</td>
<td>Contracted-out agriculture. Companies dealing with the processing of livestock products sign contracts with farmers. They guarantee a market for stall-fed products so there is less risk for farmers and herders.</td>
</tr>
<tr>
<td>Collectives</td>
<td>Cooperation between herders and farmers. Links have been developed in the whole process of stall-feeding, including fodder preparation, livestock breeding, marketing, labour and capital investments and risk-sharing.</td>
</tr>
</tbody>
</table>
Stall-feeding (fig. 2) is central to the mountain-valley-oasis system. Lambs for meat can be sold as “baby lamb” when three months old or after they have been stall-fed for six months. Stall-feeding of lambs has reduced the grazing pressure on the mountain grasslands, which are now grazed only later in the season. This deferred grazing system allows grass to grow in the spring rather than being grazed as soon as growth starts after winter dormancy. Stall-feeding has also improved the health of the herd, with sheep mortality falling by 50 per cent and the survival rate of lambs increasing by 10 per cent. This has enabled herders to slightly reduce their herd size, thus further reducing grazing pressure on the mountain pastures. In addition, by increasing the demand for fodder, farmers in the valley and oasis areas have increased their production of fodder crops, such as alfalfa, which consume less water. Thus, stall-feeding has provided new profitable alternatives for farmers.

**Improve Water Productivity**

Improving water productivity means increasing the economic return per cubic metre of water used. Water productivity in northwestern China is $0.70 per cubic metre, which is much less than the national average of $2.10 per cubic metre. At $0.40 per cubic metre, water productivity in the agricultural sector is even lower.

Improving water productivity includes integrated and complex processes, is broader in scope than simply the use of agronomic and biological solutions, and must be considered on an irrigation-district, watershed or river-basin scale.

**Optimizing Flood Irrigation**

Currently, most farmers in the middle Heihe River Basin use flood irrigation because it is simple and does not require expensive water-saving technologies such as sprinklers and drip-irrigation equipment. However, while the cost of adopting flood irrigation is low, the technique is relatively inefficient with regard to water use, particularly when the irrigation plot is large. Research carried out by CAREERI scientists has shown that a water saving of about 10 per cent can be achieved simply by reducing the size of the plot to be irrigated.

A typical flood-irrigated plot has an area of between one and two mu (one mu is equal to one fifteenth of a hectare). Research showed that to irrigate a plot of 0.5 mu required 60 to 65 cubic metres of water per mu, while a one-mu plot required 80 to 85 cubic metres of water.
and a two-mu plot required 150 to 160 cubic metres of water per mu. In addition, when the amount of irrigation water exceeded 90 cubic metres of water per mu, between five and six cubic metres per mu would leach beyond a soil depth of 1.5 metres, resulting in the loss of both water and fertilizer. Therefore, plots of 0.5 mu are the most appropriate for flood irrigation.

By scheduling flood irrigation correctly, a timely and adequate supply of water for crop growth can be provided without wasting water. Based on knowledge of the desired water balance that needs to be maintained between the soil, plant and atmosphere, CAREERI agronomists have devised rational irrigation schedules for the major crops grown in the middle Heihe River Basin from sowing to harvest. These crops include cotton, maize, peanuts and spring wheat. An irrigation schedule has also been worked out for the common practice of inter-cropping maize and spring wheat. To demonstrate these water-saving measures, CAREERI provided farmers with technical guidance and training in common applied techniques. Tensiometers were used to measure soil water content; irrigation was applied in appropriate amounts at appropriate times; soil improvement was promoted; and farmer crop-management techniques were improved.

The role of the local agricultural extension station was a key factor in the implementation of these activities, especially as the proposed activities are integral and not additional to its routine work. Technical staff from the station were also closely involved in the demonstrations, during which they had an opportunity to participate in training and receive recognition for research results and reports.

**Water-rights Cards and Water Tickets**

Water consumption in the middle Heihe River Basin is limited by the Master Plan for the Heihe River Basin. However, the Zhangye Region in the middle river basin has the authority to issue a secondary water-use right detailing water allocation to each irrigation district, each village or each WUA.

Currently, because water is priced according to the area to be irrigated rather than the volume of water used, there is no incentive for farmers to save water. To clarify water entitlement for individual farmers, water-rights cards and water tickets have been introduced in the Pinchuan irrigation district as symbols of water-use rights. On a water-rights card, the effective irrigated area is identified and classified into several categories. Based on measured irrigated areas and quotas, the total water demand for the individual farmer is specified on the individual water-rights card. Once this has been determined, farmers can apply for water tickets (fig. 3), which are issued in accordance with the amount of water to which a user is entitled in a particular year on the basis of his/her water rights. Thus, when farmers want to irrigate their plots, they are required to produce their water-rights cards and the corresponding number of water tickets.
State-controlled organizations are usually responsible for the management of irrigation districts in China. In recent years, development strategies have shifted from being State-controlled towards greater participation by local government or non-governmental organizations. In the Heihe River Basin, water users associations (WUAs) were introduced in 2001 and a transfer agreement between irrigation districts and WUAs, covering irrigation operation and maintenance, was signed. The responsibilities of the WUAs include the operation and maintenance of the tertiary and lateral canals (i.e., the smallest canals closest to the irrigated plots), the design of water-use plans, the making of contracts between water users and relevant agencies, the management of water-rights cards and water tickets, and the collection of water-use fees.

Each irrigation area has its own WUA, and any farmer in a specific irrigated area can be a member of the association. Each WUA has three management levels: assembly members are selected from respected members of society; each assembly then selects a president and three executive board members. The executive board is responsible for day-to-day management of the WUA, while any decisions are made by majority vote in the assembly. Under the executive board, irrigation managers are employed to operate irrigation delivery and to keep irrigation records for individual farmers. The number of representatives for each WUA is either fixed depending on the irrigation area or based on the number of families in the irrigation area.

Since WUAs were established, they have played a significant role in cost recovery in the irrigation districts. Between 2001 and 2005 in Linze County, for example, the number of WUAs increased from 46 to 114 and the number of members from 10,680 to 22,365 households as the successful project was rolled out to a wider group of stakeholders and irrigation areas.

Figure 3 | An example of a water ticket that provides a named farmer with the right to a given amount of irrigation water.
Agricultural Sector Adjustment

One method of enhancing water-use efficiency with limited water resources is to reallocate water to higher-priority uses. In the Heihe River Basin, a new variety of maize, “seed maize”, has been introduced that provides good-quality seed. Seed maize yields 7,125 kilogrammes per hectare and has a market price of $0.25 per kilogramme, giving an economic benefit of $1,781 per hectare. For comparison, maize grown for grain yields 10,701 kilogrammes per hectare and the market price is $0.11 per kilogramme, giving an economic benefit of just $1,177 per hectare. The average annual irrigation volume for maize is 10,275 cubic metres per hectare. Hence, water productivity for seed maize is $0.17 per cubic metre of water compared to $0.11 for grain maize. Because seed maize has a higher water-use efficiency, there has been a significant increase in the area being sown (table 3).

Compared with 1990, the crop structure has changed significantly: the areas used for grain maize and wheat have decreased by 85 per cent and 47 per cent, respectively, while that used for seed maize has increased by nearly 500 per cent. At the same time, consumption of water for agriculture has fallen by 23 per cent. However, it is recommended that the area used for growing seed maize not exceed 10 per cent of the total farmland in the oasis because of the higher market risks associated with this crop. Despite this recommendation, seed maize is currently being grown on almost 50 per cent of the cultivated land.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Change in Area 1990-2002 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>-47</td>
</tr>
<tr>
<td>Grain maize</td>
<td>-85</td>
</tr>
<tr>
<td>Seed maize</td>
<td>493</td>
</tr>
<tr>
<td>Fruit</td>
<td>-40</td>
</tr>
<tr>
<td>Oil</td>
<td>-45</td>
</tr>
<tr>
<td>Cotton</td>
<td>-38</td>
</tr>
<tr>
<td>Vegetables</td>
<td>10</td>
</tr>
<tr>
<td>Melon</td>
<td>-91</td>
</tr>
<tr>
<td>Forest</td>
<td>-11</td>
</tr>
</tbody>
</table>

Table 3 | Changes in crop structure in Pingchuan irrigation district between 1990 and 2002.
Eco-tourism in the Lower River Basin

While intensive water-saving measures have been put in place in the middle Heihe River Basin, the development strategy in the lower river basin has focused on the rehabilitation of the degraded ecological environment. It is essential that the increased river discharge remain in the stream as environmental flow and not be used for water-consuming economic production, i.e., the further development of irrigated agriculture. Therefore, many activities such as the production of cotton and hami melons, stall-feeding livestock and eco-tourism have been piloted and demonstrated in the lower river basin as new alternative sources of income for local farmers and Mongolian herders.

The Ejina Oasis in the lower reaches of the Heihe River Basin has great potential, for example as a destination for eco-tourism. Along the Ejina River valley, downstream of the Heihe River, are ancient stands of poplar (*Populus diversifolia*), an ancient tree species that originated from the Mediterranean area about 60 million years ago. The area of 30,000 hectares covered by *P. diversifolia* is the largest of three main areas of poplar forest in the world. An annual autumn poplar festival now attracts many tourists, scientists and photographers, lured by the dramatic golden colours that the poplar leaves take on during this season.

Patenting and Commercialization

The target of the Master Plan for the Heihe River Basin — to reduce water consumption in the middle Heihe River Basin by 23 per cent — has been achieved. The means by which this target has been reached have provided essential information and practical solutions for the effective management of inland river basins in northwest China.

The success of stall-feeding and lamb-fattening has been demonstrated and these activities have been widely extended by government directives; 700 households in 18 villages in the upper Heihe River Basin now use stall-feeding (mostly of sheep and cows).

High-quality fodder (alfalfa) was initially produced from an area of 440 hectares in the middle Heihe River Basin. After training and extension efforts, farmers have now planted 5,200 hectares with alfalfa. In collaboration with a local company, a factory with an annual capacity of 20,000 tonnes of alfalfa products was established in the middle Heihe River Basin. This factory has provided new employment opportunities for local people and good-quality forage for stall-fed animals.

Partnerships

CAREERI staff have worked closely with the relevant local governments, including
the government of the Zhanye region, the Sunan County government and the Linze County government in Gansu Province, and the Ejina Banner government in Inner Mongolia. The Water Resources Bureau and the agricultural extension station are key agencies in the implementation of the demonstrations. Many farmers and herders participated in the project, serving as demonstration households that received intensive training in terms of water-saving agricultural practices and stall-feeding.

**Replicability**

Oases in China cover more than 86,000 hectares. Experience in the middle Heihe River Basin has demonstrated that the water-saving measures tested are successful and could be extended to other oases, particularly in other inland river basins. The principles of holistic water-saving measures and the maximization of regional resources are appropriate for all arid areas of the world.

**Policy Implications**

The Heihe River passes through Qinghai and Gansu provinces and the Inner Mongolia Autonomous Region. The principles of integrated river management are essential for solving problems of water competition in the different administrative regions of a river basin.

The recently completed State and province eleventh Five-Year Development Guidelines for 2006-2010 highlight the integrated management approach and recommend the adoption of development strategies in inland river basins. Therefore, the lessons learned from the successes of the Heihe River Basin project are likely to be fed into sustainable development strategies for other inland basins. A new project was approved in 2007 whereby the experience and practices learned in the Heihe River Basin will be implemented in the Shiyanghe River Basin, another inland river basin in northwest China that has faced similar conflicts of development and water scarcity.

**Impact**

To date, this project has achieved impressive accomplishments relating to water saving, community participation, increased income and ecological rehabilitation.

In the lower river basin, vegetation coverage in fenced poplar woods has increased by 10 to 20 per cent.

Through the systematic implementation of integrated water-saving measures over the past four years, water productivity has increased by 42 per cent in the middle Heihe River Basin. In the Pinchuan irrigation district, for example, annual average water consumption has declined from 63 million cubic metres to 49 million cubic metres. The establishment of WUAs has improved the transparency
of water prices, reduced farmer conflicts and promoted the protection of irrigation facilities. Particularly impressive is the number of projects undertaken to maintain irrigation facilities; in Lingze County, for example, 114 WUAs completed 392 maintenance projects in 2003. In addition, farmers' costs for irrigation have fallen by 10 per cent.

The integrated mountain-valley-oasis system established under this project has produced a significant improvement in the quality of mountain grassland vegetation. As a result, the grassland provides better nutrition for grazing livestock. Combined with the stall-feeding system, this has led to a 50 per cent decrease in the livestock death rate and a 10 per cent increase in the survival rate of young animals. At the same time, the income of households using stall-feeding to rear livestock has increased by 8 per cent per year.

The innovative experiences identified in this project should be sustained beyond the lifetime of the project because (a) there has been close collaboration between CAREERI, local governments and local communities; (b) a principal objective was to increase the income of farmers and herdresses while environmental interventions were implemented; and (c) emphasis was placed on building the capacity of local agencies and communities to take advantage of alternative income-generating practices.

**Lessons Learned**

WUAs have recently been introduced in many irrigation districts in China. Although supported by most water users, the transfer of the State-owned and State-managed systems to a WUA is complicated. It is essential that successful examples be used to overcome the obstacles faced by the WUAs. These obstacles include the low capacity to participate (most WUA members have a relatively low level of education), the reluctance of farmers to take on what they perceive to be the responsibility of the government, and inadequate funds for self-management. Continuous training that will focus on improving the awareness of community ownership, participatory capacity and financial management of the WUAs is necessary.

In general, the obstacles to be overcome for the establishment of stall-feeding are a lack of communication and data-sharing, ineffective extension services, market risks, livestock nutrition and a poor transport system for livestock and fodder. Because the integrated mountain-valley-oasis system involves a large geographical area and many stakeholders, appropriate government policies are required to promote and facilitate its implementation. After the system has been established and the community and institutional capacity has been improved, the market will then become the main driving force.
**Future Plans**

Water scarcity, population growth and traditional water-use practices have constrained development in the inland river basins of northwestern China. The project in the Heihe River Basin, which is a typical inland river in China, has identified the key issues in these areas and demonstrated practical solutions to the problems. However, establishing participatory methodologies, building capacity for individuals and institutions, and changing perceptions of problems, approaches to problems and methods of management all take considerable time and require good communication and trust.

For the next stage, efforts will focus on capacity-building activities based on the lessons learned from the project. The project output relating to trials and demonstrations will be integrated into community and institutional projects in an “action learning” approach. The results of action learning will be incorporated into technical extension materials and operating procedures for use by technical staff and communities. The training strategy will be focused on training the trainers because the failure of previous technical extension efforts has been attributed to lack of capable staff and appropriate materials. Technical staff and farmers/herders will be identified to receive training in technologies and in training skills.

**Publications**


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Zhao Xinquan, director, Northwest Institute of Plateau Biology: Expert in rangeland and livestock production and responsible for rangeland recovery and stall-feeding demonstration.

Zhao Wenzhi, director, Linze Inland River Basin Research Centre: Responsible for research on and extension of water-saving agriculture.

Feng Qi, water resources specialist: Responsible for ecological rehabilitation in the lower Heihe River Basin.