



PROCEEDINGS OF THE INTERNATIONAL FORUM ON WATER RESOURCES MANAGEMENT AND IRRIGATION MODERNIZATION IN SHANXI PROVINCE, CHINA



Taiyuan and Yuncheng,
Shanxi, China
22–24 November 2006



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INTERNATIONAL FORUM ON WATER RESOURCES
MANAGEMENT AND IRRIGATION MODERNIZATION
IN SHANXI PROVINCE, CHINA**

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Foreword

Water is essential for life. It plays a key role in achieving the Millennium Development Goals. As the population continues to grow and the economy develops, the competition for water uses between different users intensifies, which induces excessive strain on the environment. Climate change and water pollution further aggravate the situation. Today, 2.8 billion people are affected by some form of water scarcity, and the number of regions affected by water shortages is on the rise. By 2025, two-thirds of the world's population will live in countries affected by water scarcity, including one-third of the populations of China and India. Water scarcity is not only a regional issue, but also a serious global concern. This is why UN-Water has identified the theme "Coping with water scarcity" as one of its priorities for the decade. Accounting for 69 percent of global water withdrawal and 84 percent of Asian water withdrawal, agriculture plays a crucial role in sustainable water management. While achieving much, irrigation is more and more frequently criticized for inefficient water use. The general consensus is to incorporate agricultural water management into integrated river basin water resource management and to promote irrigation modernization.

Shanxi is a typical inland province in the middle reach of the Yellow River in China, with an average annual precipitation of 500 mm. Average water availability per capita and per cultivated *mu* are about 381 m³ and 180 m³ respectively, accounting for 17 and 11 percent of the national average only. Unbalanced water resource development in past decades is the cause of severe groundwater overexploitation and extensive coal mining is damaging crucial water sources. Irrigated agriculture is the biggest water consumer, but its overall performance is far from satisfactory. Water scarcity has become the major constraint to sustainable socio-economic development in the province. To share national and international experiences and to study these issues systematically and comprehensively, Shanxi Provincial People's Government and FAO's Regional Office for Asia and the Pacific (RAP) co-sponsored an International Forum on Water Resources Management and Irrigation Modernization in Shanxi Province, at Taiyuan and Yuncheng Cities, Shanxi Province, China from 22 to 24 November 2006.

The forum was organized by the Shanxi Water Resources Department and attended by some 260 participants including international and national experts; senior government officials from the State Council, the Ministry of Water Resources, Shanxi Provincial Government and local governments; and the irrigation managers of all large-scale irrigation schemes in Shanxi Province. The forum reviewed the current status and future trends of water resource management and irrigation development in Shanxi Province; shared relevant national and international experiences in arid and semi-arid areas; and discussed and recommended options for integrated water resource management and irrigation modernization in Shanxi Province. This proceedings provides not only inputs for policy-making for sustainable socio-economic development in Shanxi Province but also useful references for other arid and semi-arid areas in Asia and other regions.



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Executive summary

1. Forum overview

1.1 Background

Shanxi is an inland province in the middle reach of the Yellow River in China. Average annual precipitation is only about 500 mm and is unevenly distributed both temporally and spatially. Around 60 percent of the total annual precipitation is concentrated in the summer. The province is severely affected by frequent droughts, occurring in nine out of ten years. After recent rapid socio-economic development, water competition among different users and uses is becoming increasingly intense. Currently, average water availability per capita in Shanxi Province is 381 m³, about 17 percent of the national average; average water availability per *mu* of cultivated land is 180.3 m³, about 11 percent of the national average. Irrigated agriculture is the biggest water consumer, accounting for 56 percent of aggregate water diversions, and it is criticized for abuse of crucial water resources.

Improvements in irrigation water use efficiency and water productivity have been achieved through the adoption of water-saving irrigation, infrastructure upgrading and management reform in recent years. Room exists for further significant improvement in terms of both agriculture water management and overall water resource development and management. Proposed agriculture restructuring requires quality irrigation services. Sustainable development calls for better protection of the water environment and ecosystems. Integrated river basin water resource management demands more balanced consideration of management objectives at different levels. To address all of these issues systematically and comprehensively, the provincial government intends to formulate a new provincial water strategy based on local conditions and national and international experiences. Water resource management and irrigation modernization are the two major concerns of the new strategy.

The FAO Regional Office for Asia and the Pacific (FAO RAP) has been assisting in formulating national water visions and strategies, advocating irrigation modernization concepts and disseminating relevant technologies and tools in Asia for about ten years. It has initiated a technical cooperation with Shanxi Province on irrigation modernization since 2006, including the introduction of new concepts and technologies; adoption and improvement of practical tools; pilot studies at selected irrigation schemes; and local capacity building. To provide timely and quality inputs for the formulation of a new provincial water strategy, the International Forum on Water Resources Management and Irrigation Modernization in Shanxi Province had the following objectives:

- Better understand local conditions and learn from national and international experiences on water resource management and irrigation development in arid and semi-arid areas.
- Facilitate in-depth discussion on crucial water issues, especially irrigation development and constraints, water pollution, groundwater management and protection of the water environment.
- Recommend suitable options for enhancing the implementation of integrated river basin water resource management, upgrading water delivery services (especially irrigation services), facilitating sustainable socio-economic development and improving rural livelihoods in Shanxi Province.

1.2 Execution

The forum was held in Taiyuan and Yuncheng Cities, Shanxi Province from 22 to 24 November 2006. A one-day plenary meeting and subtheme meetings were held in Taiyuan City on 22 November; one-day field visits to representative irrigation systems around Yuncheng City were conducted on 23 November; and one-day group discussions and plenary meetings took place in Yuncheng City on 24 November. It was well-attended by approximately 260 participants, including 13 international delegates from FAO, UNESCO, ICID, the United States, France, Islamic Republic of Iran, Tunisia and India; 20 senior national officials and experts including two department directors-general from the State Council, two vice-ministers and three

department directors-general from the Ministry of Water Resources, China; two vice-provincial governors, the Secretary-General and all department directors-general of Shanxi Provincial Government; directors-general of all prefecture water conservancy bureaus in Shanxi Province; directors-general of all management bureaus of large-scale irrigation schemes in Shanxi Province; as well as experts from universities and institutions. The Ministry of Water Resources, China rendered great support to this event. Shanxi Water Resources Department made considerable efforts with regard to forum preparation and implementation.

In total, 26 addresses and technical presentations were delivered — two opening addresses, 14 contributions from domestic leaders and experts and ten papers from international participants. The topics were multidisciplinary in scope and encompassed different levels, they included:

- Theories, policies and measures for water resource management.
- Calculation of the carrying capacity of regional water resources.
- Issues related to socio-economic development and water rights in the upper reaches of transboundary rivers.
- The negative impacts caused by groundwater overexploitation and relevant countermeasures.
- Water for ecologies in water-stressed areas.
- Studies on the indices of rational exploitation and utilization of rivers.
- The establishment of a water-saving society.
- The establishment of water resource information and monitoring system.
- Agricultural irrigation modernization.
- Agricultural water harvesting.

The information presented was relevant to the specific conditions in Shanxi Province, and was well-received by the participants and national and local governments. Discussions revolved around “hot” topics such as better understanding of the hydrological cycle at the river basin level; better management of groundwater resources; implications and relationships related to different water source and irrigation development systems; and technical methods and managerial options for irrigation modernization. The topics and activities of each session are summarized hereunder:

1.2.1 Session 1: Opening

The forum was formally opened by Mr Liang Bin, on behalf of Mr Yu Youjun, the Governor of Shanxi Province and Ms Jiang Han on behalf of Ms Victoria Sekitoleko, FAO Representative for China, Mongolia and DPR Korea.

The three keynote addresses provided overviews on the status, trends and options for water management and irrigation development at global, national and provincial levels. Prior to the subtheme meetings, four plenary papers were delivered that dealt exclusively with the irrigation situation in China (Table 1).

Table 1. Keynote addresses and plenary presentations

Keynote addresses

1. Establishing a holistic water-saving society to promote the sustainable development of Shanxi Province. *Hu Siyi*
2. Key trends affecting irrigated agriculture and policy options. *Jean-Marc Faurès*
3. Water projects and ecological protection. *Suo Lisheng*

Plenary presentations

1. Irrigation development policies in China. *Li Daixin*
2. Development and modernization of irrigation schemes in China. *Zhanyi Gao*
3. Construction of new countryside and related water issues. *Li Xirong*[†]
4. Water resource management and agricultural irrigation in Shanxi Province. *Pan Junfeng*

[†] Paper presented at the forum but not provided for inclusion in this proceedings.

1.2.2 Session 2: Subtheme meetings

Subtheme Meeting I on “Options for strategic and policy innovations at the river basin level” dealt with strategic and policy issues related to water resource management and irrigation modernization at the river basin level. Subtheme Meeting II on “Options for technical and material improvements at the system and farm level” addressed technical and material issues related to water resource management and irrigation modernization at system and farm levels (Table 2).

Table 2. Subtheme meetings

Subtheme I

1. Technical issues in modernizing farm irrigation systems: Some experiences in Mediterranean countries. *Bruno Molle*
2. Integrating urban and rural plans and promoting the development of rural areas. *Zhang Zhongfa*
3. Pathways for realizing water conservancy in irrigation systems. *Shahbaz Khan*
4. Concepts and practices for optimal regional water resource allocation. *Dong Zengchuan*
5. Water and irrigation management in the water-stressed Zayandeh–Rud and Karkheh River Basins, Islamic Republic of Iran. *Nader Heydari*
6. Water resource allocation in China and implications for the local environment. *Pei Yuansheng*
7. Water management strategy and irrigated area modernization: The Tunisian case. *Lebdi Fethi*
8. Ideas on irrigation modernization. *Sun Xihuan*

Subtheme II

1. The impacts of water-pricing reform on agricultural irrigation in China. *Li Yangbin*
2. Technical options at the system level: Canal lining and canal operation control. *Herve Plusquellec*
3. Modern management practices at Jiamakou irrigation project. *Zhang Xuehui*
4. A rapid appraisal procedure to assess the performance of irrigation systems: Lessons from the FAO Regional Irrigation Modernization and Management Training Programme in Asia. *Thierry Facon*
5. Participatory management and water users’ associations. *Feng Guangzhi*
6. Modernization of irrigation canals: The Uttar Pradesh Water Sector Restructuring Project, India. *M.K. Goyal*
7. Pumping stations in water resource management and irrigation modernization. *Dou Yisong*
8. The complexity of PLC-based canal automation. *Charles M. Burt*
9. Karnataka Neeravari Nigam Ltd. — a corporate model and growth engine in water resource development. *D. Satya Murty*

1.2.3 Session 3: Field visits

The participants split into three groups to visit different types of irrigation systems in Yuncheng City:

Group 1, the *surface water irrigation* group, visited the Jiamakou Irrigation Scheme, a large-scale surface water canal irrigation system at the middle reach of the Yellow River, which has practised modern irrigation management in recent years. It pumps Yellow River water to a 70-m elevation on the Loess Plateau to irrigate apple trees and crops. Participants visited its information centre, pumping stations and selected management units at different canal levels. The scheme’s high water productivity, effective management system and efficient water measurement and pricing impressed the participants.

Group 2, the *groundwater irrigation* group, visited the Zhangdian high efficiency groundwater irrigation plot in Pinglu Country, which carries out sprinkler, hose and pipe irrigation on 200 ha of fruit and vegetable fields. It demonstrates ways in which to improve water productivity and conserve groundwater resources in overexploited groundwater areas; it is one of the water-saving irrigation models that has been developed in Shanxi Province in recent years. The participants were very interested in the interaction between irrigation water use and groundwater table change and the management approach.

Group 3, the *water-harvesting irrigation* group, visited the rain-water harvesting irrigation plot in Yanhu, where 875 small water-harvesting irrigation systems have been built in the last four years on 100 ha of irrigation area. It combines rain-water harvesting, storage and small-scale, low-cost and high efficiency irrigation facilities and serves as a technical window for agricultural development in traditional rain-fed areas. The plot's technologies have been disseminated in northwest and southwest areas of China.

1.2.4 Session 4: Group discussion

Three major discussion topics were assigned to each group for each type of irrigation system: Current status and future trends; strategy and objective for modernization; measures and options for modernization. Separate group discussions and plenary group reporting after analysis of each topic produced discussion subjects for each type of irrigation system and for cross-cutting issues:

Discussion subjects for surface water irrigation systems:

Current status and constraints

- The potential of surface water resources has not been fully exploited due to inadequate water control and storage facilities.
- The capacity of current surface irrigation systems has not been fully realized due to malfunction and poor performance.
- Irrigation services cannot meet the requirements of agricultural development due to outdated concepts and technologies.
- Lack of investment obstructs the progress of irrigation upgrading and modernization.
- Low irrigation water price impacts negatively on system operation.

Measures and options

- Policy reform on water rights, water pricing, irrigation investment and water source protection.
- Institutional reform for facilitating irrigation modernization.
- Finalize and empower WUA systems to facilitate farmers' participation.
- Dissemination of worthwhile experiences such as the exercise in Jiamakou.
- Develop and adopt practical technologies for irrigation modernization.
- Adopt suitable tool-kits for appraisal and benchmarking of system modernization.
- Study the implications of water-saving irrigation on the local environment and ecosystems.

Discussion subjects for groundwater irrigation systems:

Current status and constraints

- Groundwater resources are overexploited and severely degraded.
- Water supply is inconsistent and irrigation costs are increasing due to depletion and damage to the groundwater aquifer.
- Lack of capacity in effective groundwater resource management and control.
- Lack of investment in irrigation upgrading and modernization.

Measures and options

- Mobilize resources for the modernization of groundwater irrigation.
- Enforce compulsory water-saving irrigation in overexploited groundwater areas.
- Delineate prohibited and restricted areas for groundwater exploitation.
- Promote groundwater resource monitoring, evaluation and planning.

- Conduct restrictive control of well development and groundwater exploitation.
- Integrate water options with agronomic options to promote land and water productivity.
- Study the implications of water-saving irrigation on the groundwater table and local ecosystems.

Discussion subjects for water-harvesting irrigation systems:

Current status and constraints

- Major potential in water-harvesting irrigation.
- Lack of awareness on the major potential of water-harvesting and deficit irrigation systems.
- Incomplete ideas on and limited equipment for water harvesting and deficit irrigation.
- No stable funding channel for water-harvesting irrigation.
- Insufficient study on the implications of water harvesting on river runoff and river basin IWRM.

Measures and options

- Raise awareness on the major potential of water harvesting and deficit irrigation systems.
- Promote development of water harvesting and deficit irrigation.
- Formulate sector development plans based on the integrated river basin water resource plan.
- Formulate and improve management rules and technical standards on design, construction, operation and management of water harvesting and deficit irrigation systems.
- Complete technical and equipment systems for water harvesting, storage and deficit irrigation.
- Conduct technical training, piloting and demonstration.
- Study the implications of water harvesting on river runoff and groundwater recharge.

Discussion subjects for cross-cutting results:

Major water issues now confronted by Shanxi Province

- Prolonged droughts vs. limited water control and storage capacity.
- Limited water resources vs. inefficient water use especially in irrigation and severe water pollution and damage mainly due to coal mining.
- New requirements on irrigation services from a diversified agriculture economy vs. aged irrigation infrastructure and outdated technologies and management.
- Uneven development of water resources which has resulted in rapid depletion of the groundwater table and degradation of the water environment.

Measures and options

- Strengthen the integrated river basin water resource management strategy.
- Integrate agricultural water management into integrated water resource management.
- Promote more balanced and conjunctive water use; suppress groundwater irrigation, stabilize and moderately extend surface irrigation; develop water-harvesting deficit irrigation.
- Innovate irrigation thinking and technologies; replace irrigation rehabilitation with irrigation modernization, water use efficiency with water productivity; adopt new ideas on the balance of management objectives at multi-scales and the multiple roles of irrigation systems.
- Conduct sector assessment to review current irrigation policies, technical standards and college curricula and propose a systematic irrigation modernization plan.
- Mobilize resources for the implementation of irrigation modernization.
- Build local capacity on irrigation modernization.
- Highlight the protection of the environment and ecosystems.

1.2.5 Session 5: Conclusion

After the presentations, field-visits and in-depth discussions, common consensuses were reached among the forum participants on relevant issues related to water resource management and irrigation modernization. The forum conclusions were debated and adopted by a plenary session as reported in Part 2.

1.2.6 Session 6: Closing

Mr Liu Wei Jia, Assistant Provincial Governor and Mr Thierry Facon, Senior Water Management Officer of FAO RAP — on behalf of Shanxi Provincial People's Government and FAO respectively — presided over the official closing of the forum.

2. Conclusions

Located in the Loess Plateau of China, Shanxi Province is famous for its rich coal resources, and is also the most important energy and heavy chemical industry base in China. It faces severe water shortage problems, with total annual water resources amounting to 12.38 billion m³; averaged in multiple years, water availability per capita and per cultivated *mu* is only 381 m³ and 180 m³ respectively, accounting for 17 and 11 percent of the national average level. Shanxi has made remarkable achievements in water resource management and agricultural irrigation development, and has accumulated valuable experience. Modern irrigation management at Jiamakou Irrigation Scheme and the construction of its pumping station provide good references to medium- and large-scale irrigation schemes in the Yellow River Basin in China as well as in other countries in Asia and the Pacific region. High efficiency groundwater irrigation in Pinglu County and the water-harvesting system in Yanhu District are also very relevant to Shanxi's condition and valuable reference points for other countries. Still, continuous efforts and innovative options are needed, as water shortage has become one of the major constraints to socio-economic development in Shanxi Province, and there is still ample room for further improvement. The forum concluded that it is an important strategic issue (and a difficult task) for Shanxi Province to address local water stress effectively via science and technology and to break through water restriction bottlenecks. Considering physical water scarcity and the domination of irrigation water diversion in aggregate water diversion, **water resource management** and **irrigation modernization** are the **two most important issues** among other agendas.

2.1 Water resource management

For many years, Shanxi has been taking initiatives on water resource management. Shanxi formulated the first provincial regulation and established the earliest provincial system on water resource management in China. It is the first province in China to collect water resource management fees and apply permission for water withdrawal. These measures have promoted socio-economic development in the last 20 years and contributed to the establishment and improvement of the national water resource management system. Despite all of these achievements, the current water resource management status is not so cheerful. Confronted with physical water scarcity, challenged by heavy water competition and damaged by coal mining, there is still much to be done with respect to water resource management. **The forum recommended that:**

- A strategy for integrated water resource management at the river basin level should be developed to better realize equitable, productive and sustainable water use.
- Development, allocation and conservation of various water resources, including surface water, groundwater and rain water should be better integrated and balanced from the perspectives of the hydrological cycle and river basin water resource management to harmonize human and environmental co-existence.
- Rights to water should be secured and promoted for poor farmers and marginal groups, similar to rights to food; the concept of environment flow should be better understood and incorporated into water management systems.
- The forum suggested that based on achievements and experiences, Shanxi should conduct more in-depth and intensive research, practice and exchanges on the theories, methods and techniques of sustainable water resource management. **During the next five to ten years, Shanxi should focus on:**

- The construction of water source projects that are technically and economically feasible.
- Better management and control of groundwater resources.
- Development and utilization of rainwater, floodwater, springs and small streams.
- Optimal allocation of water resources under provincial guidelines for integrated river basin water resource management.
- Maintaining reasonable water allocation to the environment and ecosystems.
- Trying to increase surface water supply.
- Reducing groundwater exploitation.
- Controlling the increase of total water diversion to a reasonable rate.
- Better protection of crucial water resources.
- Promoting wastewater re-use.
- Improving water productivity.
- Constructing a holistic water-saving society.

2.2 Irrigation modernization

Faced by the aforementioned challenges and constraints as well as deteriorated irrigation infrastructure, and sustainable development strategy competing against outdated irrigation concepts and notions, **the forum recommended that:**

- During the next five to ten years, Shanxi should significantly increase its investment in irrigation modernization (technical upgrades in engineering infrastructure and capacity building among irrigation management institutions) to promote water productivity for agriculture, protect food security, enhance local environments and foster rural livelihoods.
- A sector assessment is needed to review the current status of irrigation development; identify challenges and opportunities; and propose options and activities.
- Systematic action is needed to update relevant knowledge, college curricula and technical standards related to irrigation design, construction and management according to cutting edge irrigation concepts and technologies.
- Local capacity building is urgently needed to upgrade the skills of local experts and technicians. Different areas may focus on different fields based on typological classification, such as completion and modernization of large- and medium-scale irrigation systems in surface water irrigation areas; adoption and dissemination of modernized, high productivity irrigation facilities and technologies in groundwater irrigation areas; and development and improvement of water-harvesting irrigation systems in the eastern and western mountain areas.

Development and modernization of all of these irrigation systems shall be incorporated into integrated river basin water resource management. The internal relationship and implications of water resource use of different irrigation systems shall be fully considered and incorporated into integrated river basin water resource plans. Recommendations on detailed measures and options for promoting the modernization of different types of irrigation systems in Shanxi Province over the next five to ten years are summarized in Table 3.

Table 3. Measures and options for promoting irrigation modernization in Shanxi Province in the next five to ten years

		Surface water irrigation	Groundwater irrigation	Water-harvesting irrigation
MEASURES AND OPTIONS	Current status	<ul style="list-style-type: none"> • Effective surface water irrigation area: 0.66 million ha; accounting for 52.6% of total effective irrigation area, and 17.4% of total cultivated land area; • Surface water actually irrigated area: 0.81 million ha; accounting for 64.3% of its effective irrigation area; and 32.7% of total actually irrigated area; • Annual surface water diversion for irrigation: 1.52 billion m³; accounting for 46% of total irrigation water diversion, and 60% of total surface water diversion; • Total number of large- and medium-scale irrigation systems: 176; serving effective irrigation area: 0.7 million ha; of which actually irrigated area: 0.29 million ha. 	<ul style="list-style-type: none"> • Effective groundwater irrigation area: 0.6 million ha; accounting for 47.4% of total effective irrigation area, and 15.7% of total cultivated land area; • Groundwater actually irrigated area: 0.55 million ha; accounting for 91.8% of its effective irrigation area and 67.3% of total actually irrigated area; • Annual groundwater withdrawal for irrigation: 1.77 billion m³, accounting for 54% of total irrigation water diversion, and 45% of total groundwater diversion; • By the end of 2005, pipe irrigation area amounted to 0.43 million ha; sprinkler and micro-irrigation area amounted to 0.18 million ha, mostly in groundwater irrigation area. 	<ul style="list-style-type: none"> • Annual rainfall resource in Shanxi amounts to 78.5 billion m³, of which 65 billion m³ evaporated; some could be utilized by suitable water harvesting and storage; • Rain-fed agriculture area in Shanxi amounts to 2.53 million ha, accounting for 67% of total cultivated land, mostly in dry mountain areas; • Normal irrigation is not possible or feasible in most of the rain-fed areas due to hydrological and geological constraints; a possible way out is water harvesting + deficit irrigation; • Currently, some 174 000 water-harvesting systems developed in Shanxi; total annual water harvesting capacity: 6 million m³; irrigating crops over 11 121 ha.
	Major constraints	<ul style="list-style-type: none"> • Insufficient surface water supply due to lack of surface water sources projects, water competition climate change and watershed degradation; • Poor performance of existing irrigation systems due to incomplete and deteriorated infrastructures, outdated technologies and improper management; • Lack of investment for irrigation upgrading and modernization; • Low irrigation water price; the executed water price only accounts for 50–80% of the irrigation cost. 	<ul style="list-style-type: none"> • Unsecured water supply and increasing irrigation cost due to damage of groundwater aquifer by coal mining and overexploitation; • Weak capacity on integrated assessment, dynamic monitoring and effective control of exploitation of groundwater resources; • Lack of investment in irrigation upgrading and modernization; • Outdated farming style which warrants the adoption and dissemination of high productivity irrigation methods and technologies. 	<ul style="list-style-type: none"> • Lack of awareness on the major potential for water-harvesting and deficit irrigation systems on improving food security and poverty alleviation; • Incomplete theories, yet to be normalized techniques and limited availability of suitable equipment for water harvesting and deficit irrigation; • No stable funding channel is available for water-harvesting irrigation so far; • Insufficient study on the implications of water harvesting on river runoff and river basin IWRM.

Table 3. Measures and options for promoting irrigation modernization in Shanxi Province in the next five to ten years (continued)

		Surface water irrigation	Groundwater irrigation	Water-harvesting irrigation
MEASURES AND OPTIONS	Cross-cutting issues	<ul style="list-style-type: none"> • Incorporating all kinds of irrigation water use into river basin IWRM to judge water allocations, productivity — implications (and for the local environment and ecosystems); • Promoting more balanced and conjunctive water use; compressing groundwater irrigation, stabilizing and moderately extending surface irrigation; developing water-harvesting-deficit irrigation; • Innovating irrigation notions, theories and technologies; replacing irrigation rehabilitation with irrigation modernization, water use efficiency with water productivity; adopting new ideas on balance of management objectives at multi-scales and multiple roles of irrigation systems; • Conducting sector assessment to review current irrigation policies, technical standards and college curricula and propose a systematic irrigation modernization plan; • Mobilizing resources for the implementation of irrigation modernization, including increasing government investment, attracting commercial investments and encouraging private investments; • Building up local capacity on irrigation modernization through technical training, field piloting and demonstration; • Highlighting protection of the environment and ecosystems; harmonize human and environmental co-existence. 		
	Legal & policy	<ul style="list-style-type: none"> • Initiate water rights systems, establish a water market mechanism, realize optimal allocation and utilization of surface water resources; • Formulate policies for compensating occupation of agriculture water sources by industry and domestic users; • Formulate financial and investment policies; mobilize resources for development of water source projects and irrigation modernization; • Reform the water pricing system to create an enabling environment for sustainable operation of surface water irrigation systems. 	<ul style="list-style-type: none"> • Formulate and enforce strict rules and regulations on groundwater resource management and protection; • Formulate policies for compensating occupation of agriculture water sources by industry and domestic users; • Formulate financial and investment policies; mobilize resources for modernization of groundwater irrigation; • Enforce compulsory water-saving irrigation in groundwater overexploited areas; • Adjust water prices to improve water productivity; facilitate a shift from groundwater to surface water use. 	<ul style="list-style-type: none"> • Raise awareness on the major potential of water harvesting and deficit irrigation systems to improve food security and alleviate poverty; • Protect the property rights of privately invested water harvesting and deficit irrigation systems to inspire farmers' participation; • Establish formal and stable investment channels for the development and modernization of water harvesting and deficit irrigation systems; • Incorporate water harvesting and deficit irrigation into local water conservancy development plans.

Table 3. Measures and options for promoting irrigation modernization in Shanxi Province in the next five to ten years (continued)

		Surface water irrigation	Groundwater irrigation	Water-harvesting irrigation
MEASURES AND OPTIONS	Institutional & managerial	<ul style="list-style-type: none"> • Deepen institutional reform to implement the principles of irrigation modernization such as equity, transparency, high productivity, user-oriented, participation and decentralization etc.; • Improve management rules and procedures to highlight the concept of services; • Complete and empower WUA systems to facilitate farmers' participation; • Disseminate Jiamakou's experiences in system management, water pricing and water fee collection; • Conduct regular appraisals and benchmarking. 	<ul style="list-style-type: none"> • Complete and improve the groundwater management institutional system to better implement water exploitation permission regulations; • Establish and complete groundwater monitoring, evaluation and information systems to provide a scientific base for groundwater exploitation and protection; • Delineate prohibition and restricted areas for groundwater exploitation; • Conduct regular appraisals and benchmarking to improve performance and modernization of groundwater irrigation systems. 	<ul style="list-style-type: none"> • Formulate a feasible sector development plan based on an integrated river basin water resource plan; • Establish and complete relevant technical extension and service systems at different levels; • Formulate and improve management rules and technical standards on design, construction, operation and management of water-harvesting and deficit irrigation systems; • Conduct information campaigns to raise awareness on water harvesting and deficit irrigation.
	Technical	<ul style="list-style-type: none"> • Develop and adopt practical technologies on pipe system control and canal operation; • Improve the capacities on dynamic data sensing, monitoring, collecting and processing; • Improve water measurement at canals and pipe systems for better water pricing; • Study and develop water-saving schedules adopted to local conditions; • Adopt suitable tool-kits for appraisal and benchmarking of system modernization; • Study the implications of water-saving irrigation on the local environment and ecosystems. 	<ul style="list-style-type: none"> • Develop and adopt suitable technology on groundwater resource monitoring, evaluation and planning; • Study practical methods on effective control of well development and groundwater exploitation; • Adopt typological methods to select suitable irrigation models for different farming systems; • Combine irrigation options with suitable agronomic options to promote land and water productivity; • Study the implications of water-saving irrigation on the groundwater table and local ecosystems. 	<ul style="list-style-type: none"> • Strengthen studies on theories and technologies for deficit irrigation under local conditions; • Develop and disseminate practical techniques on design, construction, operation and management of water-harvesting and deficit irrigation systems; • Research and produce suitable equipment and tools for water harvesting, storage and deficit irrigation; • Conduct technical training, piloting and demonstration; • Study the implications of water harvesting on river runoff and groundwater recharge.

Editorial note

Water resource shortages and increasing insufficiency in water supply have been bottlenecks to the economic development of Shanxi Province. In this regard there has been a need to: (i) Study in-depth experience and advanced techniques on water resource management and irrigation modernization at home and abroad; (ii) explore fundamental measures to combat water shortages and analyse the future direction of irrigation modernization in Shanxi Province. To address these issues, the International Forum on Water Resources Management and Irrigation Modernization in Shanxi Province, co-sponsored by FAO's Regional Office for Asia and the Pacific and Shanxi Provincial People's Government was held in Taiyuan and Yuncheng Cities of Shanxi Province, China from 22 to 24 November 2006. It was organized by Shanxi Water Resources Department. Due to the significant outputs from the forum and the important decision to safeguard the status of local water resources taken by the Shanxi Provincial Committee of the Chinese Communist Party (CCP) and the Shanxi Provincial People's Government, a water development strategy is going to be implemented throughout Shanxi Province. A Mobilization Meeting for Implementing the Water Development Strategy in Shanxi Province was thus convened in March 2007, during which Mr Zhang Baoshun, Secretary of Shanxi Provincial Committee of the CCP and Mr Yu Youjun, Governor of Shanxi Provincial People's Government delivered two speeches, which outlined the main elements of the strategy and priority objectives and programmes. These speeches have been included in this publication.

Speech at the Mobilization Meeting for Implementing the Water Development Strategy in Shanxi Province

Zhang Baoshun

Secretary of Shanxi Provincial Committee of the CCP

Dear Colleagues,

This mobilization meeting has three major tasks. The first task is to carry out the instructions given by Mr Hu Jintao, the Secretary-General of the CCP and the President of China, and Mr Wen Jiabao, the Prime Minister of the State Council, when they inspected Shanxi Province. The second task is to implement the water development strategy. This strategy was formulated according to the current status of the water sector in Shanxi Province with an eye to providing guarantees for developing the economy as rapidly and as successfully as possible. The strategy includes six key water projects. The third task is to motivate all concerned people throughout the province to work hard and generate an upswing in advancing water management. I have three particular topics that I would like to address.

1. Improve awareness about water shortages: Importance and urgency for implementing the water development strategy

Water is both a fundamental natural resource and a strategic economic resource and it plays an irreplaceable role in the development of human welfare. Former administrations in the past have attached considerable importance to the water issue, unremittingly encouraged people to develop water resources, expended much effort and achieved remarkable success. Systems related to flood control, irrigation and drainage, soil and water conservation and water supply for urban and rural area have been improved. The water utilization coefficient has been increased. The construction of large-scale water projects has supported economic development. On the behalf of the provincial party committee and the provincial people's government, I would like to pay my respect and express my thanks to everyone who has contributed to water development in Shanxi.

On inspecting the province, Mr Hu Jintao said, "We should be persistent in the principle of both broadening new sources of income and reducing expenditure at the same time and giving priority to reducing expenditure, forming resource-saving patterns of production and consumption and accelerating the construction of a resource-saving and environmentally friendly society". Mr Wen Jiabao indicated, "As water shortage is the most serious constraint in Shanxi Province, we should investigate the fundamental measures for solving water shortages in the long term and place water resource development high on the agenda of economic development". In line with these instructions, we have conducted in-depth investigations on water shortage problems in Shanxi since last year. Mr Yu Youjun and Mr Liang Bin in particular have headed departmental *in-situ* surveys and from the results we have further heightened awareness on the current status of water shortage and on the urgent need to implement a water development strategy. This has resulted in the formation of key projects to address the issue.

Shanxi Province is located in a loess region where rainfall is low and water resources are scarce. In addition, local industries have exacerbated water shortages. Influenced by both natural conditions and industrial activity, groundwater has been overexploited, waterbodies have been seriously polluted and the gap between water supply and water demand has become increasingly wider. Water shortage has been the most serious constraint for the economic development of Shanxi Province. All departments at all levels throughout the whole province should be more informed about the following four aspects.

1.1 Developing water supply to expand industry and realize sustainable economic development

The traditional key industries of Shanxi Province are high water consumers. According to the 11th Five-year Plan and the current level of water use, consumption by coal, electricity, coke and metallurgy industries after

five years will be double the amount of 1.394 billion m³ in 2005. This will be a serious challenge for undersupplied Shanxi Province where annual groundwater overexploitation is 0.7 billion m³. Water scarcity also constrains the development of new key industries. As the goal is to transform a province dominated by coal production into a province with multiple industrial activity (e.g. coal–chemicals, new sectors), according to the 11th Five-year Plan, 20 to 30 million tonnes of coal–chemical products will be produced every year. It is estimated that water consumption for each tonne of coal–chemical product will be approximately 10 m³; *in toto*, 0.2 to 0.3 billion m³ of water will be needed to support the development of the coal–chemical and other industries. Finally, owing to water deficits, a number of national coal–chemical projects are not established here and the agendas of some projects funded by foreign organizations are consequently constrained. Therefore, we cannot bypass the issue and need to find solutions. If this is not done, the 11th Five-year Plan will not be implemented effectively and the objective of building a new Shanxi will be difficult to accomplish.

1.2 Water development is essential for modern agriculture and building new rural areas

Water is the lifeblood of agriculture and water development is an important component for building new rural areas. Currently the irrigation area of the province encompasses 18 million *mu* but only 12 million *mu* are actually irrigated. Due to serious riverine water deficits groundwater is overexploited; consequently crops, livestock and the populace experience considerable trauma in times of drought. The aftermath is very difficult to conceive. Thus increasing comprehensive agricultural production capacity, accelerating agricultural modernization, fostering the “four reconstructions” in rural areas (reconstructing water supply, kitchens, pens and latrines) and enhancing inhabited environments have to be realized by constructing water storage infrastructure and developing water-saving agricultural techniques.

1.3 Water development is essential for rehabilitating the ecological environment

For many years water and soil losses have occurred over 34 million *mu*. On average, 0.118 billion tonnes of soil are eroded annually. Moreover the future of the ecological environment is bleak. Throughout the province, 69 percent of the land experiences soil and water loss and desertification degrades 10.4 percent. Forested area per capita and the proportion of forest to the entire area account for 0.5 and 38 percent only of the national average level, respectively. Meanwhile, owing to heavy industrial water consumption and insufficient utilities, a vicious circle forms between water shortage and environmental pollution. More serious is the fact that polluted water has penetrated groundwater and karst springs thus endangering urban water supplies. Out of 119 counties, 91 produce coal. Around the coal mines, wells and springs have been rendered useless forcing people to migrate from some sites. Therefore, relieving water shortages is the main agenda for enhancing ecological development in the province.

1.4 Water development is essential for enhancing welfare and promoting harmony

Although in recent years the supply of potable water for six million people has been achieved, two-thirds of the rural population does not have access to safe drinking water and still drink water that is contaminated by high fluorin, arsenic or salt concentrations. This is injurious to people’s health, increases the farmers’ burden and generates social problems. We must ensure that people in general drink clean and safe water in order to promote social stability.

2. Make principles clear, adopt focal points and implement the water development strategy firmly

To resolve the present water dilemma in Shanxi Province, the water development strategy should adopt a scientific approach. Thus there is a need to address the following five focal points.

2.1 Establish a scientific vision for water development

Exploitation of water has undergone three historical stages: (1) Sourcing river water and being at the river’s command; (2) Sourcing river water and controlling floods; (3) Human transformation of the river.

Now, scientific practices and societal development have generated a fourth stage in which humans and nature can exist in harmony and we should foster this relationship. While we develop and exploit water resources,

we should respect the natural balance, prioritize environmental management and rehabilitate ecological structure that has deteriorated. We should establish the sustainable development of water resources.

The sustainable development of water resources comprises the following elements:

- Owing to increased water use, practise water conservancy and increase the sustainability of water supply.
- Meet the water requirements of not just the present but future generations also.
- Harmonize water resource development and socio-economic development.
- Balance water supply and water demand by increasing water supply and attenuating water demand to sustain water-bearing capacity.
- Balance development between regions and between urban and rural areas.
- Increase investment and projects in areas where water is in seriously short supply and the ecological environment is degraded.
- Construct a water resource development system in which the interaction between urban and rural areas is coordinated.
- Establish a people-centred concept, regarding human interests from start to finish in implementing the water development strategy.

2.2 Persist with overall planning and coordinate progress

Contingency planning should encompass:

1. Addressing the relationship between the development of new water sources and water-saving activities:
 - Alleviating water shortages, expediting the construction of water infrastructure projects and building storage facilities next to river systems.
 - Strengthening water demand management, improving water conservancy plans and practising strict water-saving measures.
2. Controlling the development and protection of water resources:
 - Exploit surface water carefully, strictly control groundwater use and effectively utilize air-borne moisture.
 - Determine the different functions of various rivers regionally and formulate corresponding development and protection measures.
 - Streamline economic behaviour.
 - Promote ecological rehabilitation.
3. Understanding the water-use relationship for industrial and agricultural production, urban living and ecological sustainability:
 - Formulate scientific water resource development and a general scheme for water resource allocation.
 - Prioritize water allocation for human welfare, industrial and agricultural production and environmental needs.
4. Resolve water pollution issues:
 - Improve the prevention and control of water pollution.
 - Accelerate the construction of water quality monitoring systems.
 - Ban the discharge of wastewater that exceeds safety standards.
 - Reverse the trend of deteriorating water quality and ensure that chemical oxygen demand decreases by 13 percent during the 11th Five-year Plan.
 - Re-evaluate rapid economic development that comes at the cost of sacrificing the environment.

2.3 Constructing quality water projects

The six key projects in the water development strategy are: Water supply for emergency use; irrigation and drainage; damming for soil and water conservation; potable rural water supply; water conservancy in urban and rural areas; and protection of rivers and groundwater. All of the projects are closely connected. The following conditions apply to project implementation and quality:

1. Strictly adhere to the mandate of the overall plan.
 - Make every effort to put the plan into effect according to stated requirements.
 - Ensure that each project starts on time and makes orderly and scientific progress.
 - Ensure each project is completed and put into effect within the time schedule.
 - Prioritize scientific and technological inputs, conduct technical research, popularize and apply modern and practical techniques.
2. Remember that quality is the lifeline of water projects.
 - Improve monitoring systems and practices.
 - Impose strict monitoring and supervisory regulations.
 - Reject poor quality; avoid suboptimal — but nice appearance.

While we are building the six key projects, we should continue work on the Yellow River Diversion Project. We will start the North Main Line as soon as possible to try to increase water supply to Taiyuan, broaden the scope of water supply and decrease water costs and diminish groundwater exploitation.

2.4 Establishing water-saving patterns in production and consumption

Water conservancy is essential for resolving the water deficit in Shanxi. Water-saving activities should feature in daily departmental work, industrial development, project implementation, urban and rural construction and residential life. Moreover protection of the natural environment should figure prominently in the course of development activities. In these contexts the following activities should be carried out:

1. Developing water-saving industries.
 - Popularize water-saving techniques and equipment in traditional industries.
 - Reconstruct or eliminate enterprises, equipment and techniques which have high energy consumption and manifest excessive pollution.
 - New industries should meet water-saving requirements.
 - Develop a sophisticated water-saving industry.
 - Decrease water consumption.
 - Encourage water-harvesting projects and limit projects that cannot meet water-saving requirements.
 - Assess conditions for water resource augmentation and environmental protection before new projects are started.
2. Develop water-saving urban and rural areas.
 - Plan and build towns according to needs with water-saving facilities in place.
 - Enhance existing water-saving facilities.
 - Promote water-saving products and in some towns supply water of differing quality according to needs.
 - Improve wastewater treatment in towns. Build wastewater treatment plants in every county and ensure they operate efficiently to generate suitable recycling of waste.
 - Incorporate water conservancy strategies while building new rural areas and developing water-saving agricultural techniques.
 - Enhance the extension of water-saving techniques, reconstruct various irrigation districts, strengthen the regulation of large, medium and small rivers, develop small storage facilities such as rainfall collection points and further improve comprehensive agricultural production.

3. Ensure potable water supply for every citizen.
 - In areas contaminated by fluorin, arsenic and salt concentrations, provide a clean and safe supply within three years.
 - Strictly protect the water quality of water sources, improve the water supply facilities in urban areas and ensure continuous supply of potable water to urban areas.
 - Establish provision of emergency water supply and over time resolve water availability issues and concomitant disputes.
4. Develop a water-saving society.
 - Promote a water-saving province that employs innovative practices, a market economy and sustainable development of the coal industry.
 - Reverse water shortages by removing wastewater and pollution threats.
 - Improve local water regulations, encourage enterprises and people to develop water-saving products and techniques and enforce laws.
 - Raise awareness on water-saving and establish a water-saving culture by propagating the eventual benefits and the disgrace associated with water wastage.

2.5 Reforming the system for water resource development

There is a need for four structural reforms.

1. Reform in the water resource management system by establishing administrative bureaus for water affairs to strengthen integrated catchment and regional water resource management.
2. Reform in the investment system.
 - Encourage different sectors to invest in water projects and implement various investment modes according to the project type.
 - The government should increase investment in key projects and key fields such as potability, flood control and environmental protection as they are related to the national economy and people's livelihoods.
 - The government should be the main stockholder in these projects or fields.
 - Attract local funds for the construction of medium- and small-scale water projects that will have specific local beneficiaries.
3. Reform in the management and operation of water projects.
 - Establish a new management system in which water rights management is highlighted and water resources are controlled, combined with water quota management.
 - Inculcate responsibility in the management of large-scale water projects and irrigation districts.
 - Transfer the operational rights of medium- and small-scale irrigation districts to water users by various fiscal means in order to recover the capital, then use the capital again to develop new water projects that are empowered by the users.
4. Reform in the internal re-engineering of water management units.
 - Stabilize institutions that undertake fundamental and public tasks and provide some financial support. Enterprises and institutions that contribute to public welfare should enter the market step-wise.
 - Through township organization reform, we should further clarify the function of town water management stations and provide corresponding support to ensure normal operation.

3. Strengthen organization and leadership to provide firm support for promoting water issues

Starting the construction of the six key water resource projects at the same time is a test of our leadership and control capacity. Each level of the government and departments should conscientiously implement the strategy with confidence, enthusiasm and efficiency.

3.1 Imbuing importance and employing careful organization

Each government level should regard the water issue as critical to socio-economic development. Key government officials should be responsible for leading the implementation of the strategy, especially the six key projects and coordinate issues and solve problems promptly. The leaders who are assigned to take charge of strategy implementation should energetically work at project sites, have profound understanding of the situation and solve problems on the ground. We should strengthen the supervision and inspection of project implementation and consider progress as the main basis for evaluating leaders. Management teams should improve their technical knowledge and be bold in their approach by grasping the essential characteristics of water projects and progressively improve water development capacity.

3.1.1 All striving to form a united force

There are numerous departments involved in the strategy, each having a particular mandate:

- The water resources department should be skilled in administration, ready to address new situations and problems, innovative with regard to water management practices and collaborative with governmental officials.
- The development and reform department should carefully evaluate the procedure for examination and approval of water projects.
- The finance department should ensure that funds for the construction of water projects are in place and available on time.
- The urban construction and economic or commercial committees should promote water-saving activities within their departments.
- The environmental protection department should investigate and penalize enterprises and institutions that discharge wastewater illegally.
- The commodity price department should check and approve water prices carefully.
- The disciplinary commission, the control commission and the auditing department should investigate and deal with violations of the law and breaches of discipline related to water issues.
- The propaganda department should promote the propagation of the law, regulations and policies related to water and upbraid those who waste water, pollute sources or otherwise degrade the environment. Efforts should be made to make water conservancy “fashionable”.

3.1.2 Strengthening management and organizing team spirit

To achieve success we need first-class administrative and professional personnel and experienced market operators. Obviously we need to select the right candidates. We should optimize the talent structure in order to put appropriate people where they are needed most. Staff welfare should be addressed by improving their working conditions and helping them to handle stressful situations. We should improve the outputs of the water resource department and the overall quality of the whole group.

Speech at the Mobilization Meeting for Implementing the Water Development Strategy in Shanxi Province

Yu Youjun

The Governor of Shanxi Provincial People's Government, China

Dear Colleagues,

The major task of this mobilization meeting is to carry out the important instructions on coping with water scarcity given by Mr Hu Jintao, the Secretary-General of the CCP and the President of China, and Mr Wen Jiabao, the Prime Minister of the State Council, when they inspected Shanxi Province. This includes implementing the water development strategy in Shanxi Province and its six key water projects in order to promote the water sector in Shanxi Province. It is hoped that this will lead to a historic breakthrough in water management and a leap forward in socio-economic development. I have four specific issues to consider:

1. The need for a water development strategy

The protection, development, utilization and control of water have always been associated with the progress of civilization. The twenty-first century is regarded as the “water century”. The availability of water resources and concomitant development will be an important factor for influencing regional development. Currently we are entering an era of water scarcity and many international organizations and experts predict that water supplies in many regions in the world will diminish as the earth becomes warmer. Water is now an important strategic resource and owing to water shortages it is likely that conflicts over use will become increasingly more bitter in the future.

China is ranked sixth in world placings with regard to total water availability. However, average available water per capita remains low — statistically 121 in world rankings. China is listed as one of 13 countries in which water resources are in short supply. The distribution of water resources in China is very uneven. Eighty percent is distributed by the Yangtze River and to its south while northern China has a serious deficit. Shanxi Province is one of the provinces in which water supply is meager. Total available water amounts to only 12.38 billion m³ and per capita distribution is only 381 m³, which is only 17 percent; this is well below the world average and much lower than 500 m³, the threshold according to international standards. Therefore, addressing water conservancy and protection and achieving the sustainable development of water resources are urgent issues for Shanxi, China and the world.

The instructions of Mr Hu Jintao, the General Secretary of the Communist Party of China and the Premier of the State Council Mr Wen Jiabao have already been elaborated by Mr Zhang Baoshun (Part 1) as well as the consequences of not developing water-saving measures or failing to build a water-saving society.

From April to September 2006, representatives from the provincial water resource department and from water resource bureaus in every city and county conducted an in-depth investigation of Shanxi's water resources and analysed historical data. From September to November 2006, Mr Liang Bin and I led a group of officers from various water resource departments and experts on a tour of 57 project sites including rivers, springs, reservoirs and irrigation districts that covered all 11 cities in Shanxi Province. We investigated water resource development, water-saving and protection measures, irrigation and drainage as well as soil and water conservation activities. Representatives from the academe, industry and rural/urban areas attended 15 symposiums at which various issues were addressed and concerns voiced. Consequently we have a much clearer perception on matters pertaining to water use/abuse in Shanxi.

1.1 Water resources in Shanxi Province are inadequate due to geographical and climatic factors

Shanxi Province lies in the east of the loess region; mountains and hilly areas account for over 80 percent of the total land area. Terraces, ravines and gullies that traverse the land make it difficult to exploit rainfall and river water. The arid climate and frequent droughts also exacerbate water shortages.

1.2 Slow infrastructure construction induces considerable surface water loss

Besides natural factors, slow infrastructure construction is another significant factor that results in water shortages. Since 1949, 730 reservoirs have been built, which constitute 0.9 percent of the 84 000 reservoirs nationwide. The total storage capacity is 4.5 billion m³, which is 0.8 percent of the total storage capacity of the whole country. In Shanxi, 63 large- and medium-scale reservoirs were built before 1976; only three reservoirs started construction in the last 30 years and none has been put to efficient use. The existing reservoirs are ageing. The sedimentation of reservoir storage capacity has reached 1.2 billion m³. If sedimentation and flood capacity are deducted, the effective reservoir storage capacity in a normal year is only 0.5 billion m³ for the whole province. Because the construction of headworks has lagged, the annual stored water amount is less than one-tenth of the runoff in the whole province. According to data, surface water resources available annually have amounted to 8.677 billion m³ in the last 50 years — even 7.2 billion m³ during the drought period after the 1980s. Runoff exiting from the province ranges from 4.88 billion m³ to 7.3 billion m³; two-thirds to three-quarters of the total surface water flows out of the province. Therefore, the water utilization rate in Shanxi Province is low. The exploitation of the Yellow River in Shanxi is also very low. According to the Yellow River water allocation scheme approved by the State Council, Shanxi can annually use 4.3 billion m³ water from the Yellow River, however in reality only 1 billion m³ are used, accounting for 23 percent of the total allocated water.

1.3 Groundwater is overexploited and the water supply structure is unconventional

The low utilization of surface water results in the overexploitation of groundwater. Since the 1970s, in order to meet water demands generated by economic development, groundwater exploitation has increased annually. In 1971, annual groundwater withdrawal in the whole province was 1.1 billion m³; currently this figure is 4.0 billion m³ or 60 percent of total water use. Hindered by insufficient infrastructure or influenced by low water price, many regions and enterprises meet water demands for development by overextracting groundwater. There are 22 seriously overexploited locations covering 11 000 km². The groundwater table level has fallen sharply in the last ten years; well depths in Yuncheng, Linfen, Taiyuan and Yangquan Cities are as deep as 700 to 800 m, some even exceed 1 000 m. Moreover, outflow from karst springs has been radically affected.

1.4 Coal mining degrades water resources and exacerbates problems

Undisciplined and excessive coal mining activities sever groundwater connections, damage the aquifer and induce seepage and pollution. It is said that for every tonne of coal mined, 2.48 m³ of groundwater are degraded in Shanxi. Groundwater losses generated by coal mining amount to 1.5 billion m³ annually. Furthermore, because of the serious damage to the aquifer, water seepage creates ground settlement, declines in groundwater water levels, abandonment of wells and cessation of karst spring flow near coal mines — consequently people have to carry drinking water from remoter areas.

1.5 Water pollution is serious and the level of wastewater recycling is low

Currently 0.8 billion m³ of wastewater is emptied into rivers annually throughout the province, accounting for 10 percent of the total runoff and one-third of the runoff in non-flood periods. Among the 103 river cross-sections monitored, 88 percent had been polluted to varying degrees and 62 percent had been polluted heavily. More worrying, polluted water has penetrated groundwater and karst springs, thus endangering urban water supply. However, the construction of wastewater treatment facilities continues to lag. This causes low operational efficiency and wastes valuable water resources.

Other problems caused by water deficits in Shanxi are outlined hereunder:

- Impeded socio-economic development.
- Many new industrial projects have not been approved by the central government.
- Nearly 50 percent of the irrigation area in the whole province is not fully irrigated.
- The development of two-thirds of cities has been constrained.
- Eight million rural inhabitants have insufficient access to potable water.
- Many rural people drink water contaminated by high fluorin and arsenic concentrations or salt.
- Many rural people exist by transporting water from distant places.

We should hasten to formulate and implement a water development strategy that features the rational development, efficient use, conservancy and protection of water resources as its key components. Each stratum of society should understand the significance and far-reaching influence of this strategy.

2. Overall implementation of the water development strategy

The water development strategy will be implemented through six key water resource projects. By the end of the 11th Five-year Plan provincial water storage capacity will have increased to 7.5 billion m³ to meet water demands generated by industries, cities and agriculture. We will increase the actual irrigated area of four million *mu* to create an effective irrigated area of up to 20 million *mu*. We will build 10 000 new storage facilities for silt and add 0.8 million *mu* of farmland. We will ensure potable water for ten million people. We will progress in the construction of the water-saving society. We will reverse the trend of urban abuse of the rural water environment and water quality in rivers will meet approved standards.

2.1 Strive to build projects for emergency water use

The most fundamental and effective measure to increase water supply capacity and to avoid groundwater overexploitation is to build dams along rivers. This will also help to mitigate the effects of floods and droughts and protect human lives. It is also the hardest task of the water development strategy in Shanxi Province. All departments must pool their resources to complete the construction of 35 large- and medium-scale dams and various large diversion projects within three to five years. The main elements of these projects are outlined hereunder:

- Build infrastructure along the Hutuohe River, in particular, Pingshang Reservoir, Xishuixing Reservoir, Longhuahe Reservoir and Dabao Reservoir. Pingshang Reservoir will be the key project to meet water demand for industrial and agricultural development and urban life in Xingding Basin and Yangquan City.
- Build infrastructure along the Zhanghe River, in particular, Wujiazhuang Reservoir, Shuangfeng Reservoir, Xiajiaozhang Reservoir and Luansi Reservoir. Wujiazhuang Reservoir will be the key project to meet water demand for industrial and agricultural production and urban life in Shangdang Basin.
- Strengthen the development of water diversion from the Yellow River. Implement the Jiamakou extension project and the creation of Beizhao irrigation district which will pump water from the Yellow River for agricultural irrigation and prevention of groundwater depletion.
- Develop the Qinhe River Basin where surface water is relatively abundant. Build Hechuan Reservoir to divert water upstream of the Qinhe River into the Fenhe River Basin to address industrial and agricultural water shortages in Linfen Basin and downstream of the Fenhe River.
- Develop the water and hydropower potential of Qinhe and Danhe Rivers. Build Weitan, Dongjiaohu and Caohe hydroelectric plants, together with Zhangfeng Reservoir, to provide water for industrial and agricultural production and urban life in Jincheng City.
- Build Baiyekou Reservoir and Songta Reservoir to exploit water midstream of the Fenhe River. Meanwhile manage the South Main Line of the Yellow River Diversion Project and increase water supply to Taiyuan City to meet the water demand of industrial and agricultural production in Taiyuan Basin.
- While increasing the water supply of Cetian Reservoir, build Tanghe Reservoir, Shoukoubu Reservoir, Gushan Reservoir and Taipingyao Reservoir. Promote the construction of the North Main Line of the Yellow River Diversion Project to address water demand in Shuotong Basin. In addition, build Pingdi Reservoir, Qianian Reservoir and Baquanxia Reservoir to meet water demands in western and eastern mountainous areas and new industrial districts.

These developments can increase annual surface water supply by 1 to 1.5 billion m³ and recharge groundwater supply by 0.2 to 0.3 billion m³; this will create a storage capacity (surface water) of up to 3.5 billion m³ for the whole province. The exploitation of groundwater will also decline. Together with water from the Yellow River Diversion Project, total water supply is predicted to meet annual water demand of 7.5 billion m³.

In addition, we should try to rehabilitate damaged reservoirs within two to three years. Cities and counties should be motivated to build small reservoirs, ponds and dams to collect rainfall.

When we design reservoirs upstream, we should consider downstream water demand. We should control the water diverted or stored to 40 percent of the runoff to balance water demand between upstream and downstream users.

Project design should strive for efficient use and consider water supply benefit and practical allocation as important factors in the water source “scale”. We will ensure that 20 to 25 projects start this year, while remaining projects will start in the first half of next year.

2.2 Strive to build irrigation and drainage projects

Irrigation and drainage measures are effective for enhancing agricultural production and increasing farmers’ income. The economic benefit in the irrigated area is considerably higher than the rain-fed area. Nationwide, per capita irrigated area is 0.64 *mu*. In neighbouring areas, this figure is 1 *mu* in Hebei Province, 1.09 *mu* in Inner Mongolia and 0.76 *mu* in Henan Province. However, it is only 0.42 *mu* in Shanxi Province. In recent years, influenced by decreasing river inflow and the ageing of water infrastructure, water diversion for irrigation has become increasingly difficult, the cost of irrigation has become higher and the actual irrigated area has decreased. This situation has constrained increases in crop yield and economic benefits. Therefore improving agricultural irrigation and increasing the irrigated area are important components of the water development strategy. During the 11th Five-year Plan, the main tasks for irrigation and drainage in the whole province are:

- Building a core irrigation district of ten million *mu* by integrating all irrigation sources in Yuncheng Basin, Jinzhong Basin, Xinding Basin, Shuotong Basin and downstream of the Fenhe River to ensure grain security. These sources are reliable and irrigation facilities are in a healthy condition.
- In order to improve water use benefits, increase water conveyance efficiency and meet the water demands of agriculture we will implement the reconstruction of water-saving infrastructure for medium-scale irrigation districts in the western and eastern mountainous areas and in districts irrigated by wells. These developments will meet the water demands of the local rural population.
- Develop rainfall collection projects via government subsidies, encourage sectoral investment, promote collection by villages and farmers and build 0.4 million water-retention wells and ancillary irrigation facilities in the eastern and western mountainous areas. Water resource departments and transportation departments should closely cooperate when building new roads by devising rainfall-collection surfaces on roads, building water retention wells and installing water-saving irrigation facilities on the sides of roads to meet water demands for forestry and agricultural production.

By adopting these measures and promoting water-saving agricultural techniques, by the end of the 11th Five-year Plan, the effective irrigated area of Shanxi will be approximately 20 million *mu* and the target of providing each farmer with 1 *mu* (irrigation field) and 0.85 *mu* (effective irrigated field) will be accomplished, thus stimulating agricultural production in the whole province.

2.3 Strive to build infrastructure for soil and water conservation

Silt storage facilities for expanding farmland area have many functions such as silt control, flood control and combating drought. Crop yields in the expanded area are six to ten times higher than that of cultivated sloping land. Therefore their construction can move agricultural pressure away from sloping lands and their forests, help farmers increase income and improve the ecological environment of the loess.

Shanxi counties along the Yellow River experience serious soil and water loss and silt draining into the Yellow River has been recorded at 0.4 billion tonnes. But this natural condition has become an asset for expanding arable area. Currently, over 40 000 silt storage facilities have been built throughout the province and 1.57 million *mu* of farmland have been added. During the 11th Five-year Plan, we will build a further 10 000 facilities and supplement 0.8 million arable *mu*; this will enhance agricultural production in mountainous areas over 19 600 km² in 48 counties along the branch rivers of the Yellow River — the Pianguan, Xianchuan, Zhujiachuan and Lanyi Rivers. After completion of these projects, each farmer will have 0.3 *mu*

of farmland, or 0.5 *mu* of farmland in some areas; silt drained into the Yellow River will be reduced to 0.15 billion tonnes and 0.2 billion m³ water will be recharged to groundwater. In coming years, the administrations of provinces, cities and counties should increase financial inputs and use money from land lease and landownership fees for the construction of silt storage facilities. Meanwhile, we will seek to move sloping land cultivation practices onto newly generated farmland and plant trees and grass on the “vacant” sloping land.

2.4 Strive to build rural water drinking projects

Recently, Mr Wen Jiabao said, “We should regard the treatment of water with high fluorin concentration as an important task and must absolutely prevent people from drinking water which endangers their health,” when he inspected Shanxi Province. The 11th Five-year Plan stipulates that drinking water safety for ten million people will be assured within the next five years.

The next four years is the key stage for resolving the problem of rural drinking water. Every department should organize suitable projects and promote public welfare. This should be accomplished through the following activities:

- Establish projects to address drinking water safety in remote mountainous areas where there is insufficient water supply or water is contaminated.
- Accelerate the construction of drinking water supply projects in the central area through careful planning and increased investment.
- Provide tap-water supply in each village and potable water province-wide within three to five years.

2.5 Strive to build urban and rural water-saving projects

A number of measures should be introduced to conserve water in urban areas:

- Accelerate the development of water-saving infrastructure.
- Incorporate appropriate water-saving technology in urban planning.
- Rehabilitate water-supply networks and facilities to reduce losses from seepage.
- Allocate water according to quality and usage.
- Deploy surface water for industrial activity instead of groundwater which can then be sourced for use in urban areas.
- Upgrade the payment structure for users of water resources so prices are distributed equitably.
- Enhance awareness about the benefits of water conservancy and ensure that usage conforms with relevant laws.

With regard to agricultural water conservancy objectives include:

- Expand water-saving projects, rehabilitate infrastructure, provide demonstration sites, develop rainfall-collection schemes and improve the condition of tertiary canals.
- Promote advanced water-saving irrigation techniques and build small-scale water intake structures.
- Expand advanced water metering facilities — establish water-monitoring networks in 50 counties where groundwater is seriously overexploited, install IC cards at every well, implement real-time monitoring and strictly control groundwater exploitation.
- Create water users’ associations (WUAs).
- Ensure water rights are observed.
- Enhance water-saving awareness among farmers.

By implementing these measures, during the 11th Five-year Plan, the rise of water use in Shanxi should be contained to 10 percent. Total water use (per 10 000 yuan GDP) will decrease from 155 m³ to 100 m³ and

re-use of industrial water should reach 85 percent. By the end of the Plan, the irrigation water utilization coefficient for the province will increase from 0.47 to 0.56; this means that approximately 0.4 billion m³ will have been conserved from agricultural activities. By 2015, water use efficiency and conservancy will have reached an advanced level.

2.6 Strive to protect groundwater and river sources

In the overall development of the national economy (e.g. urban planning, project inception and adjustment of industrial structure) there are various water protection measures that can be taken:

- Consider the bearing capacity of water resources and the water environment. In future, the water demand from industrial and extension projects should be assessed before they are approved. Exploitation of groundwater should be strictly controlled and balance maintained between withdraw and recharge. In areas where groundwater has not been tapped, efforts should be made to regulate withdrawal and protect the supply. In areas where withdrawal and recharge of groundwater is balanced, the current situation should be maintained and not allowed to deviate negatively. In areas where groundwater is overexploited, extraction should be reduced and a balance between withdrawal and recharge created within five to ten years.
- Consolidate the protection of springs and other water sources via legislation — both at national and provincial levels — and strictly implement protection of the Fenhe, Sanggan, Qinhe and Hutuo Rivers. There is also a need to control or disband coal mines and enterprises that are potential polluters. Control groundwater overexploitation in karst areas and forbid further increase. If there is no other option, then it must be approved by the provincial water resource department.
- Increase the amount of water diverted from the Yellow River and encourage water recycling; river health must be emphasized.
- Prevent water pollution — a network for monitoring water quality is advised. Administrative bureaus should be responsible for ensuring that water quality within respective districts meets acceptable standards.
- Strictly supervise sewage disposal and ban excess discharge of pollutants.
- Improve wastewater treatment capacity to increase the water recycling rate.
- Increase wastewater treatment fees and expand the scope for levying such fees.
- Make water pricing systems equitable.
- Accelerate the construction of wastewater treatment plants and facilities and try to enlarge the scale of wastewater recycling. During the 11th Five-year Plan, wastewater treatment and recycling plants will be built in every city and some counties if possible.

While we implement the six key projects, we will continue to improve the South Main Line of the Wanjiashai Yellow River Diversion Project and seek approval for the North Main Line of the Yellow River Diversion Project from the central government. The Yellow River Diversion Project is an important decision which will help to solve water shortages in Shanxi. We should improve the General Main Line and the South Main Line (already completed) to increase efficiency, decrease operational cost, ensure water quality, enlarge the water diversion scale and optimize project benefits. With respect to future socio-economic and environmental benefits, we should carefully prepare the North Main Line of the Yellow River Diversion Project and seek approval from the central government for implementing the project as soon as possible.

3. The water development strategy in the context of liberalization and the need for progress

In the past, funding for water resource projects was mainly provided by government departments or obtained through mass campaigns. However liberalization has opened up new ways to explore the development of water projects.

According to plans, total investment for implementing the water development strategy amounts to 20 billion yuan. If we follow the existing approach, i.e. by relying on investment from government departments, it is will be impossible to acquire the needed funds. Therefore, we should relinquish old ideas, update our approach, broaden our vision, be innovative and explore new investment opportunities that have been generated by liberalization.

3.1 Reform the fund-raising system to attract sectoral interest for water project development

We need to scale investment for water projects with different functions, i.e. support local funding for public goods such as flood control and combating drought (such as large reservoirs). Government and local funding could be combined for water projects that benefit human welfare and the economy and are thus a quasi public good. Foreign and state-owned enterprise investment should be encouraged for major projects that have a stable return on investment.

The construction market in water projects provides many corporate opportunities. Major water users, local government, foreign- and state-owned enterprises should be encouraged to enter the construction and management of water projects through joint stock businesses. Stock preferences for reservoirs of different size are:

- Large reservoirs (as a public good): Mostly state-owned stock. Multiply stockholders and welcome foreign investment.
- Medium reservoirs (as a public good): Mostly state-owned stock. If not used for public service, local or foreign investors could be major stockholders; permission could be granted to manage the reservoir on a sole investor basis.
- Small reservoirs: Open to all investors.

The government could provide support in the form of subsidies or government purchase of public services provided. Investors' rights needed to be protected legally.

Government investment needs to be increased. Each level of the government should increase investment in water projects through various modes. The property rights system should be reformed in order to provide returns to investment which will be used to build new water projects. Provinces and cities may establish fund-raising measures for water project construction.

We should strengthen the planning and management of water projects. All water projects should follow the overall plan for the whole province; project sites must not be selected arbitrarily and construction must be carried out carefully under proper supervision. Water projects should also be inspected regularly to ascertain whether they are promoting, *inter alia*, long-term development of the regional economy, rational development of water resources and protection of the environment.

3.2 Improving the “water user pays” system to promote water saving and to optimize water resource allocation

All WUAs should pay fees to the government according to provisions made by the law. The water resources belong to the state and levying fees is an expression of the state's proprietorial rights over water resources. As there is serious water shortage in Shanxi and groundwater is overexploited, economic levers can be exercised to control extraction. This should encourage the use of surface water, restrict extraction of groundwater and create a water-saving society. Except for cases when the central government clearly approves the absence of water fees or the provincial government postpones collection, all organizations and people who extract water from rivers, lakes, springs and groundwater should pay fees to water bureaus. This includes investors and managers of water facilities. All other levels of government cannot exempt or reduce fees arbitrarily.

Due to diminishing supplies, groundwater extraction fees should be increased. We should formulate different water fees for industrial water users, agricultural water users and residential water users.

If these water tariffs are not charged, then it will not be possible to recover costs for the construction and operation of water projects and investment will not be rewarded. Consequently no one will be prepared to invest further. Therefore, while implementing the water development strategy we must strengthen awareness that water is a commodity — this can be accomplished via awareness campaigns and legislation.

At present, the water price is low and the water pricing system is not rational. Therefore we should reform and rationalize the water price system as soon as possible:

- Establish a water pricing system that meets the needs of the market economy and complements the sustainable use of water resources. Water price should reflect water scarcity and take into account engineering, operational and environmental costs and return of investment in the development of water resources.
- The water pricing system should stimulate the creation of water-saving society.
- We should gradually differentiate the water fee collection systems according to water users and water sources, strengthen quota management and comprehensively practise the tariff system.

Based on the principle that water resources belong to the state and water should be paid for, we should launch pilot projects on water property rights. Pilot projects will help to: Summarize experiences, gradually find measures and regulations for determining initial water rights, explore trading facets of water property rights, formulate rules for water rights trading and develop a water rights trading market to allow the legal owner to transfer surplus water or saved water to other water users. We should popularize water ticket trading among agricultural water users, encourage industrial water users to invest in agricultural water-saving facilities to obtain water property rights from agricultural water users in return, launch pilot projects on water property trading between regions and establish a compensation system between upstream and downstream water users.

We should strengthen supervision of the water market and uphold the legal rights on water supply and water demand. Therefore, in order to set up a payment system for water resources and water commodities, we must improve the pattern and regulation of government supervision. Government departments should hasten to issue regulations on water market supervision and improve technical standards, management and services.

4. Consolidate water resource management to improve efficiency and protection

The water resource management system directly influences water allocation and water use efficiency. There are many human and physical barriers in the water resource systems in our province. These problems aggravate water shortages to some extent.

The General Secretary of the Communist Party, Mr Hu Jintao said at the National Conference on Population, Resources and Environment, “We should strengthen the integrated catchment of water resources and build authoritative, efficient and concerted water resource management systems”. The Premier of the State Council, Mr Wen Jiabao clearly pointed out on different occasions that we should coordinate the protection, development and use of water resources. To conduct the water development strategy properly, we must conform with the law and the provincial situation. Therefore we must attach importance to law formulation. According to the Water Law of the People’s Republic of China and the situation in Shanxi Province, we should expedite the drafting of regulations related to water management. These include:

- A Revised Draft of Shanxi Provincial Water Resources Management Regulations.
- Opinions on Setting Up the Water Resources Payment System in Shanxi Province.
- Measures on Building the New Water Source Projects by the Social Funds in Shanxi Province. Schemes on Adjusting the Scopes and Standards of Levying the Water Resource Fees in Shanxi Province.
- Opinions on Practicing the Financial Support in Electricity for Agricultural Irrigation and Drainage in Shanxi Province.

Drafts were submitted at the aforementioned conference and will be forwarded to the provincial congress and provincial government for issuance.

We should also build a law enforcement agency to form a composite force to combat illegal activities related to water, deal with water disputes and provide a safe environment for implementing the water development strategy.

Lastly the development of an inter-regional water management group that addresses infrastructure construction, water supply, drainage, wastewater treatment and water recycling for both urban and rural areas will serve to encourage operational consistency, promote investment and protect areas that are especially vulnerable to water deficits.

SECTION 1: OPENING SESSION

OPENING ADDRESS

Yu Youjun

The Governor of Shanxi Provincial People's Government, China

I would like to welcome all forum delegates on behalf of Shanxi Province People's Government. My sincere thanks to FAO's regional office for its contribution to water resource management and irrigation modernization in Shanxi, to the Ministry of Water Resources for supporting the development of water conservancy in the province and to the many experts who are involved in water conservancy research and practice.

Governments worldwide and international communities share strategies to: (i) Support sustainable socio-economic development through the sustainable utilization of water resources, (ii) improve integrated agricultural productivity through the modernization of agricultural irrigation and (iii) ensure adequate supply and safety of food. I will now provide a brief introduction on the status and challenges for water resource utilization in Shanxi and our corresponding thoughts on action to be implemented. I look forward to advice and suggestions from leaders and experts present at this forum.

Water resources in Shanxi: Status and challenges

Shanxi Province has ample coal deposits but is disadvantaged by water supply. This is a good summary of Shanxi's natural resources. Annual drought and topography contribute to water resource depletion in Shanxi. In the administrative area, except for the Fenhe River Basin in the centre, all rivers flow outwards from the watersheds on both sides. Utilization of rainfall and recharge of groundwater are poor owing to steep slopes and rapid runoff.

From the early 1970s to the mid-1990s, socio-economic development was slow; thus conflict between demand for and supply of water resources was not prominent and the implementation of water conservancy measures was minimal. With the central government's strategy to boost the development of Middle China and Shanxi Province's strategy to industrialize, Shanxi is stepping into an era of rapid socio-economic development and the concomitant demand for water in general will peak. According to preliminary estimates, in the coming ten years, the total demand for water will rise from the current 6.5 billion m³ to 7.5 billion m³. The gap between demand and supply will become more and more striking for the following reasons:

1. Limited water resources are continuously diminishing and the state of surface water loss is severe. Shanxi is one of China's poorest provinces with respect to water supplies. According to the results of the Second Water Resources Evaluation in 2003, Shanxi's water resources, on average, amounted to 12.38 billion m³, which is only 4 percent of China's 2 800 billion m³. The per capita volume was 381 m³, only 17 percent of China's 2 200 m³ and 1 200 m³ less than the six dry northwest provinces. Since 2000, water resources have continued to decrease. Gross supplies from 2001 to 2004 were 6.971 billion, 7.871 billion, 12.15 billion and 9.247 billion m³ respectively, all below average. Moreover, the average amount of surface water in the last 20 years has been 7.2 billion m³ while the average amount of water flowing out of Shanxi exceeds 4.8 billion m³ — 66 percent of the surface water gross.
2. The water supply structure is not equitable and the overexploitation of groundwater is severe. On average, Shanxi's annual gross water use is 6.5 billion m³; 60 percent is groundwater (4 billion m³) and 40 percent is surface water (2.5 billion m³). For the groundwater figure, 0.7 billion m³ is the result of overexploitation, which occurs in the five basins of Datong, Xinding, Taiyuan, Linfen and Yuncheng. The overexploited area covers 46 percent of Yuncheng Basin (230 million m³ of groundwater annually). Among 19 karst springs in Shanxi, three are dry, two are almost dry and 12 have a vastly impeded flow rate. In some areas, well depths have reached between 600 and 1 000 meters.

3. Water resources are degraded by coal mining. The coexistence of water and coal is a feature of the coal mines in Shanxi. Coal mining directly results in damage to aquifers, seepage of or pollution to groundwater. As surveyed in the Research on Coal Mining's Impact upon Water Resources, completed in 2002, the price of mining of coal/tonne was 2.48 m³ of water. On the assumption that 600 million tonnes of coal are mined every year in Shanxi, this would result in the loss or degradation of 1.5 billion m³ of water. For severe damage to aquifers caused by coal mining, seepage directly results in ground collapse, groundwater level recession and death of wells and springs.

The severe lack of water resources and the increasing gap between demand and supply have become a heavy burden on sustainable socio-economic development in Shanxi. How to alleviate this burden by harnessing technology and finding radical solutions to water loss, how to deal successfully with the water issue for the citizens of Shanxi and how to support sustainable socio-economic development through the sustainable use of water resources are all difficult issues currently.

Addressing the situation

The long history of water treatment in Shanxi can be traced back to the origins of irrigation and flood prevention in China. With thousands of years of practice, we have a wealth of experience and a series of effective solutions to water resource management. In the context of changes in socio-economic conditions, water resources can be managed by applying indigenous knowledge and modern technology.

In the fourth quarter of this year I joined leaders of related departments to investigate the status of water resource demand and supply, the construction of related infrastructure as well as the protection, development and economic use of water resources. We conclude that the water problem in Shanxi is attributable to both the natural environment and the impact of human activities, inadequate development of water conservancy schemes, weak economic structure and development modes and limited knowledge about the market economy. Therefore, we have developed ideas to enhance water conservancy infrastructure and resolve the problem of diminishing water resources. We will employ scientific knowledge for guidance and strive for harmonized development of the economy, society, environment and water conservancy. We will balance all concerned factors, address both symptoms and root causes and consolidate management. Further, we will establish policies, laws, mechanisms and institutions for the conservation, protection, development and optimized distribution of water resources. Lastly we will try to realize the sustainable use of water resources to safeguard sustainable socio-economic development through the use of available technology and the active participation of the public. The critical tasks will be:

- (i) *Continue the reform of investment and financing systems and expedite water-related projects according to open and market economy principles*

During the 11th Five-year Plan, we will try to strengthen water infrastructure. We will develop and utilize water from rainfall, small springs and rivers; we will strive to increase the supply of surface water by conserving, diverting, lifting, allocating and optimizing water resource distribution throughout the province to increase the utilization rate of surface water from 30 to 40 percent. Currently, the lack of reform in investment and financing systems is the primary reason for sluggish water conservancy, especially in the context of developing water infrastructure. From henceforth, we will develop a new vision for water conservancy that does not depend on national investment. We will encourage everyone to participate in water projects and adhere to the principles of the market economy. That is to say, financing shall be diversified through different levels and channels and enthusiasm among governments, enterprises, society and individuals shall be encouraged. Major water users shall be encouraged to construct WI and implement water supply projects. For the construction of large- and medium-scale water conservancy projects, all levels of governments shall invest seed funding and promote government investment opportunities to attract funding from major water users and other private or foreign sources. Stock companies shall be established and shall be operated and managed commercially. The reform of the ownership system for small water conservancy projects shall be deepened with new tenure modes to activate water assets and exploit project benefits.

(ii) Strictly control the exploitation of groundwater and continue to improve the natural water environment

The current mandate is to carry out strong measures to strictly control the exploitation of groundwater and to optimize the distribution of water resources. The primary measure is to strictly control the volume of groundwater exploitation and to increase the price of extracted groundwater when surface water supply is of good quality. During the 11th Five-year Plan, the general objective of Shanxi's groundwater control plan is to decrease the volume of exploited groundwater from 4 to 3 billion m³ (60 percent reduction in overexploited groundwater). By 2020 the amount of groundwater pumped and recharged will be balanced.

(iii) Advance the development of a water-saving society and promote water use efficiency and water resource benefits

A water-saving society is distinguished by a water resource management system that is based on water rights and the water market. Establishing a water-saving society in Shanxi will be implemented in two stages. The objective of the first stage is to have a main system, mechanisms and institutions in place by 2008; stage 2 will target a functional water-saving society by 2015. The primary measures will be: (1) Ensuring sufficient water supply for living; regulating and controlling water for industry; stabilizing water for agriculture; maintaining enough water for ecosystems; and establishing water resource plans for basins and regions; (2) Determining macrocontrol and microquota indices for water resources; fixing water use rights for all regions, industries, departments and units; determining scientific water use quotas for life, production and services; and clarifying initial water use rights; (3) Establishing water use computation and control systems and groundwater change monitoring systems for pumping wells and irrigation districts; (4) Ensuring the realization of a water use control index (integrating factors related to law, administration, engineering, the economy and science and technology); (5) Establishing a standard and legal water rights market and a system for water use rights transfer.

At the same time, to conserve natural resources in general, we will align the economy structure and transform the mode of economic growth. During the 11th Five-year Plan, we will try to limit the increase of water use within 10 percent throughout Shanxi Province, decrease water use per 10 000 yuan in the GDP from 155 to 100 m³ and enhance the recycling rate of industrial water to 85 percent.

(iv) Underscore irrigation and water conservancy for rural development

According to the central government and our provincial administration, promoting rural development and accomplishing a harmonized urban–rural relationship is the strategic thrust for the future development of Shanxi. Water conservancy infrastructure is essential for this achieving this goal. We will improve conditions for agricultural production with emphasis on water conservancy, improve comprehensive agricultural productivity and ensure domestic water supply and hygiene in rural areas. We will also take the following action:

Firstly, implement irrigation modernization rigorously. We will develop agricultural irrigation and disseminate the latest techniques. We will focus on the major food production areas of the province, continue water-saving projects in major irrigation areas (e.g. Fenhe, Xiaohe, Fenxi and Zuncun) and in medium-scale irrigation areas; we will increase the premium water-saving arable area to 800 000 ha and irrigated area to one million ha — a further 200 000 ha. We will also start work on the northern extension of the Jiamakou irrigated area and the Beizhao irrigated area as soon as possible (to increase the area of 66 667 ha of irrigated farmland), implement rainwater harvesting and utilization projects such as dry wells and herringbone gates in the eastern and western mountains to provide 30 million m³ of water supply and prepare 100 000 ha for extended irrigation in times of drought. By 2010, the irrigation water utilization coefficient of the whole province will be elevated from 0.46 to 0.56. By 2015, agricultural water utilization will be transmuted from the traditional crude irrigation system to modern water-saving technologies and high-efficiency irrigation. The modernization of agricultural irrigation will have been effected.

Secondly, the construction of a soil and water conservation warping dams will be undertaken vigorously. Constructing a warping dam in the soil- and water-deficient area of the Loess Plateau is a multipurpose and

effective measure to prevent siltation in rivers, to help farmers increase production and income, to promote the conversion of slopes from crop to forest land and to recharge groundwater. During the 11th Five-year Plan, Shanxi intends to build 10 000 warping dams; they can prevent the siltation of 1 500 million m³ of waterbodies, increase 26 667 ha of land, return 160 000 ha of sloping land to forests and realize 0.02 ha of furrow land per capita in loess hilly and mountain areas, even 0.03 ha in areas under better condition.

Thirdly, steadily improve the safety of drinking water in rural areas. In 2010 we will provide potable water for ten million rural inhabitants and supply tap water in every village. This will be done by vigorously developing a centralized water supply project and implementing a small water diversion project so the public can have hygienic and convenient water supply.

Fourthly, vigorously develop hydropower and the aquaculture industry. The “Small Hydropower for Firewood” (SHPFF) project in rural areas is an important feature of the 11th Five-year Plan. We will have 11 hydropowered counties or villages, 34 hydropower plants, 70 SHPFF projects, annual increase of 175 million kW and 340 000 SHPFF families. We will make every effort to develop aquaculture. At the end of the 11th Five-year Plan, we will attempt to produce 75 000 tonnes of aquatic products, establish 20 000 ha of aquaculture area and increase the yearly income of each fisher to 7 000 yuan.

To resolve the problem of water shortages in Shanxi requires great effort by the whole province and the support and help of the general public. There is also a need to strengthen multilateral communication and cooperation and collaboration with international organizations. Shanxi has maintained long-term and good cooperation with FAO in many aspects. In the 1990s, the “3932” project was a successful cooperation with regard to soil and water conservation and harnessing the resources of the Luliang mountain area. This International Forum on Water Resources Management and Irrigation Modernization in Shanxi lays a solid foundation for our latest venture.

OPENING ADDRESS

Victoria Sekitoleko

FAO Representative in China, DPR Korea and Mongolia

On behalf of FAO I warmly welcome you to this International Forum on Water Resources Management and Irrigation Modernization. I would like to express our appreciation to Shanxi Provincial Government for generously hosting and co-organizing this activity.

Water is the source of life. In many places worldwide, water is the most crucial determinant not only for food and animal production but also for human livelihoods. Water scarcity is one of the major constraints to socio-economic development in Shanxi Province. Many worthwhile practices have been piloted in Shanxi in the past years, especially high productivity irrigation, water conservancy projects and management improvement in large irrigation schemes, such as the Jiamakou Irrigation Scheme. With rapid economic development, increasing and migrating populations, agricultural and economic restructuring, water use is competing among different sectors, so multiple challenges exist and need to be addressed further.

Considering the large irrigation scale and intensive irrigation upgrading in China in the past and coming years, FAO has targeted China as its major work area for water resource management and irrigation modernization in this biennium. Recent cooperation includes training and capacity building on irrigation modernization with the Ministry of Water Resources and the Chinese National Committee on Irrigation and Drainage (CNCID) as well as introduction and testing of the Rapid Appraisal Procedure for Performance Evaluation of Irrigation Systems in Shanxi and Hubei Provinces.

The FAO Regional Office for Asia and Pacific has recently signed a Letter of Agreement with Shanxi Water Resources Development (SWRD) and CNCID on further cooperation for irrigation modernization and water environment study. We can assure you that FAO will further strengthen cooperation with Shanxi and other parts of China. FAO not only has the interest but also the technical capacity needed in this cooperation.

Recently, FAO has been developing a GEF regional project, covering Bangladesh and China, on the risks of using arsenic-contaminated groundwater for irrigation in crop production and subsequent hazards to food safety. Hopefully project implementation will be approved soon. We expect wide and active participation among various stakeholders.

The water problems faced by Shanxi are representative of North China and other arid and semi-arid areas in the region and the world. Options and solutions developed and practised in Shanxi will provide valuable references for relevant areas in other countries. FAO is willing to cooperate in this context with the Shanxi Government and institutions involved in the agenda.

Under FAO's South-South Cooperation programme, China has sent almost 700 specialists to other developing countries to assist with the implementation of the Special Programme for Food Security, in which water control is the first component. This May in Jakarta, FAO and China signed a strategic alliance to bring 3 000 Chinese experts and technicians to other developing countries. The strategic alliance has been once again confirmed during the participation of FAO's Director-General at the Beijing Summit on China-Africa Cooperation early this month. I hope Shanxi Province will continue to share its practical technical experience with other developing countries in the world.

To conclude, I would like to thank you all on behalf of FAO for participating at this forum. I also hope that your deliberations will be successful and I can assure you of FAO and FAO China's full support to further national socio-economic development.

KEYNOTE ADDRESS

Hu Siyi

Vice-Minister of the Ministry of Water Resources, China

Establishing a holistic water-saving society to promote the sustainable development of Shanxi Province

I am greatly honoured to be here today. On behalf of the Ministry of Water Resources of China, I'd like to offer my congratulations on the opening of this forum. Also, I would like to express sincere thanks to FAO and other related organizations, to specialists and scholars for your inputs with regard to water resource governance in China.

Water and food security is critical for the existence and development of human life worldwide. Most nations worldwide have mandates to ensure food production quotas and socio-economic development through the sustainable use of water resources. China has a huge population and scarce cultivated land per capita; moreover floods and droughts occur frequently. Promoting water benefits and mitigating water disasters is a major issue for stable governance in China. In recent years, according to the national development strategy, China has re-aligned water management concepts and policy and has made the transition from engineering-oriented water conservancy to resource-oriented water conservancy and from traditional water conservancy to water conservancy through sustainable development; the core theme being harmonized coexistence between humans and the environment. During the 11th Five-year Plan, we will develop our activities in five ways: (1) Adapt to water resource capacity and promote the establishment of a water-saving society; (2) address flood risks and make every effort to balance water use; (3) re-inforce the management of water zones and safeguard supplies according to the natural bearing capacity; (4) strengthen water conservancy in rural areas; (5) protect and maintain river health.

Shanxi Province is an important new energy and chemicals' base in China and will play a critical role in the strategy for national energy distribution and in the strategy for the central region of China. The central government and the provincial government have always paid considerable attention to water resource issues in Shanxi as elaborated hereunder.

1. The water resource issue in Shanxi with a strategic perspective on sustainable development

Shanxi has vast supplies of coal; its reserves, outputs and exports are ranked first in China. But Shanxi is an inland province and has comparatively lower precipitation; thus droughts are common and water resources are scant. The lack of water resources constrains socio-economic development.

In the long term, the Shanxi Provincial Committee of the Chinese Communist Party and the Shanxi Provincial People's Government have always paid considerable attention to water conservancy and made laudable contributions in the initial liberalization period. Shanxi has had many "firsts" in China: The first to carry out a provincial evaluation of water resources, the first to issue regulations on water resource management (to adopt integrated water resource management), the first to implement (contracted) family-based harnessing of small watersheds and the first to develop sand-thorn resources to conserve water and soil and to manage gorges and gullies in the Loess Plateau. The development of water conservancy in Shanxi has not only safeguarded and supported socio-economic development in Shanxi but also created many references for the development of national water conservancy and boosted the healthy development of national water conservancy.

In recent years, under the direction of the central government, the establishment of water conservancy in Shanxi has developed rapidly; however today it faces new questions and new challenges:

The accelerating depletion of water resources. According to the early results of integrated water resource planning survey, between 2000 and 1980, the runoff volume of rivers in Shanxi was reduced by 24 percent and average recharged groundwater volume was reduced by 12 percent. At the same time, the gap between the demand for and supply of water has been widening.

Serious ecological degradation. Increased seepage of polluted water, reduced natural runoff and the diminishing self-purification capacity of rivers has resulted in the chronic pollution of major rivers and a low percentage of quality water in functional areas. Coal mining has severely affected water resources, caused loss of water and soil, jeopardized the safety of drinking water, impacted on food and crop production and induced major economic losses in other sectors.

Unfair distribution of water resources. Groundwater has been heavily overexploited, while the great Water Diversion Project from the Yellow River to Shanxi Province has not exerted its expected effect.

Weak water conservancy infrastructure. Water conservancy engineering projects in the 1950s and 1960s ended with low standards and inadequate infrastructure. They were dated and worked at low efficiency. The construction of water conservancy infrastructure has not kept pace with other developments and agricultural production is not protected properly.

Slow water law legislation. The water issue needs to be administrated systematically and obstacles in institutions and mechanisms need to be removed.

Thus it is necessary to consider water resource issues in Shanxi strategically. The relationship between economic development and water use, development and protection and supporting and safeguarding sustainable socio-economic development through the sustainable use of water resources need to be addressed.

2. Innovating development modes and constructing a holistic water-saving society

The only solution for Shanxi's water shortage problems is the development of a holistic water-saving society juxtaposed by harmony in the human–water–technology nexus.

(i) Conform to the bearing capacity of water resources and the environment and coordinate economic development and water resource distribution

The bearing capacity of water resources and ecology in a particular area is limited in the context of socio-economic development. Once the threshold is breached, water resources and ecology will degrade and development will become unsustainable. When water resources in Shanxi are used to satisfy socio-economic development, the economy needs to adjust its development mode to adapt to the natural bearing capacity. First, socio-economic development objectives will be determined and fair distribution among main industries will be made. A strict industry entry policy will be stipulated to prohibit industries with high water consumption, low efficiency and heavy pollution; it will support high efficiency and environmentally friendly industries and develop a recycling economy. Second, traditional industries will be upgraded by introducing water-saving technology to increase water-use efficiency and productivity. Third, water resource plans will integrate socio-economic water demands and scale water demands in different sectors scientifically to reserve water for future development and for the environment.

(ii) Make every effort to develop an institutional system for a water-saving society

Problems regarding incentives and water-saving mechanisms will be resolved institutionally for the establishment of a water-saving society. Water management institutions, based on theories related to water ownership and the water market will be consolidated to shape the water-saving society according to financial principles. A water control index will be initiated based on water basin resource planning and initial water distribution. Index systems for total macrocontrol of water resources and microquota management will be established for an explicit water resource use index of different areas, industries, units, businesses and irrigation schemes to realize regional development and accommodate natural bearing capacity. Instruments relating to law, engineering, economy, administration and science will be implemented comprehensively to govern the

water control index. Economic instruments will receive greater attention. Heavy water use will be priced more highly, while saving will be rewarded and transfer compensated. Water users will participate in management and water users' associations (WUAs) will be established and promoted. The public will be encouraged to participate in the distribution, management and supervision of water rights, water volume and water pricing. A water rights' market will be initiated. Water rights can be transferred with compensation and the market will serve as an instrument for resource distribution.

(iii) Develop water resources fairly and optimize water resource distribution

It will be mandatory to use water in an optimal and sustainable way and to distribute water resources fairly. Groundwater shall be used for domestic purposes; other water sources and recycled water will be used mainly for industry and agriculture. Water distribution will be strictly managed. Paying careful attention to natural bearing capacity, the level of industrial water consumption and the level of environmental protection in Shanxi, a water resource distribution policy and a water use quota standard will be established to encourage, restrain or prohibit the development of different industries. These tools will also support and encourage the development of high efficiency industries that conserve water and are environmentally friendly. A water distribution project will be effected soon. Based on integrated river basin planning and water allocation plans or protocols, surface water distribution projects will be initiated in appropriate areas. We will build small water conservancy projects (e.g. rainwater conservancy in mountain areas), develop various water resources and assist water-deficient areas.

(iv) Safeguard drinking water and the environment; strengthen water resource protection

The first thrust will be to safeguard potable water for the general public and ensure clean drinking water supply. In rural areas, this will be done by implementing potable water safety projects in rural areas. The next agenda item will be to strengthen groundwater protection. Prohibited and restricted areas for groundwater pumping will be determined soon. We will institute strict groundwater protection policies, raise the water-pricing standards and ensure the sustainable use of groundwater. Lastly in this context, we will strengthen water resource protection. Environmental impacts will be considered when developing and utilizing water flowing from Shanxi. The relationship between the upper reaches and the lower reaches as well as that between left and right banks will also be addressed. We will re-inforce the management of rivers and reservoirs, enhance water pollution prevention, invigorate sewage treatment and recycling, improve the water environment, protect drinking water sources and intensify potable water safety in urban and rural areas.

(v) Establish and fine-tune the systems and mechanisms for establishing a water-saving society

There is a need to upgrade water resource management regulations and intensify water management by law. Pursuant to national water laws, we will accelerate the revision of local water rules and regulations that are in effect; institute the strictest water resource management system; specify the objectives of water resource management, conservancy and protection, as well as management responsibilities and measures; implement a governmental management target and responsibility system; and strengthen governmental macrocontrol of the resource. We will also promote the construction of infrastructure to resolve disputes related to water resources, water intake permission, water metering, monitoring and surveillance with the ultimate aim of improving water resource management. We will vigorously carry out consolidated management of water resources, refer to foreign experience, reform the water management system and integrate water resource administrative functions. We will establish a long-term mechanism for investment in constructing a water-saving society. We will make the fullest use of relevant policies concerning prosperity in China's central area, increase local investment in water conservancy and establish an eco-environmental compensation system (e.g. a compensation system for coal mining's destructive effect on water resources), institute preferential policies and develop capital investment.

The new Shanxi Provincial Committee and the Shanxi Provincial Government attach great importance to the water resource issue. This year the Shanxi Provincial Government organized a special investigation on water resources. During the 11th Five-year Plan, the Ministry of Water Resources will continue to support water conservancy in Shanxi, implement plans such as sustainable utilization of water resources in the capital and try to advance sustainable socio-economic development in the basin and the sustainable utilization of water resources.

KEYNOTE ADDRESS

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Key trends affecting irrigated agriculture and policy options¹

1. World irrigation in perspective

1.1 Trends in modern irrigation development

In the last few decades, the rate of investment in irrigation has closely followed food prices (Figure 1), with a lapse of a few years corresponding to planning and construction periods. After the Second World War, the rate of investment growth in irrigation increased rapidly and peaked just after the 1974 oil crisis. As a response to increased prices of staple foodgrains and fears of food shortages, many governments felt the need to seek national self-sufficiency.

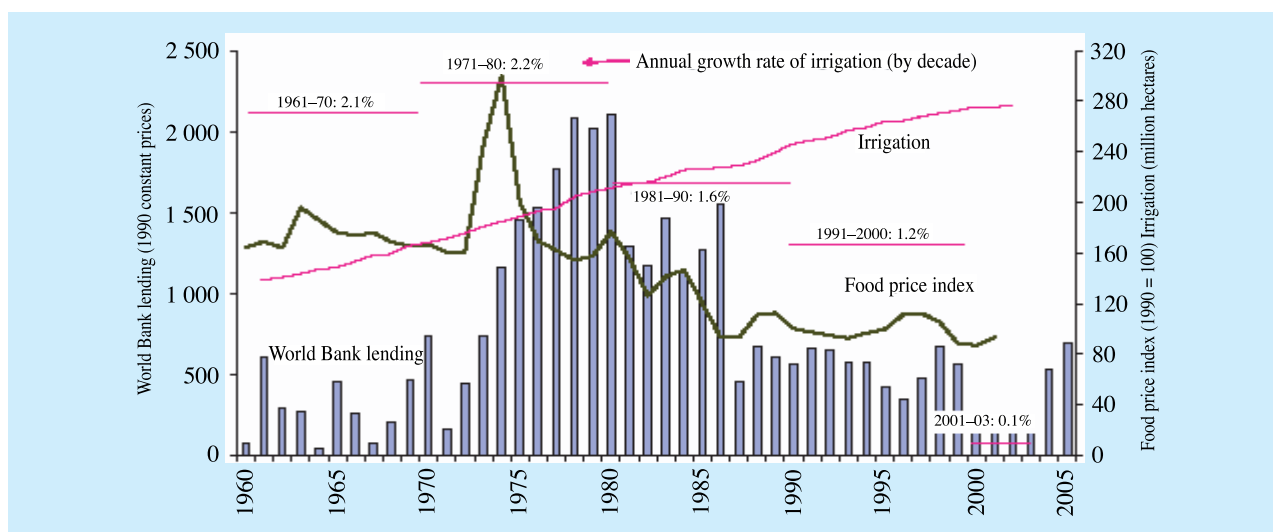


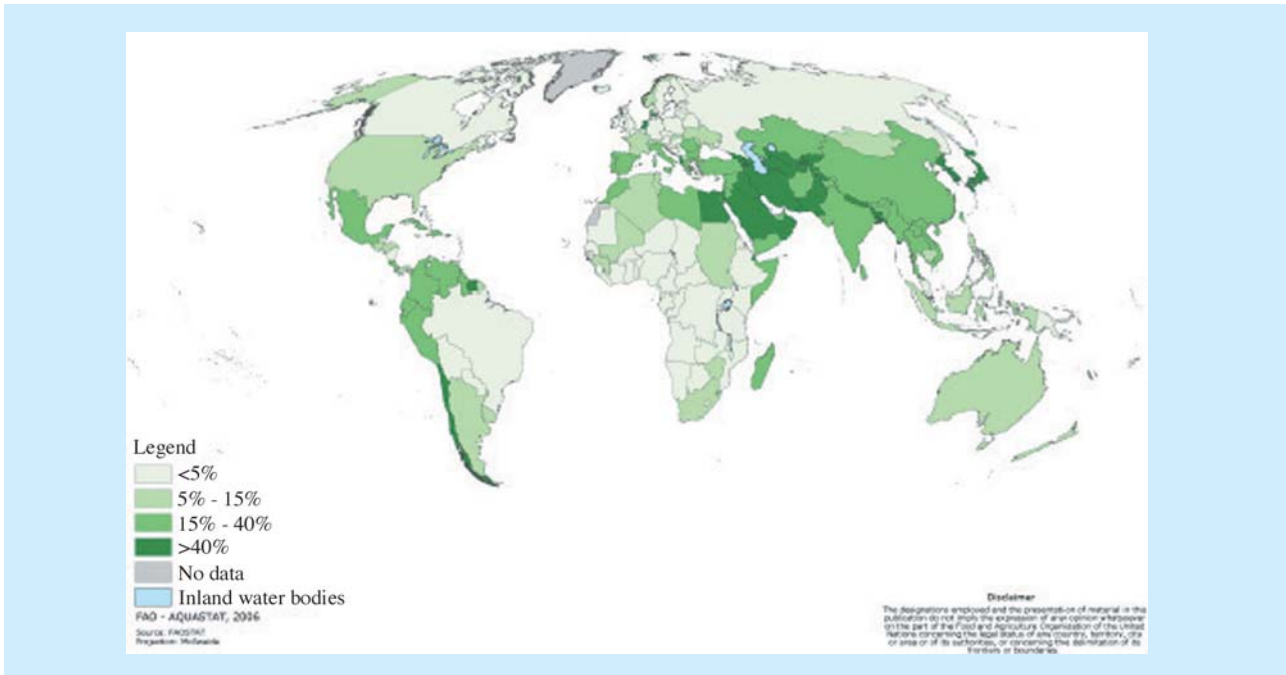
Figure 1. World Bank lending (bars) for irrigation and drainage and world food prices (line) (of 1990 constant US\$)

The volumes of water used for irrigation consequently increased, making irrigation by far the main water use sector, both in terms of freshwater appropriation and consumption. Irrigation growth rates have decreased since then, following a progressive reduction in the price of most staple food commodities. Asia has over 60 percent of the world's irrigation area and it plays a particularly crucial role in sustaining agriculture across the "dry belt" that extends from the Middle East to Northern China and Central America (Map 1).

1.2 Technological development

Technological developments of the last 50 years for system management include automated and downstream water control mechanisms, laser land levelling, telemetry systems for water measurement and control, pressurized distribution networks and information and data management systems. Over the last two decades,

¹ This paper relies extensively on work made in preparation for the irrigation chapter of the *comprehensive assessment of water management in agriculture* by Jean-Marc Faurès, Mark Svendsen and Hugh Turrall. The Comprehensive Assessment is a five-year multistakeholder assessment process aimed at guiding investments in water management in agriculture in the forthcoming decades. More information can be found at <http://www.iwmi.cgiar.org/Assessment/index.htm>



Map 1. Irrigation in percentage of cultivated area (2003)

advances in theory and technology have allowed much more precise determination of crop water needs and irrigation schedules. However, the application of both system management technologies and improved crop water requirement calculation methodologies remains limited in developing countries that are hampered by low managerial capacities and correspondingly poor responses in capacity building, a systematic underestimation of maintenance requirements and inflexible and unresponsive irrigation infrastructure.

The advent of affordable drilling and pumping technologies in countries like India and Pakistan in the mid-1980s changed the nature of irrigation investment, leading to the rapid development of shallow tubewells and conjunctive use of surface and groundwater. The direct control of the source of water by farmers, either through groundwater pumping, drainage re-use, or direct pumping from canals and rivers, brought the flexibility and reliability in water delivery that farmers did not get from most large-scale surface distribution systems. It also brought new challenges related to management of irrigation schemes under conjunctive use, falling groundwater tables and massive public subsidies through cheap or free electricity from public distribution systems.

1.3 Current state of irrigation in the world

The term “irrigation system” covers a diversity of situations associated with a variety of crops, leading to multiple development and management strategies. There are fundamental differences between public and privately managed schemes, between cash crop and foodgrain production and between the humid tropics and arid areas. Irrigation plays different roles in different climatic contexts, supplying full, partial, or supplementary irrigation. To organize the discussion here, a simplified typology with five categories of irrigation systems is used, based principally on mode of governance (Table 1).

Table 1. Typology of irrigation systems

1.	Large-scale public irrigation systems in dry areas, growing mostly staple crops.
2.	Large-scale public paddy irrigation systems in humid areas.
3.	Small- to medium-scale community-managed (and -built) systems.
4.	Commercial privately managed systems, producing for local and export markets.
5.	Farm-scale individually managed systems, producing for local markets, often around cities.

Large-scale public irrigation systems in dry areas are mostly run by public management agencies and for the last ten to fifteen years have been the focus of irrigation management transfer programmes. In these schemes, water service is usually inadequate and inflexible and inequities between head and tail ends of the schemes are marked. In response to poor service, farmers typically seek to improve the reliability of supply through water theft, pumping from drains or use of shallow groundwater in conjunction with canal water. These schemes were built to provide many people with either full or partial irrigation to stabilize and augment staple foodgrain production and were usually not expected to pay their own operating expenses. Today, they face the challenge of economic and financial viability, and of the technical and managerial upgrading that would allow them to respond to the new needs of their farmers.

The analysis of irrigation systems and implication in political terms must also take into account the economic environment. This typology is thus further refined by defining three stages of economic development of a particular region or country:

Stage 1: Countries or regions within countries where agriculture accounts for a substantial share of the economy and employs a large proportion of the population (including most of sub-Saharan Africa; Diao *et al.* 2005).

Stage 2: Countries or regions in transition to more market-based and industrial economies where the relative importance of agriculture is falling in economic terms but where most of the population still derives its livelihood from it (including most of Southeast Asia and the Middle East).

Stage 3: Countries or regions where agriculture contributes only a small share of the economy and further large-scale investment is unlikely (Republic of Korea and Malaysia).

The farming sector in these countries may follow divergent paths: From a competitive international market orientation (such as Australia or Brazil) to redefining the role of farmers as “guardians of the landscape,” as in Europe, Japan and Republic of Korea (Hung and Shih 1994). In large countries all of these outcomes can occur and national policies must account for regional specificities.

Evolution within and between categories of irrigation farmers are shaped not only by agricultural policies but also by the capacity to ensure allocations of water in all three stages, by wider financial restrictions and by local capacity to overcome pollution and environmental damage in countries moving through stages 2 and 3.

1.4 Evolution of public irrigation

While most major changes affecting public irrigation are progressive, the end of the Cold War and acceleration of globalization have certainly intensified some of these trends. Table 2 presents the main changes affecting public irrigation systems.

2. Directions for future investments in irrigation

Investment decisions in irrigation, whether for new development or for improvement in irrigation management have long-term implications. On the other hand, rapid changes affect the world’s economy and have profound implications for agriculture. It is important to understand the drivers of change in irrigation and value the multiple roles, benefits and costs of irrigation in the future.

Irrigation will remain a critical element in the world food system. Irrigated agriculture will continue to expand, but at a significantly slower pace than during the past half century. New investments in irrigation will be required, and will certainly be made, but they will be made more democratically and will be more site-specific, more market-oriented and more closely linked with policies and plans in other sectors. The decision environment in which irrigation investments will be made is far more complex than in the past — more stakeholders, more expressed competing demands, less water to go around and the lack of a single overwhelming motive for investment, i.e. food security. Irrigation investments must thus be much more carefully tailored to particular circumstances, circumstances reflecting stages of national development, the degree of integration into the world economy, land and water resource availability, the importance of agriculture in the national economy and comparative advantage in regional and world markets.

Table 2. Evolution of public irrigation since the 1960s

	1960s to 1980s	1990s to present
Goals: drivers	Food security	Livelihood, income
Resources: land, water, and labour	Abundant	Increased scarcity
Hydraulic development stages	Construction, utilization	Utilization, allocation
Dominant expertise	Hydraulic engineering, agronomy	Multidisciplinary, sociology, economics
Irrigation governance	Public	Mixed
Irrigation technology	Surface	Conjunctive use, pressurized
System management	Supply-driven	Farmer-oriented
Crops	Fixed, cereals and cotton	Diversified
Cropping intensity	1-1.5	1.5-2.5
Value of water	Low	Increasing
Concern for environment	Low	Increasing

Source: Adapted from Barker and Molle 2004.

2.1 Drivers of change for the irrigation sector

Globalization (opening of markets and information) will continue over the long term even if there are repeated setbacks of substantial duration (say five to ten years). Commercial and high value agriculture will increasingly take advantage of globalization, but countries may also tend to intervene increasingly to protect their rural populations who subsist on basic food production, justifying this by the increasing importance of indirect roles of agriculture (i.e. agriculture is a “special case” in global economy). The historical spectre of famine in Asia will maintain a high political priority for food self-sufficiency. Financial interventions by developed countries in agriculture may be reduced, under pressure from emerging countries. Nevertheless, the predominant trend is for continually decreasing prices of all commodities (Figure 2) and even high value crops. World commodity prices have declined for 500 years in real terms, and it has been calculated that across the board removal of OECD subsidies and tariffs would result in a one-step rise in real prices of about 15 percent, after which the trend of falling prices would continue.

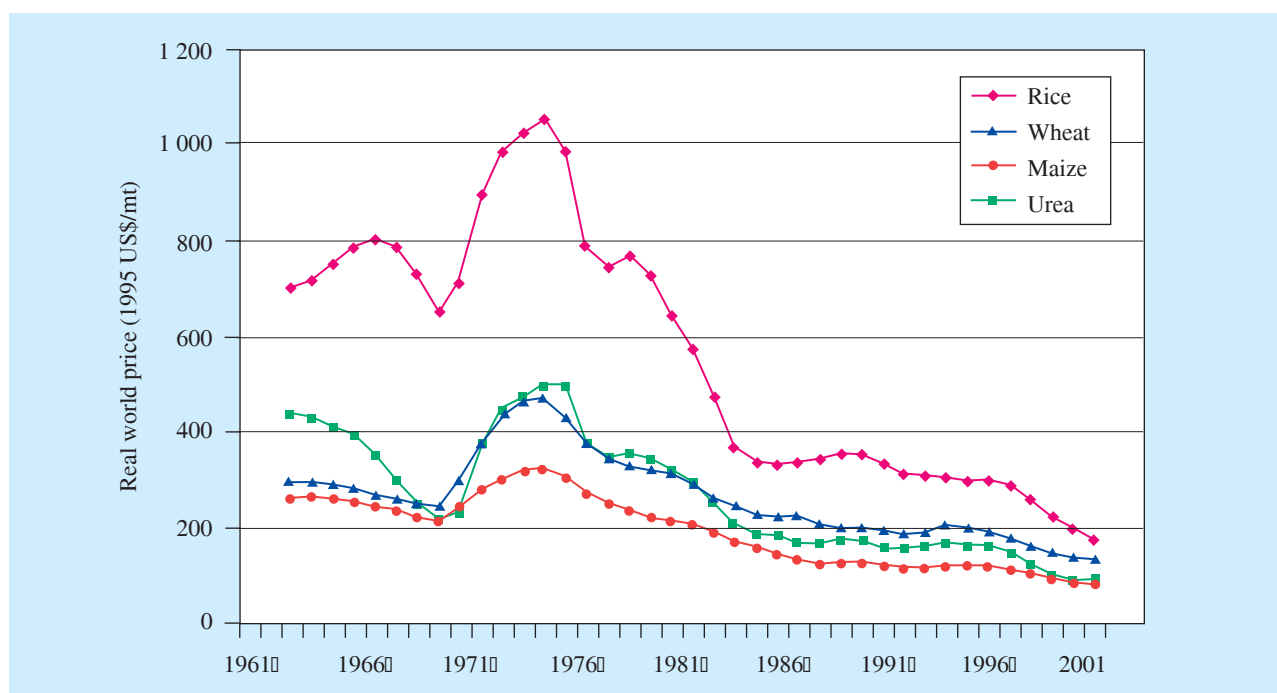


Figure 2. World price for rice, wheat, maize and urea (Barker and Molle 2005)

Population and its changing diet preferences determine the demand for food and fibre and will therefore be the primary driver for irrigated agriculture, both for staple crops, feed crops and others. UN population projections are continually revised and illustrate the difficulties in assessing global population increase. However, there is agreement that population growth is decreasing and that population should stabilize at approximately ten billion around 2075 (Figure 3). Demand will continue to rise initially, but subsequently, demand for food crops will stabilize (we are already producing 2 800 kcal per person per day, enough to feed the world.).

There are major regional differences, and some countries, such as India, Pakistan and Islamic Republic of Iran will still face rapid population increases in the near term, placing increasing local and regional burdens on natural resources.

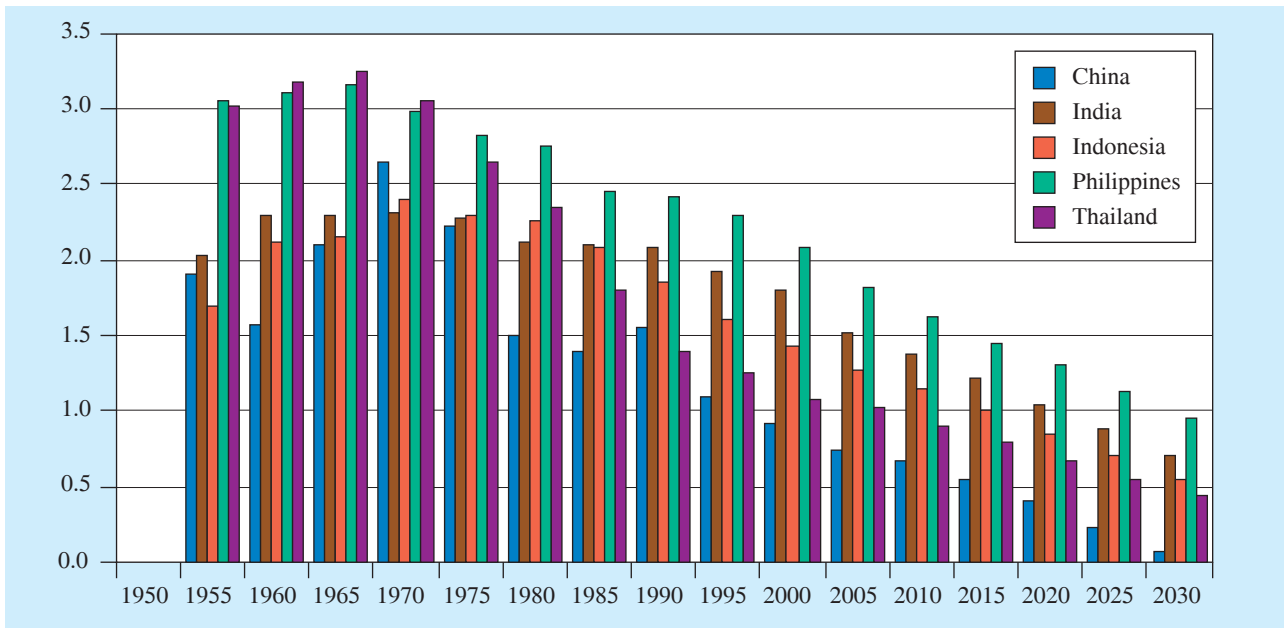


Figure 3. Evolution of population growth rates 1950-2030 (percentage p.a.; Source: UN)

The agriculture sector’s contribution to GDP will continue to decrease as countries’ economies grow (Figure 4). There will be increasing pressure to internalize the true costs of agricultural production. However, there will be more widespread diversification into fuel crops to produce ethanol and diesel fuel substitutes, which are already becoming competitive with petrochemical products. The extent and value of this market is hard to predict, but it will provide more opportunities to generate incomes for farmers and at the same time introduce more competition for land to be sown to food crops.

Urbanization is expected to continue its current trend (2006 marks the historic passage from a rural world to an urban society), and it is expected that the urban population will reach six billion in 2075 (Figure 5). This implies an increasingly looser linkage between food production and food security, more transportation and the rising role of commercial chains, including supermarkets. Peri-urban agriculture will become increasingly important. Already only 17 percent of the global population lives outside the reach of supermarkets and their role as an intermediary will become more important in terms of quality, environmental standards and market access. This offers new opportunities to irrigated farming that is well connected to markets.

Labour demand in other sectors has raised both wages and expectations so mechanization is becoming increasingly important in Asia and Latin America, for both land preparation and harvesting. There will be increasing pressure to adopt labour-saving practices and this in turn will fuel further mechanization and reduced demand for labour. This cycle has profound implications for rural poverty, especially for the landless who have in the past relied on irrigation to generate employment (for example in Punjab and Haryana in India). The rate at which other sectors of the economy will be able to absorb excess labour from agriculture will vary from one country to another.

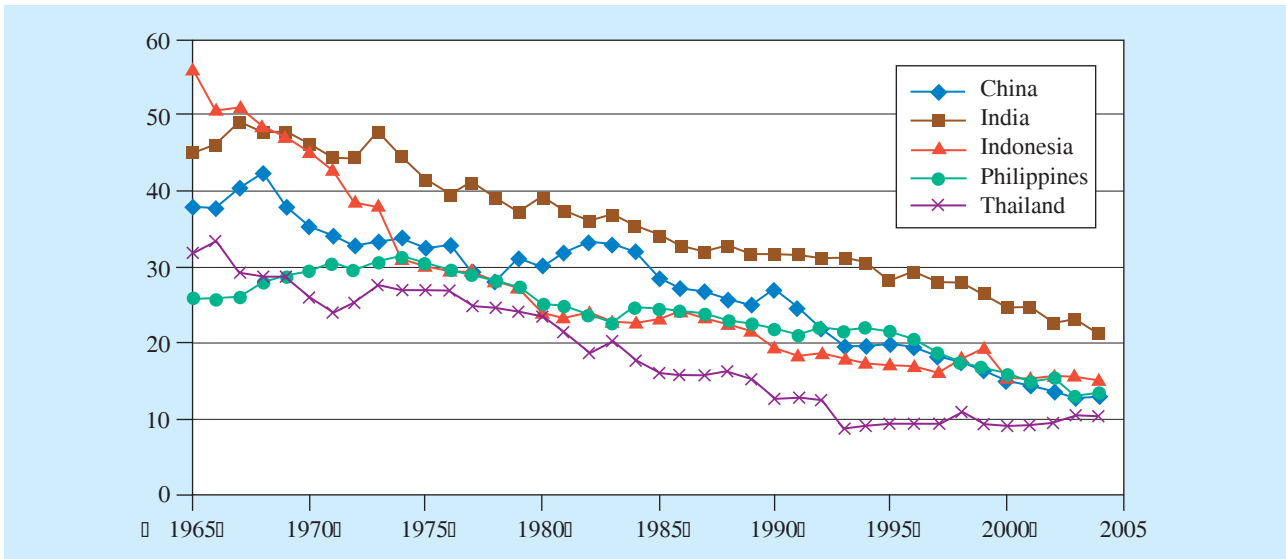


Figure 4. Agriculture in percentage of GDP for different countries (1965-2004). (World Bank, 2005)

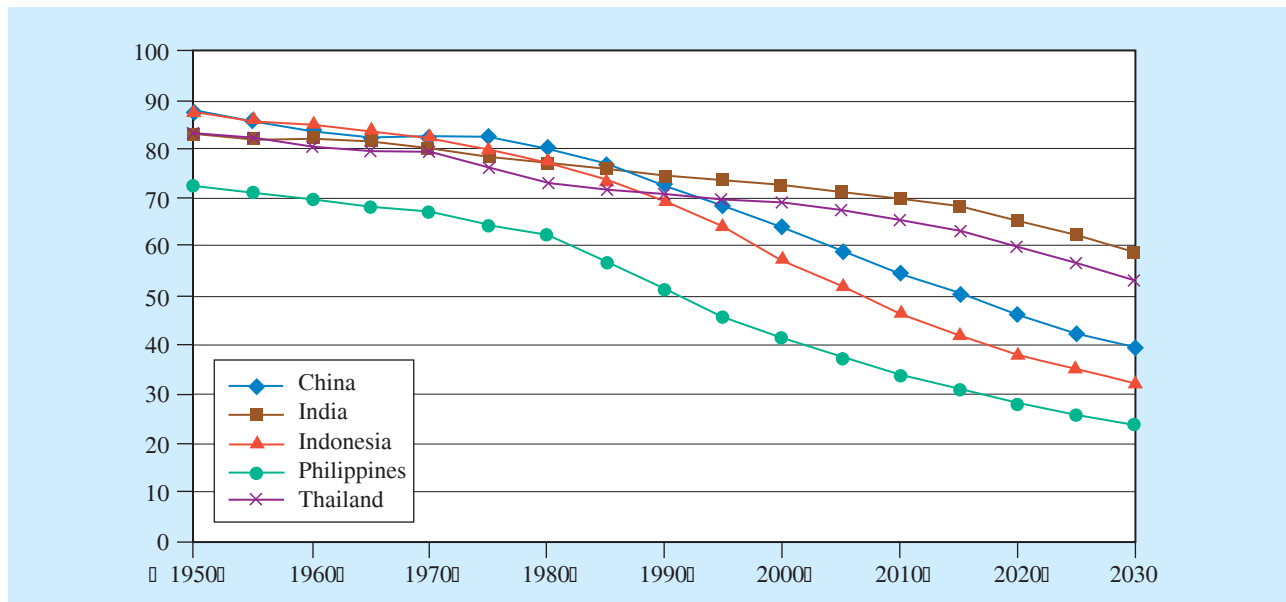


Figure 5. Rural population in percentage of total population 1950-2030

Rural landscapes of the future will be determined by many factors. The rate of rural outmigration is mostly a result of the perceived urban–rural differential in living conditions and employment opportunities. The extent to which rates of rural migration can or should be reduced is a function of livelihood opportunities in rural areas, but it is also related to globalization and overall changes in productivity in agriculture worldwide. The consequences of urban migration, changing aspirations among the young and the ageing of populations (as growth rates decline) will have important effects on the remaining rural farming population.

Many outcomes are possible, but it is expected that the active rural farming population will decline in size, farms will increase in size and the income derived by those left in farming will increase. Most developing countries in Asia will face the transition problem now being tackled in China, where there will be constant tension between “industrial and service” opportunities and the pool of unskilled and semi-skilled rural labour for the next 20 years. The net trend in farm employment will follow that of agriculture in industrialized countries due to economic pressure and a quest for a better quality of life.

Agricultural productivity is expected to continue to grow for most crops, although at slower rates than from 1950 to 2000. Combined with reduced population growth, it will continue to contribute to reductions in farmgate prices of major agricultural commodities, putting more farmers out of business and further encouraging migration to cities. Commercial and high value agriculture will become increasingly important in irrigated areas, subject to the security and flexibility of water supply. More commercial and high value agriculture will provide new opportunities but the intensification they imply may present an increasing challenge for health and the environment. However, it is reasonable to expect that the quality of farm management, farmer education and the adoption of more environmentally sound practices such as integrated pest management (IPM) will counteract or even negate this possibility.

Biotechnologies are expected to have an important impact on agriculture, boosting yields and reducing the need for pesticides, but such improvement has so far concentrated on a few crops that are controlled by the private sector. Fears that genetically modified organisms (GMOs) will only be available via the private sector and impose higher costs on poor farmers may be allayed by state-sponsored development of yield- and nutrition-enhancing varieties in countries such as China and India: Locally developed Bt cotton in China is already making a major impact. The impacts on farmers in developing countries will be mixed, depending on their capacity to access these technologies.

Technologies for water control are not expected to develop much further and the rate of adoption of existing irrigation technologies will depend much more on farming conditions than on their availability. There are plenty of existing technologies available that are awaiting favourable conditions to become widespread in irrigation.

Competition for resources (land, water, energy and finance) will always be at the expense of agriculture in developing countries. Increased competition over water will put increasing strain on irrigation and in most cases will reduce the volumes of water allocated to agriculture. Cities and industries at the global scale will impose relatively small stresses on water supply for agriculture, but it will be important locally around cities and may even change the location of irrigated agriculture (from upstream to downstream of large conurbations) and increase the areas of (untreated) wastewater use. Environmental allocation will have a much greater impact on agriculture, as it is generally a consumptive use, and it will become larger as public awareness increases and better valuation techniques are developed. Investments in new hydraulic infrastructure (water control, storage and transfer) will still take place where the potential exists but under much more scrutiny over possible environmental impacts.

Climate change is expected to have significant impacts on agriculture and food production patterns over the next century. Effects will be manifested through spatial, temporal and magnitude changes in daily and seasonal temperature ranges and precipitation patterns. The impacts on crop yields will vary considerably across regions and among species. While yields may rise in some cases, interannual variation in yields may also increase. Dry continental areas, such as central Asia and the Sahel, are expected to experience drier and hotter climates, while longer growing seasons and increased rains may boost productivity in temperate regions. Shifts in diurnal temperature ranges have been shown to decrease yields; an International Rice Research Institute (IRRI) study indicates decreased rice yields from increased night-time temperature (Peng *et al.* 2004). Higher temperatures will also influence production patterns, shifting production ranges of specific crops towards the poles. A similar expansion of the range of pests increases the risk of crop losses.

In drought-prone areas, the number and duration of dry spells are expected to increase, affecting crop production. Those who are the most vulnerable to climate variability and change are the poor, landless and marginal farmers in rural areas dependent on isolated rain-fed agricultural systems in semi-arid and arid regions. Many of these vulnerable populations live in sub-Saharan Africa, Asia, tropical areas of Latin America and some Pacific island countries. The Intergovernmental Panel on Climate Change (IPCC) finds that the greatest adverse impacts are expected on areas where resource endowments are poorest and the ability of farmers to respond and adapt is most limited. Thus, changes in production and management activities will be important measures for mitigating climate change impacts.

2.2 Projections for the future expansion of irrigation

Farmers around the world will continue to integrate into a global market that will increasingly dictate their choices and behaviour. While irrigated grain production will remain important, a variety of niche markets will emerge, creating opportunities for innovative entrepreneurial farmers where suitable national policies are in place.

Projections of developing country irrigation expansion predict much lower rates of expansion of irrigated land over the next twenty to thirty years. FAO (2003) predicts an average increase of 0.6 percent per year between 1997/1999 and 2030 in developing countries, substantially lower than the 1.6 percent per year from 1960 to 1990. Such projections are systematically lower than those given by most national irrigation departments, which generally rely more on past trends than on a careful analysis of demand for agricultural outputs. Nevertheless, irrigation's contribution to total agricultural production is expected to exceed 45 percent by 2030 as yields continue to increase and cropping patterns shift to higher value crops (FAO 2003). This means 12 to 17 percent more water will be withdrawn for irrigation.

Countries with a legacy of ageing irrigation infrastructure will need to invest more in technical and managerial upgrading and less in new development, progressively improving the performance of irrigation in response to growing demand for more reliable water service. Investment in drainage will continue at relatively modest levels, although regional waterlogging and salinization problems resulting from past development will continue to require remediation. Thus there will be considerable tension arising from these financial needs compared with government willingness and ability to finance them.

2.3 Rationale for future investments in irrigation

There are five principal reasons to invest in irrigation over the next three to five decades. First is to preserve and modernize the present stock of irrigation infrastructure. Continuing investment will be required to preserve the safety and improve the functionality of existing irrigation. Different elements have different lifetimes. Large dams may last hundreds of years with proper maintenance and attention to safety (unless rapid siltation reduces their lifespan), while pumps and other equipment may last only a decade.

Second, irrigation can be a path out of poverty for the rural poor. Where pockets of rural poverty exist within an irrigated agricultural context, intensification and shifts to higher value crops will create new employment opportunities, as will value-added postharvest processing and water-dependent off-farm rural employment in handicrafts, livestock raising, and similar activities (Bakker *et al.* 1999). Where rural poverty is widespread, other employment options are absent and climate variability impacts production; soil moisture control, along with complementary investments in rural infrastructure (such as roads and stronger local institutions) provide new farming opportunities. However, the extent to which irrigation contributes to poverty alleviation remains a contentious issue, with alternative vigorous arguments about ways to address rural poverty (Lipton *et al.* 2003; Bhattarai and Narayanamoorthy 2003; Berkoff 2003).

Third, adapting to changing food preferences and changing social priorities. Most of the increased production of staple crops in the coming decades will come from intensification in existing irrigated areas, with higher yields per unit of water and land and higher cropping intensities. This implies investment in modernizing equipment and in improved water control. Irrigated basic foodgrain production will remain a priority in some countries. Rising incomes and growing urbanization in many developing countries are shifting demand from staple crops to fruits, vegetables, and "luxury" goods such as wine, as in China, for example (Figure 6). These shifts are typically associated with investment in supply reliability and precision water application, but — more important for farmers — they also raise yields and improve product quality. Other shifts, such as increased meat and milk demand, also require increased grain production. Increased global trade also opens developed country markets to these commodities. Notably, these production shifts also require major investment in the entire postharvest marketing chain.

Fourth, rapidly expanding urban populations and industrialization increase demand for both surface water and groundwater (Molle and Berkoff 2006). Changing social values that emphasize natural ecosystem protection will increase water allocations to the environment. In many cases these competing uses will take

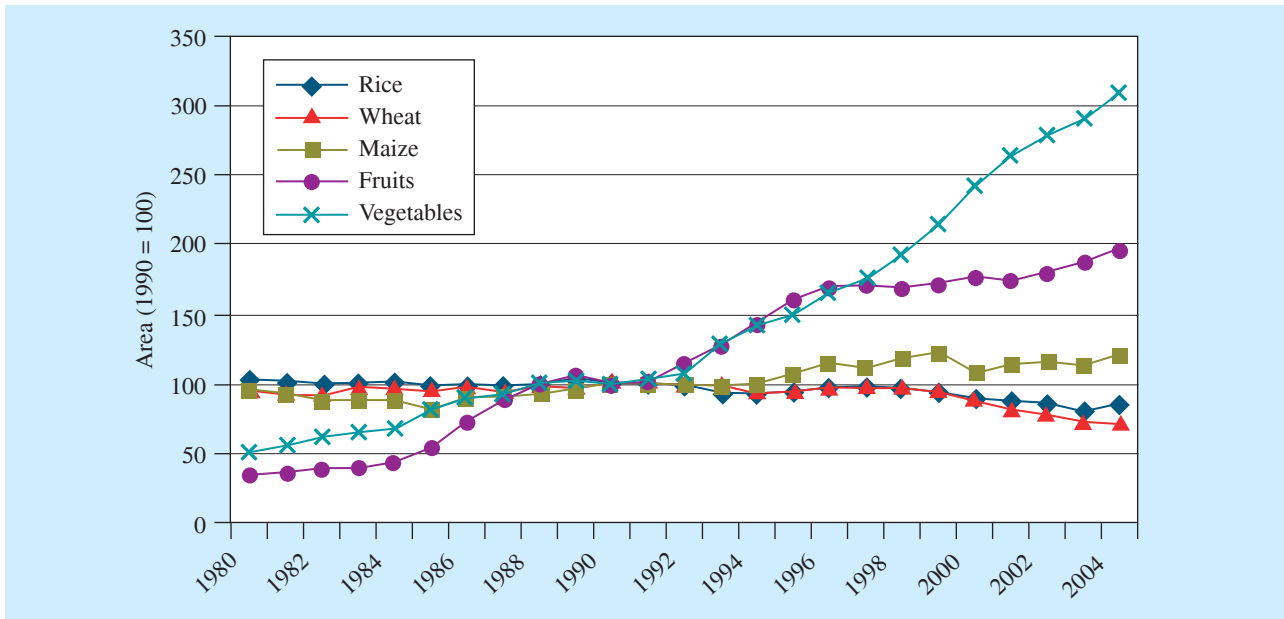


Figure 6. Evolution of harvested area for major crop groups in China, 1980-2004

water directly away from agriculture, requiring compensating investment in new supplies or increased water productivity. Re-using urban and industrial wastewater in agriculture will require new investment in water treatment and conveyance.

Fifth, investment will probably be needed to respond to climate change. Predictions by global climate models are gradually converging, and several characteristics now seem clear (IPCC 2001) weather patterns will become more variable and will include more extreme events. The assured supply of water will decline and the need for additional storage, above or below ground, will increase to compensate. Rainfall distribution and volumes will change, and investment in groundwater and surface storage will be required in response. Table 3 presents the focus for future investments in irrigation by type of irrigation system.

3. Prospects for future irrigation governance

With the general decline in construction of new systems and the increasing shift of management responsibilities to users, the role of public irrigation agencies is rapidly changing. Activities involving planning and designing systems, contracting for and supervising civil works and delivering water to farms will be less important than in the past. New responsibilities will include resource allocation, bulk water delivery, basin-level management, sector regulation and the achievement of global social and environmental goals such as the Millennium Development Goals.

3.1 Irrigation management

Poor management of irrigation systems has been mentioned repeatedly over the past 30 years as a prime cause of poor system performance and improved management is widely expected to boost performance. Initial attempts at management reform of public management agencies in the 1970s and 1980s through intensive training generally failed. Reformers realized that changes in governance were necessary, concomitant to management changes; in the 1990s such dual reforms were introduced in Mexico, Turkey and elsewhere. Evolution along this path will continue with incremental positive impacts. The main conditions of success and reasons for failure of irrigation governance reforms are summarized in Table 4.

Different types of systems have different needs for management reform. Community-managed, private and individual schemes, in general, are managed effectively. It is the large public agency-managed scheme that will change most radically. The level and complexity of system management must correspond to the intended purpose of the system. There is no point in providing highly sophisticated on-demand systems if lower levels

Table 3. Focus for investment by type of irrigation system

System type	Category	Agricultural economy, large rural population	Transition	Industrial, market-based economy
Large-scale public irrigation systems in dry and humid areas	Policy focus	Integrated rural development	Linking water and agriculture policies	Implementing IWRM approach
	Capital investment, water	Small and large dams, gravity irrigation development, drainage development, on-farm groundwater development		Upgrading irrigation and drainage infrastructure
	Capital investment, other	Rural infrastructure, roads, markets, social and health infrastructure, electrification		Upgrading rural infrastructure
	Regulation	Land tenure and water rights, stakeholder involvement in scheme management	Water rights, local institutions regulations, participatory irrigation management	Irrigation management transfer
	Management	Increased reliability in system operation	Restructuring, improved accountability and transparency, improved system control and operation, enhanced flexibility of water service, enhancing system multifunctionality	
	Capacity building	Training irrigation staff and farmers, water user association formation and strengthening		Strengthening of professional organizations, market information systems
	Finance	Term finance, rural credit and micro-credit, grants	Term finance, agricultural savings and loans	Commercial financing
	Technology	Land leveling, shallow wells, small-scale pumping technology, conjunctive use of surface water and groundwater		Automation, pressurized irrigation systems, water quality monitoring
Small- to medium-scale community-managed systems	Policy focus	Integrated rural development	Linking water and agriculture policies	
	Capital investment, water	Runoff river, weirs, diversion, local storage and small dams	Local storage and small dams, improved water distribution infrastructure	
	Capital investment, other	Rural infrastructure, roads, market access and information, social and health infrastructure, electrification		
	Regulation	Water rights, including traditional water rights	Recognition and formalization of water rights and bulk water allocation	
	Management	Conflict management, on-farm water management		
	Capacity building	Training of extension staff, water user association formation and empowerment	Water user association monitoring and support, staff training	
	Finance	Grants; targeted subsidies	Rural finance	
	Technology	Small-scale micro-irrigation systems, tanks	Mechanized agriculture, deep tubewell drilling, pressurized irrigation systems	
Commercial privately managed systems	Policy focus	Market chain; Negotiating favourable trade policies		
	Capital investment, water	Diversion dams, deep tubewells	Runoff recycling, automation of water supply	Automation
	Capital investment, other	Markets, communication and storage infrastructure, including for export		
	Regulation	Bulk water allocation, water rights, tariffs		
	Management	Irrigation scheduling, soil moisture monitoring		
	Capacity building	Water quality monitoring		
	Finance	Commercial finance		
	Technology	Overhead irrigation, sprinkler and micro-irrigation technologies	Precision farming, pivots, lateral moves, micro-irrigation, fertigation	
Farm-scale individually managed systems for local markets	Policy focus	Food safety, food security and nutrition policies		
	Capital investment, water	Shallow well drilling, canals		
	Capital investment, other	Market and infrastructure development	Rural electrification, energy pricing	Market and infrastructure development, wastewater treatment
	Regulation	Tenure security, water rights, food safety control		Tenure security, food safety control, environmental control
	Management	Wastewater re-use		
	Capacity building	Training on on-farm water management and food and water quality control		
	Finance	Micro-finance		
	Technology	Low-cost, robust irrigation technology	Mechanized groundwater use	Water measurement and control, automation, low pressure irrigation