Table 4. Main conditions of success and reasons for failure of institutional reforms

Conditions of success	Reasons for failure
• Strong political backing. • A clear role for the different stakeholders. • Support for the empowerment of institutions at all levels (including water user associations, local government, etc.). • The autonomy of the water user associations. • The legal framework needed to accommodate the proposed changes in authority. • Capacity building of the people governing the transferred system. • Functioning infrastructure. • Success in recovering operation and maintenance costs.	• Lack of political support. • Resistance of public agencies and water users. • Insufficient resources. • Poor water quality. • Lack of proper involvement of water users. • Transfer of dilapidated or badly designed infrastructure that is dysfunctional and needs major improvement.

of reliability and flexibility are sufficient. A substantial difference exists in irrigation requirements and scheduling between staple crop and high income production. If farmers require greater flexibility and better service, it is important to ensure their backing and support for the necessary investment.

The historical bias towards infrastructure investment to the neglect of training, capacity building and institutional strengthening interventions is one cause of poor irrigation performance. A more balanced approach will characterize future interventions as the synergies are recognized and the cost effectiveness of an integrated approach is demonstrated.

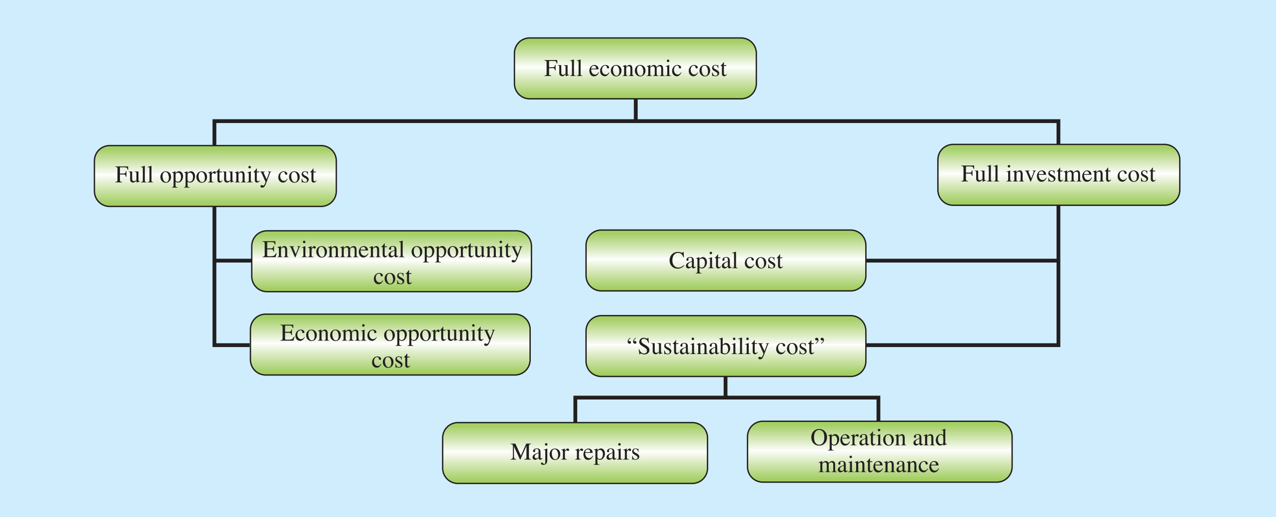
3.2 Cost recovery, water charging and sustainability

Cost recovery and associated water charges have been the subject of intense debate and controversy. As financial resources become scarcer, the issue is becoming critical and will have a major impact on the sector in the near future. Evidence confirms that most governments in developing countries already face a serious funding crisis with broad consequences for rural services, including irrigation. Funding for housing, infrastructure, education and social services in urban centres competes with requirements in rural areas. Given these conditions, a drastic reduction of government funding can be expected for irrigation programmes in many countries. The irrigation landscape will undoubtedly change in response to this pressure, but in ways that are hard to predict, ranging from gradual disuse and disbandment to dynamic self-financing.

The current school of thought in the water sector is well illustrated by GWP (2000): Full cost recovery should be the goal for all water uses. However, assessment of the full cost of water is often out of reach (Figure 7). GWP (2000) also argues that while every effort needs to be made to estimate costs in order to ensure rational allocation and management decisions, these costs should not necessarily be charged to the user. In irrigation, the relevant question therefore is how users (through water charges) and taxpayers (through subsidies) should share the costs associated with irrigation (ICID 2004).

In addition to a thorough understanding of the costs associated with irrigation, information on the economic benefits of irrigation is critical to efficiently allocate irrigation costs across sectors. Indeed, in many cases society as a whole receives a much larger share of irrigation benefits through induced and indirect benefits than a typical irrigated farmer receives through increased crop productivity (Mellor 2002).

This is evidenced by the high multiplier of investment in irrigation — between 2.5 and 4 in India — a factor to consider in setting cost-recovery policies for irrigation.



Source: Adapted from ICID 2004; Rogers, Bhatia, and Huber 1998; FAO 2004b.

Figure 7. Components of costs associated with irrigation

Contention usually focuses on whether and what to charge: Service, operation and maintenance only, or these factors plus the full cost of capital investment, either in the past or as a future replacement annuity. The answer varies widely according to the role irrigation plays in the country's economy: While some advanced economies may seek full cost recovery from irrigation, others may consider subsidies in irrigation as part of wider rural development strategies. In both cases the concept of sustainable cost recovery, which is gaining increasing attention, remains valid and deserves decision-makers' attention: Ensuring the sustainability of existing irrigation infrastructure requires that operation, maintenance, administrative and renewal costs be covered adequately.

Modes of charging for water service vary widely and must be adapted to the level of development of the irrigation scheme. While volumetric water charging may epitomize the service-payment concept and allow for possible demand management, the transaction costs associated with volumetric measurement are rarely justified. Semi-volumetric measurement methods, or area-based water charges, which are often added to other land taxes, may be appropriate as long as transparency and equity are guaranteed.

3.3 Regulation and oversight

Because water is generally regarded as a public good, the state has a duty to sustain its availability and quality. Users often easily enjoy the benefits of water use while passing on environmental and social costs to others, leading to problems of equity, groundwater mining, pollution of drainage water, poor health of farm workers and contamination of consumer products. The state should play an increasingly important role in regulating these externalities. Moreover, water will increasingly become a commodity, quantified and governed by agreements among users and between public authorities and users. Governments will play important roles in sanctioning and regulating these agreements.

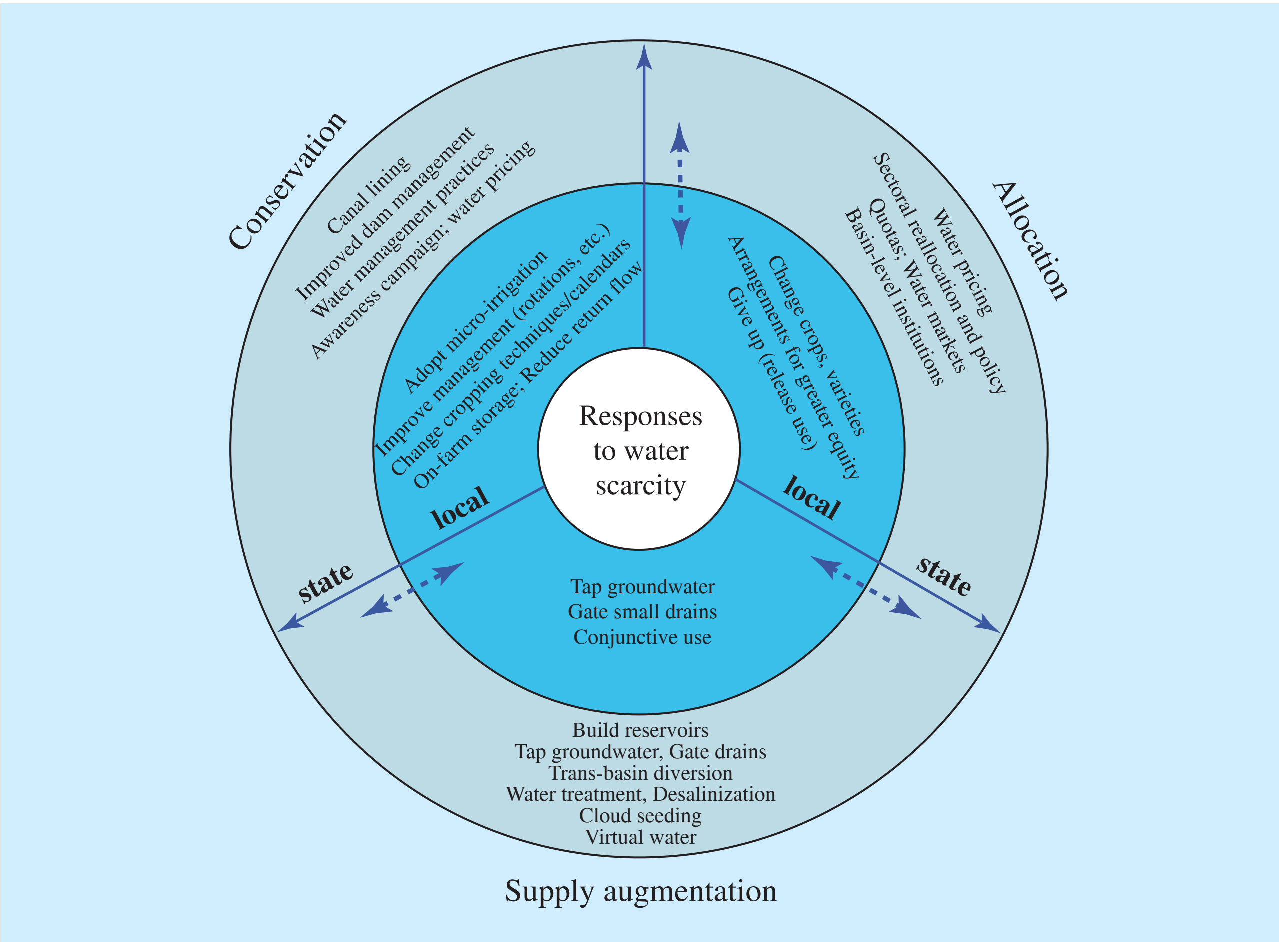
Most governments will need to adapt their water-related agencies in carrying out these new responsibilities. There will be a tendency to separate regulatory agencies from water management and supply agencies to avoid conflicts of interest within the government. Private or client-controlled organizations are likely to be responsible for water supply to users in an increasing number of cases. Adjudication mechanisms will be developed to resolve disputes among parties over water allocation, quality and use. These mechanisms may be a part of the national legal system or a separate set of institutions that rely more heavily on mediation and consensus. In all cases, institutional development should be shaped by context and the existing laws, regulations and approaches to water rights and priorities.

Assessing and collecting fees and taxes has been a key role for many agencies in the past. With increased devolution of irrigation system management, there is a corresponding need to change financing structures to allow those who actually collect or generate sufficient funds to sustain their operations: Therefore, there will be increasingly complicated cost-recovery mechanisms in large irrigation systems involving local service charges as well as bulk water supply costs.

Governments will continue to play the role of water wholesaler by operating (or contracting to private service providers) large and strategic facilities such as dams (in particular multipurpose dams) and main irrigation infrastructure such as main canals and pumping stations.

4. Adapting to sectoral competition

In the growing political and economic tussles over access to water, agriculture is increasingly perceived as a wasteful low-value residual user. Experience shows that water conservation in agriculture does not drive transfers of water from agriculture to other sectors, and the scope for water conservation strategies that free water from agriculture to satisfy the requirements of other sectors is rather limited. Focusing on water conservation alone is certainly not sufficient to sustain agricultural production while releasing the water for environmental, urban and other uses. Rather, a strategy that provides farmers with the means to increase their productivity within the broader context of agricultural modernization is more likely to succeed (Kijne *et al.* 2003). Types of responses to water scarcity are presented in Figure 8 (Molle 2003).



Source: Molle (2003).

Figure 8. Types of response to water scarcity

4.1 Water saving and water use efficiency in irrigation

The concept of water use efficiency (the ratio between effective water consumption by crops and water abstracted from its source for the purpose of irrigation) is subject to controversies and misinterpretation. Because only 30 to 50 percent of the water withdrawn from its source is actually transpired by crops in a typical irrigation system, many conclude that substantial gains in water volumes can be obtained by increasing water use efficiency in irrigation.

However, investments aiming primarily at increasing water use efficiency (in particular through canal lining), in most cases result in few changes in terms of water savings, especially when there is minimal water quality degradation: Large surface irrigation systems circulate massive volumes of water through canals and drains. Because a substantial portion of these flows is recaptured downstream, water-saving technologies on farms may make only minor contributions to savings at larger scales, such as the irrigation system or river basin (Seckler *et al.* 2003). This is most evident where irrigation efficiencies are low in a fully allocated basin, such as the Yellow River, and there is little outflow to the sea.

Nevertheless, the concept of water use efficiency is site-, scale- and purpose-specific (Lankford 2006). Efficiencies matter locally, in terms of irrigation design, for the satisfactory operation and monitoring of existing systems (Bos *et al.* 2005) to ensure equitable access to water within the irrigation schemes and for energy saving and control of waterlogging and salinization.

4.2 Tools for demand management in irrigation

Many economists argue that the low prices paid for irrigation water are a disincentive to efficient use and that a water-pricing policy could save water and increase productivity. But there are almost no examples of pricing as a primary mechanism for efficiency gains in irrigation.

There are two reasons for this. First, water pricing must be based on measured deliveries. In the vast majority of irrigation schemes, delivered volumes of water are not measured, making volumetric water pricing impossible; measuring them would involve huge investments. It is now more widely recognized that the applicability of volumetric water pricing to individual farms is limited to a small subset of technologically and managerially advanced irrigation schemes. Second, the water charges currently levied in most irrigation schemes have rarely reached even a fraction of those needed to constrain demand (Perry *et al.* 1997). In these systems the political consequences of increasing water charges to the point that the demand elasticity becomes significant can be expected to be severe and constraining. In countries where water rights exist and are separate from land rights, markets can, in theory, lead to efficient re-allocation of water among sectors. In practice, water trading has so far re-allocated only small volumes of the resource (less than 1 percent per year of permanent entitlements in Australia and the western United States) (Turral *et al.* 2005). It is unlikely that water markets will affect irrigation water use and re-allocation in most countries of Asia or sub-Saharan Africa in the coming 20 to 30 years because of the time lag in the development of suitable water rights and allocation frameworks and the marginal nature of markets once established. Water markets will also need to adopt more comprehensive water valuation approaches that encompass the broad range of benefits and costs of water management in agriculture — and this includes payment for environmental services. In the interim, consultative and participatory arrangements for water allocation will be required. Consultation is a key process in water allocation — along with data collection, analysis and promulgation, and negotiation — to find optimal sharing of benefits. The challenge over the next 20 years is to develop cost-effective arrangements for doing this and to provide a functional framework of facilitating laws and regulations. As the water allocation process is inherently political, effective representation is crucial. A major challenge for the coming decades is to develop strong and effective representative voices on behalf of those stakeholders who are currently under-represented, including small-scale farmers, women and the environment (Ostrom *et al.* 1993; Blomquist 1992).

Governments will have to be proactive in managing the growing competition for water by establishing effective water rights systems, setting out targeted policies on conservation and implementing appropriate land-use restrictions to facilitate equitable transfers from irrigation to other sectors. In the case of environmental demands, some public recognition of its value is necessary prior to any re-allocation. The degree of recognition and the magnitude of the unmet environmental need for additional water vary considerably from country to

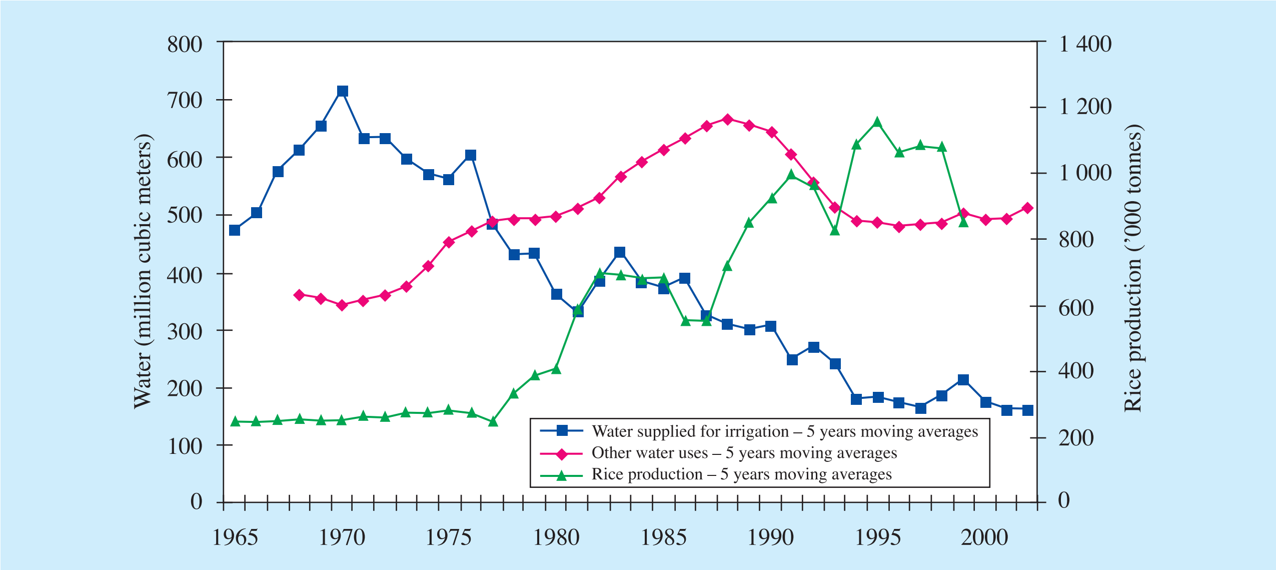


Figure 9. China – Zhanghe water use and rice production 1965-2005

country. In future, the magnitude of environmental re-allocations and their impact on agriculture will be greater than incremental demands rising from cities and industry, as is already the case in many higher income countries such as Australia and the United States because environmental uses are essentially consumptive.

Water conservation in irrigation systems can be achieved through better technology (that minimizes losses, leakages and unrequired deliveries) and through better matching of demand with supply via better management systems and control technology. Better service and flexibility in supply is also implied. Such system-level technologies are "expensive" and can be funded as part of a re-allocation process. More professional irrigation management will also prove to be more expensive than at present.

At the farm level, the adoption of water-saving technology implies capital investment that is out of reach for smallholder irrigators. The ability to generate real and transferable savings at the farm level will depend on the development of different combinations of technological investment, accompanied by definition and management of water rights (through better measurement and monitoring) that allows savings to be quantified. Investment may be made through subsidy or through likely increases in farm size, improved economies of scale and greater "private" investment.

At the landscape level, it is possible that some re-orientation between irrigated and rain-fed agriculture may allow more crops to be grown whilst diverting or storing less water for irrigation. However, current forecasts predict the need for increases in the productivity of both irrigated and rain-fed agriculture to meet future food demand at national and basin levels in many Asian countries. Such arguments are also tempered by the fact that increased rain-fed development is not hydrologically neutral and wherever agriculture uses water, it is lost directly to evapotranspiration, which also occurs with natural vegetation.

Bibliography

Albinson, B. & Perry, C.J. 2002. *Fundamentals of smallholder irrigation: The structured system concept.* Research Report 58. Colombo, International Water Management Institute.

Bakker, M., Barker, R., Meinzen-Dick, R.S. & Konransen, F., eds. 1999. *Multiple uses of water in irrigated areas: a case study from Sri Lanka.* SWIM Report 8. Colombo, International Water Management Institute.

Barker, R. & Molle, F. 2004. *Evolution of irrigation in South and Southeast Asia.* Comprehensive Assessment Research Report 5. Colombo, International Water Management Institute.

Barnett, T.P., Adams, J.C. & Lettenmaier, D.P. 2005. Potential impacts of a warming climate on water availability in snow-dominated regions. *Nature,* 438(7066): 303–09.

Berkoff, J. 2003. *Prospects for irrigated agriculture: has the international consensus got it right?* Alternative Water Forum, 1–2 May, Bradford, UK.

Bolton, P. 1992. *Environmental and health aspects of irrigation.* OD/P 116. Wallingford, UK, Hydraulics Research.

Bos, M.G, Burton, M.A. & Molden, D.J. 2005. *Irrigation and drainage performance assessment: practical guidelines.* Wallingford, UK, CABI Publishing.

Carruthers, I., Rosegrant, M.W. & Seckler, D. 1997. Irrigation and food security in the 21st century. *Irrigation and Drainage Systems,* 11: 83–101.

Dougherty, T.C. & Hall, A.W. 1995. *Environmental impact assessment of irrigation and drainage projects.* Irrigation and Drainage Paper 53. Rome, Food and Agriculture Organization of the United Nations.

FAO (Food and Agriculture Organization of the United Nations). 1999a. *Modern water control and management practices in irrigation: impact on performance.* FAO Water Report 19. Rome, International Programme for Technology and Research in Irrigation and Drainage.

FAO. 1999b. *Transfer of irrigation management services. Guidelines.* FAO Irrigation and Drainage Paper 58. Rome.

FAO. 2003. *World agriculture towards 2015/2030: an FAO perspective.* Rome and London, FAO and Earthscan Publishers.

FAO. 2004. *Water charging in irrigated agriculture: an analysis of international experience.* FAO Water Report 28. Rome.

FAO. 2006. FAOSTAT database. [http://faostat.fao.org/].

FAO. 1997. *Modernization of irrigation schemes: past experiences and future options.* FAO Technical Paper 12. Rome.

FAO. *Forthcoming. Irrigation management transfer: worldwide efforts and results.* Rome.

GWP (Global Water Partnership). 2000. *Integrated water resources management.* TAC Background Paper 4. Stockholm, Technical Advisory Committee.

Horst, L. 1998. *The dilemmas of water division, considerations and criteria for irrigation system design.* Colombo, International Water Management Institute.

Huang, Qiuqiong, Rozelle, S., Lohmar, B., Huang, J. & Wang, J. 2006. Irrigation, agricultural performance and poverty reduction in China. *Food Policy,* 31(1): 30–52.

Huppert, W., Svendsen, M. & Vermillion, D.L. (with Wolff, B., Burton, M. van Hofwegen, P., Meinzen-Dick, R., Scheumann, W. & Urban, K.) 2001. *Governing maintenance provision in irrigation: a guide to institutionally viable maintenance strategies.* Eschborn, Germany, GTZ.

ICID (International Commission on Irrigation and Drainage). 2004. *Irrigation and drainage services: some principles and issues towards sustainability.* ICID Position Paper. New Delhi.

Johnson, S., III, Svendsen, M. & Gonzalez, F. 2004. *Institutional reform options in the irrigation sector.* Agriculture and Rural Development Discussion Paper 5. World Bank, Washington, DC.

Kendy, E., Molden, D.J., Steenhuis, T.S. & Liu, C.M. 2003. *Policies drain the North China Plain: agricultural policy and groundwater depletion in Luancheng County, 1949–2000.* Research Report 71. Colombo, International Water Management Institute.

Kijne, J.W., Molden, D. & Barker, R. eds. 2003. *Water productivity in agriculture: limits and opportunities for improvement.* Comprehensive Assessment of Water Management in Agriculture Series, No. 1. Wallingford, UK, CABI Publishing.

Lankford, B. 2006. Localising irrigation efficiency. *Irrigation and Drainage,* 55: 1–18.

Lipton, M., Litchfield, J. & Faurès, J.-M. 2003. The effects of irrigation on poverty: a framework for analysis. *Water Policy,* 5(5): 413–27.

Loeve, R., Hong, L., Dong, B., Mao, G., Chen, C.D., Dawe, D. & Barker, R. 2004. Long term trends in intersectoral water allocation and crop water productivity in Zhanghe and Kaifeng, China. *Paddy and Water Environment,* 2(4): 237–45.

Malano, H. & Hofwegen, P.V. 1999. *Management of irrigation and drainage systems: a service approach.* IHE Monograph 3. Rotterdam/Brookfield, A.A. Balkema.

Mellor, J.W. 1999. *Faster more equitable growth — the relation between growth in agriculture and poverty reduction.* Paper prepared for United States Agency for International Development, Bureau for Global Programmes, Center for Economic Growth and Agricultural Development, Division of Agriculture and Food Security. Cambridge, Mass., Abt Associates Inc.

Mellor, J.W. 2002. Irrigation, agriculture and poverty reduction: general relationships and specific needs. *In* I. Hussain & E. Biltonen, eds. *Managing water for the poor: proceedings of the Regional Workshop on Pro-Poor Intervention Strategies in Irrigated Agriculture in Asia, Bangladesh, China, India, Indonesia, Pakistan and Viet Nam.* Colombo: International Water Management Institute.

Molle, F. & Berkoff, J. 2006. *Cities versus agriculture: revisiting intersectoral water transfers, potential gains, and conflicts.* Comprehensive Assessment of Water Management in Agriculture Research Report 10. Colombo, International Water Management Institute.

Molle, F. & Berkoff, J., eds. Forthcoming. *Irrigation water pricing policy in context: exploring the gap between theory and practice.* Colombo, CABI Publishing and International Water Management Institute.

Ostrom, E., Schroeder, L. & Wynne, S.G. 1993. *Institutional incentives and sustainable development: infrastructure policies in perspective.* Boulder, Colorado, Westview Press.

Perry, C.J. & Narayanamurthy, S.G. 1998. *Farmer response to rationed and uncertain irrigation supplies.* IWMI Research Report 24. Colombo, International Water Management Institute.

Rosegrant, M.W. & Svendsen, M. 1993. Asian food production in the 1990s: irrigation investment and management policy. *Food Policy,* 18(2): 13–32.

Rosegrant, M.W., Cai, X. & Cline, S. 2002. *World water and food to 2025: dealing with scarcity.* Washington, DC, International Food Policy Research Institute and International Water Management Institute.

Rosegrant, M.W., Paisner, M.S., Meijer, S. & Witcover, J. 2001. *Global food projections to 2020: emerging trends and alternative futures.* Washington, DC, International Food Policy Research Institute.

Seckler, D., Molden, D. & Sakthivadivel, R. 2003. The concept of efficiency in water-resources management and policy. *In* J.W. Kijne, R. Barker & D. Molden, eds. *Water productivity in agriculture: limits and opportunities for improvement.* Wallingford, UK, CABI Publishing.

Vermillion, D.L. 1997. *Impacts of irrigation management transfer: a review of the evidence.* IWMI Research Report 11. International Water Management Institute, Colombo.

Ward, C., Peacock, A. & Gamberelli, G. 2006. *Investment in agricultural water for poverty reduction and economic growth in sub-Saharan Africa.* Synthesis Report. African Development Bank, World Bank, IFAD, FAO, consultative group.

KEYNOTE ADDRESS

Suo Lisheng

Former Vice-Minister, Ministry of Water Resources, China

Water projects and ecological protection

1. Prospects and constraints for water conservancy development

Physiographic conditions and essential water availability determine the need for major water conservancy development. The next 15 to 20 years will be an important period for such development and are likely to witness the following prospects and constraints.

1.1 Prospects

1. There will be urgent requirements for water-saving infrastructure, flood control, drought relief, grain safety, urban and rural water supply as well as environmental protection.
2. A more affluent society is going to need improved electrical power supply; this should be juxtaposed by a reduction in the discharge of greenhouse gases.
3. Construction of water-saving infrastructure will lead to a greater influx of western technology and conversion of resource assets into economic benefits.

1.2 Constraints

1. Hydropower projects are at different stages so some areas are likely to benefit earlier than others.
2. Skilled technician availability.
3. Economic challenges.
4. Market restriction.
5. Ecological problems.
6. In-migration (the increasing number of immigrants, for instance around Yangliu Lake, Lu River, Yuanming Palace, Pubu Valley, Baise, Nierji).

2. Functions

Water projects have the following important functions:

- They promote socio-economic development and help to resolve the issues of “population, poverty, environment (PPE)”.
- They can provide hydropower and help to decrease greenhouse gase emissions.

For example, the South-to-North Water Diversion will help to prevent the exploitation of groundwater. Diminishing fuel resources can be substituted by small hydropower projects, which in turn will play a role in protecting forests and vegetation.

3. Water conservancy development

3.1 The main elements of a water project

- Harmonize human and environmental coexistence. Devise a good strategy.
- Water resource development should be adapted to carrying capacity and coordinated with socio-economic development and ecological protection.

- Project construction should conform with the strategic plan.
- Participatory management among stakeholders, including farmers, is needed.
- Expedite appropriate legislation, observe water rights, make fees equitable.
- Promote investment by different sectors and stakeholders.
- Quality control monitoring (operation and maintenance)
- Disseminate project benefits (e.g. disaster mitigation, improved livelihoods).

4. Conclusion

Physiographic conditions and scarce water resources dictate that water conservancy will be making considerable strides in China. The next 15 to 20 years will be a significant period for water development. Stakeholders and other concerned parties should ensure that the construction of water projects is carried out responsibly, especially with regard to ecological protection.

SECTION 2: PLENARY PRESENTATIONS

Irrigation development policies in China

Li Daixin[1]

1. Opportunities and challenges

Ample fresh water resources are an essential condition for socio-economic development and an important factor in realizing sustainable development. In China, the relationship between water and socio-economic development has become an important topic.

Factors such as growing population, intensive crop use, changing climate and diminishing water resources demand irrigation development to conserve water supplies. Throughout Chinese history, irrigation has had an important role in sustaining socio-economic development. Since the founding of New China, the Chinese Government has attached great importance to irrigation development; for the past five decades, the irrigated arable area in China has increased from 15 million to 56 million ha. Each year, the grain yield from irrigated areas accounts for 75 percent of the nation's total grain production. Moreover the irrigated area only accounts for 45 percent of the total planted area, with economic crops accounting for over 90 percent of the total output. Although cropped area per capita in China only accounts for 30 percent of that in the rest of the world, our irrigation rate for cropping is three times that of the world average and our irrigated area per capita is also on par with the world average. With only 6 percent of the world's total renewable water resources and 9 percent of the world's total arable land area, China has successfully solved the problem of providing adequate food and clothing for its population of 1.3 billion (accounting for 22 percent of the world's total population); this is a significant achievement and the contribution by irrigated agriculture should not be neglected.

With the further increases in population, rapid economic development and accelerated urbanization, irrigation in China is confronted by many positive development opportunities and numerous challenges.

1.1 The opportunities

1. The central government has devised strategies for building an affluent society in a holistic manner and building New Social Villages. This calls for expediting the development of irrigation to increase agricultural production and farmers' incomes as well as to enhance rural socio-economic development.
2. The need to guarantee national grain safety calls for accelerating the development of irrigation and drainage; this will further enhance comprehensive grain throughput.
3. Irrigation for water conservancy is now a commonly understood concept by society in general.

Sustainable economic development in China and increased financial capacity have laid a solid foundation for urban–rural assistance, agricultural development and building a multiple investment mechanism for irrigation.

1.2 The challenges

1. Water deficits for agricultural irrigation in China annually amount to over 30 billion m^3; at the same time, lower water use efficiency results in excessive waste of water resources.
2. As it is difficult to increase the amount of available water, industrial and urban areas are tapping water supplies intended for irrigation. To increase water reserves for agricultural irrigation, we need to urgently develop water-saving irrigation techniques.
3. Pollution of water resources has not yet been brought under effective control; while developing irrigation techniques, we must pay greater attention to environmental protection.

---

[1] Director-General, Department of Irrigation, Drainage and Rural Water Supply, Ministry of Water Resources, China.

2. Current policies on irrigation development in China

Government leadership for irrigation development needs to be strengthened. China's Law on Water stipulates clearly that the government at various levels should consolidate leadership for irrigation work and promote the development of agricultural production. Farmland irrigation and drainage are important components of water-saving infrastructure (WSI); the government, at various levels, should strengthen WSI by drawing up specific targets and adopting strict measures.

The guidelines of the 11th Five-year Plan for National Economic and Social Development list construction activities for large-scale irrigation areas and water-harvesting facilities as one of the key programmes for building New Social Villages. This will require a greater focus on increased agricultural fixed assets' investment as recorded in 2005 and 2006 by the Central Committee of the Communist Party of China (CPC) and the State Council.

The Medium- and Long-term Programme for National Grain Safety of the National Development and Reform Commission (NDRC) considers the construction of WSI as a key programme for guaranteeing national grain safety. Recent key planning by the Ministry of Water Resources endorsed the upscaling of rehabilitation and follow-up construction of existing large-scale irrigation areas and water-harvesting facilities to further improve a guaranteed irrigation rate and grain output. Also, to further enlarge irrigation areas in regions where there are good natural water supplies and soil resources and to exploit these reserves for grain production.

In the context of promoting water conservancy for agriculture and constructing related infrastructure to meet socio-economic needs, the Third Plenary Session of the Fifteenth CPC Central Committee noted the need to formulate policies for promoting water conservancy, to develop water-harvesting agricultural practices and to undertake the promotion of water-harvesting irrigation as well as to enlarge the effective irrigation area. China's Law on Water clearly stipulates: (i) Strict economy in the use of water, (ii) measures for economical water use, (iii) dissemination of new technologies for economical water use and (iv) the development of a water-saving society.

While developing WSI techniques and expediting WSI, we must attach importance to the system's framework. First, a management system for the control and allocation of irrigation water needs to be established. According to available water resources in irrigation areas and trends in local socio-economic development, water must be distributed scientifically and rationally; the control index for irrigation water volume must be fixed. Water allocation and supply plans — according to crop water requirements and water management requirements — need to be devised. According to Article 47 of China's Water Law, the state controls national water resources and their allocation.

Second, it is essential to conduct the transfer of agricultural irrigation water rights. There is a need to conduct research on water rights and distribution mechanisms and to progressively establish market mechanisms for water rights transfer. Saved water can be transferred to other industries in a compensatory manner and water users can be taught how to use water economically and effectively in order to improve water use efficiency. Further, there is a need to promote the establishment of multiple investment mechanisms for WSI.

Third, it necessary to fine-tune the compensation mechanism for using irrigation water and irrigation facilities. Water for agriculture and associated water facilities that are exploited by industry and cities should be protected in order to respect farmers' legal water rights.

To promote agricultural water conservancy calls for the creation of an equitable water-price mechanism that addresses compensation costs, reasonable income, economical use of water and fair allocation. At the same time, water fee collection and management mechanisms should be finalized and the usage of water fees should be transparent. China's Water Law stipulates clearly that anyone who uses water provided by a water-supply project shall pay a water fee to the supplying unit in accordance with the relevant provisions. The law also contains the condition to measure the amount of water used and to use it according to the approved water use plan and to collect water fees through measurement and staged prices for the use of water. In recent years, the central government has promoted a number of policies to enforce water-saving activities and to promote the effective and economical use of water resources.

Irrigation is closely related to the environment. In inland river basins with fragile ecosystems and degraded water resources, it is necessary to further strengthen integrated water resource management in large river catchments; the development of new irrigation areas should be strictly controlled in order to protect natural water reserves. In groundwater-deficient areas (especially in North China) the exploitation of groundwater should be strictly controlled.

To develop water-harvesting irrigation calls for scientific and rational plans. According to agricultural requirements and socio-economic development in rural areas there is a need to devise an irrigation plan. The formulation of the plan should be based on the carrying capacity of water and soil resources, paying particular attention to the economy, allocation and protection of water resources. At the same time, key points should be emphasized: Priorities should be given to major grain-producing regions, regions suffering from severe water shortage, regions with fragile environments and relatively depressed areas. In recent years, the Ministry of Water Resources has promulgated a series of policies in this regard.

With respect to water-harvesting irrigation, a guaranteed mechanism for steady increase of investment is warranted. The central government and local governments at various levels should actively guarantee funding inputs, ensure the steady increase of inputs for irrigation facilities and strengthen standardized, systemized and scientific management of projects. Simultaneously an evaluation system should be fine-tuned in order to guarantee the standardized and orderly implementation of projects and to enhance investment benefits.

The development of water-harvesting irrigation relies on scientific and technological progress, which can enhance irrigation supply. An innovative science-oriented network should comprise government-supported enterprises that manufacture water-harvesting materials/equipment as well as scientific research units, universities and polytechnic institutes. It should be a network that cooperates with water-producing units and water consumers. The network should introduce advanced water-harvesting irrigation technologies from overseas and develop new water-harvesting irrigation technologies that are adaptable to our national situation. Other tasks are to promote the popularization of grassroots technology and to continuously improve the level of irrigation modernization. In this context, the *Outline for water conservation technologies and policies in China* was published jointly by the National Development and Reform Commission, Ministry of Science and Technology, Ministry of Water Resources, Ministry of Construction and Ministry of Agriculture.

After the 1998 flood disaster in the Yangtze Basin, the Ministry of Water Resources demanded a focus on reform with regard to water conservancy and management systems as well as the heightening of water use efficiency. The implementation of “Two Reforms and One Heightening” has optimized the allocation of water resources, enhanced agricultural production, increased farmers’ income, fostered the management of irrigation districts and improved the condition of natural environments. Comprehensive achievements have been made in terms of socio-economic and ecological aspects.

With respect to the reconstruction of WSI, project management needs to study and prepare relevant regulations for projects to follow. This will reduce random implementation and intensify standardized, systematic and scientific management. For project organization, priorities should target irrigation areas afflicted by severe water shortages and areas with notable supply and demand anomalies.

In the context of funding, special accounts and concomitant account management procedures are warranted (declaration, examination, verification and approval). Arbitrary payments, stockpiling or embezzlement funds will be punished. The construction phase should strictly adhere to regulations governing terms of reference for project staff, tender invitations, bidding systems, construction supervision and contract management to guarantee quality. Moreover efforts should be made to introduce new technologies, materials and techniques. The state has prepared a number of important policies to address all of these issues.

The main thrust of irrigation reform is to energetically advance management and operational reform with a focus on developing WUAs). According the Ministry of Water Resources, local conditions should be analysed carefully for the development of WUAs, which should not automatically adopt a single mode. Local governments must strengthen guidance and support for WUAs and devolve management to them. Farmers should realize that success lies in voluntary contributions and subsequent mutual benefit.

Each irrigation area should be strict in fixing the number of staff and the number of engineering posts in water conservancy management units. Management and maintenance of completed projects must be supervised carefully. Employees should be encouraged to continuously improve management efficiency and strive to lower management costs.

The development of irrigation areas calls for an ideal evaluation system that comprehensively determines local outputs, experiences and problems related to the infrastructure. This will enable the preparation of appropriate countermeasures and suggestions to ensure orderly and standardized implementation of the project and raise the investment profile.

Development and modernization of irrigation schemes in China

Zhanyi Gao[1]

1. Introduction

Located in the Asian monsoon region, most of China experiences uneven distribution of precipitation. Consequently, drought and waterlogging occur frequently. China has a long history of irrigation, dating back more than 4 000 years. The famous Dujiangyan Project was built 2 250 years ago and it still functions today as the second largest irrigation district in terms of total irrigated area. Agricultural production and Chinese civilization have depended heavily on the development of irrigation practices.

In China, irrigation has matured beside socio-economic development and technological progress. Irrigation schemes have played an important role in increasing crop yields, securing food safety, supplying drinking water to rural areas, generating job opportunities, increasing farmers' income and ameliorating poverty. However, owing to rapid socio-economic development and climate change, water shortages and environmental degradation are becoming increasingly serious, thus challenging the sustainable development of irrigation. The irrigation sector is still the largest water user although the proportion of water supply it receives is declining. It is a key area for modernization — via new concepts and technology — in order to increase water use efficiency and agricultural productivity. During the last ten years, 306 large irrigation schemes in China have been upgraded but it will take a long time to compete the task.

2. Irrigation development review

In 1949 the total irrigated area in China was 15.9 million ha. Since then irrigation has expanded very quickly and this expansion can be divided into three stages (Figure 1).

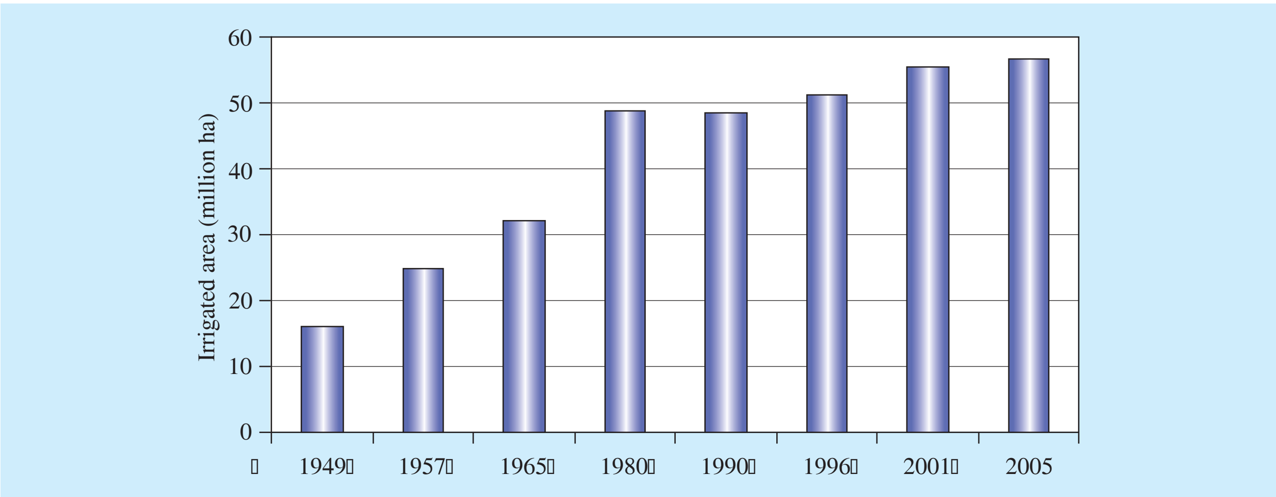


Figure 1. Expansion of the irrigation area in China since 1949

1949 to 1980: The focus was on the construction of reservoirs, water diversion projects, large and medium irrigation districts and tubewells. The irrigated area increased from 15.93 million ha in 1949 to 48.89 million ha in 1980 with an average annual increase of 1.06 million ha.

1981 to 1990: Institutional reform in rural areas was implemented, agricultural institutions and input mechanisms were restructured, state investment and labour input for development and maintenance of irrigation

[1] China Institute of Water Resources and Hydropower Research Beijing 100044, P.O. Box 366, China.

projects were reduced. Meanwhile, more irrigation water was diverted for rising industrial and domestic use. As a result, the irrigated area declined from 48.89 million ha in 1980 to 48.39 million ha in 1990; the average annual rate of decline was 50 000 ha. During this stage the focus shifted from construction to management.

1991 to present: The focus has been on developing water-saving irrigation, improving irrigation management, reforming management institutions and rehabilitating large irrigation projects. State investment for the irrigation sector has increased. As a result, the irrigated area expanded from 48.39 million ha in 1990 to 56.53 million ha in 2005 with an average annual increase of 690 000 ha.

By 2005, there were 402 large irrigation schemes each with an irrigated area exceeding 20 000 ha. The total irrigated area serviced by the large irrigation schemes amounted to 16.3 million ha, accounting for 29 percent of the total irrigated area in China. The large irrigation schemes produced 22 percent of total grain production and 33 percent of the total agricultural output from only 12.8 percent of the total farmland in China.

3. Irrigation scheme modernization

In China most irrigation schemes were built from the 1950s to 1970s. Due to the lack of technology and funding, the design standard was low and the irrigation systems remained incomplete. Furthermore, after 30 to 40 years of operation, weaknesses have developed in canals and infrastructure. Water shortage, water pollution and climate change have exacerbated the problem.

In 1991 the Ministry of Water Resources evaluated the condition of irrigation schemes in China. The major findings were:

- Most of the irrigation schemes built between the 1950s and 1970s were of poor standard and construction was incomplete.
- The long operational period induced structural ageing and damage which caused high leakage and canal collapse. In pumping irrigation schemes, pumps, motors and pipelines were too old and one-third of the facilities was obsolete.
- Owing to rapid socio-economic development, water supply could not meet demand and irrigation water was being diverted for other users. Meanwhile, irrigation efficiency was only 42 percent.
- Investment was insufficient, management was inadequate and irrigation benefits were disappearing.

From 1998 to 2005, 18.9 billion yuan was allocated to upgrade intake structures, canal systems and control facilities in 306 large irrigation schemes with a focus on solving “bottleneck” problems. In recent years modernization of irrigation system management has been piloted in 30 irrigation schemes by adopting modern technologies.

In 2005 the Ministry of Water Resources organized a mid-term assessment of the modernization of 255 large irrigation schemes. The results showed that from 1998 to 2004, 12 784 km of canals had been lined and 39 583 structures had been re-inforced or built. The safety of the irrigation schemes had improved, water conveyance duration and irrigation intervals had been shortened and water losses had been reduced. After the modernization was complete, 646 000 ha of irrigated area were recovered, 3.31 million ha of irrigated farmland were improved and grain production was increased by 5.82 million tonnes. Total agricultural output in the project area increased by 46.1 percent and net income per capita increased by 43.8 percent. Management staff declined from 5.68 to 4.12 persons per 10 000 ha of irrigated area (reduced by 25.7 percent).The irrigated area managed by water users’ associations (WUAs) increased from 9.1 to 36 percent of the total irrigated area. Average annual losses induced by natural disaster declined by 3.2 billion yuan in the 255 irrigation schemes. Losses induced by accident were reduced by half in 67.8 percent of the assessed irrigation schemes. The modernization of irrigation schemes facilitated the introduction of new cropping patterns, increased farmers’ income, returned more water to ecosystems and improved the ecological condition of the rural area.

4. Discussion on irrigation scheme modernization

As a key project, the modernization of large irrigation schemes has been included in 11th Five-year Plan. During the planning period the development of water-saving irrigation has been further highlighted and modernization of irrigation schemes has been listed in key areas for investment allocation.

The purpose of such modernization is to improve service to water users, including improvement of water measurement and control; increase water supply; improve water use efficiency and productivity; and realize socio-economic benefits.

The modernization of irrigation schemes is part of socio-economic development and can be tracked historically. It is part of the transition from a traditional to a modern society:

- The initial modernization involves a move in bias from agriculture to industry — from an agricultural to an industrial economy and from an agricultural to an industrial society.
- The second modernization involves a move in bias from an industrial to a knowledge-based economy and from an industrial to a knowledge-based society.

If the major socio-economic objective of the initial modernization was to enhance economic development, then the major objective of the second modernization was to improve quality of life. If the initial modernization plundered nature, then the second modernization addressed conservation and rehabilitation.

In developed countries, the initial modernization is already history and the second modernization is underway. Developing countries are confronted by both scenarios.

The characteristics of both scenarios should be reflected in the modernization of irrigation schemes. The modernization of irrigation schemes not only includes application of new materials, new technology and new techniques for upgrading and constructing irrigation systems, but also includes adoption of modern management technologies, concepts and institutions. Democracy and legalization should be incorporated in institutional reform. Knowledge, specialization and learning should be incorporated in capacity building. Information systems, automation, computer technology and networking should be adopted to modernize irrigation system management. Empowerment, users' rights, participation and equity should be components of WUAs. The modernization of irrigation schemes should promote agricultural production, raise living standards, enhance the rural environment and develop a stable society.

Bibliography

Department of Rural Water, Ministry of Water Resources. 2005. *Report on appraisal of modernization of large irrigation schemes.* October 2005.

FAO. 2004. Improving the operation of canal irrigation systems. November 2004.

He Chuanqi. 2002. *What is modernization?* China Research Centre for Modernization, Chinese Academy of Science, August 2002.

Zhanyi Gao. Discussion on selection of efficient water saving technology for large irrigation schemes. *China Water,* December 2005.

Zhanyi Gao. 2006. Development of irrigation and its multi-function in China. *Water Economy,* January 2006.

Water resource management and agricultural irrigation in Shanxi Province

Pan Junfeng[1]

1. Background

Shanxi Province is located in the western quadrant of North China, the middle reaches of the Yellow River and the eastern edge of the Loess Plateau. The total land area is 156 000 km^2, forming a long narrow parallelogram from north to south, with encompassing mountains and rivers. The geographic coordinates are 110°14′–114°33′ east and 34°34′–40°43′ north. The interior is complex; it can be divided into three major regions — the eastern mountains, the western plateau and the middle basin. Mountains and hills account for over 80 percent of the total area; plains are mainly distributed in the middle basin. The province governs 11 prefecture-level cities, 119 counties (cities, districts) and a total population of 33.55 million. Taiyuan is the capital city.

2. Water resources and agricultural irrigation

2.1 Water resources

The weather in Shanxi Province is characterized by a mid-latitude continental monsoon climate and average annual precipitation is 508.8 mm (annual rainfall ranges from 650 to 400 mm). The aridity index increases from 1.5 to 3 from southeast to northwest, transiting from a semi-humid to a semi-arid climate.

Medium-sized rivers in Shanxi Province include the Fen and Qin in the Yellow River Basin and the Sanggan, Hutuo and Zhang in the Haihe Basin; all rise in the interior and flow outwards. As the sole major river passing through Shanxi Province, the Yellow River flows through 968 km of provincial boundaries among Shanxi, Shaanxi and Henan Provinces. The average annual river runoff recorded at Longmen hydrological station on the Yellow River is 28 million m^3.

In 2003, Shanxi's total water resources, on average, amounted to 12.38 billion m^3. Water supply in 2005 was 5.9 billion m^3, of which surface water accounted for 2.2 billion m^3 and groundwater 3.7 billion m^3 (37 and 63 percent of the total water supply respectively).

In recent years, total water usage for the whole province has increased from 5.8 billion to 6.5 billion m^3 — domestic water usage in urban and rural areas totals 0.85 billion m^3, industrial water usage 1.7 billion m^3 and agricultural water usage 3.4 billion to 3.95 billion m^3.

2.2 Agricultural irrigation

The main natural disaster for agriculture in Shanxi Province is drought. Severe drought has occurred every 2.6 years on average for the past 600 years; the frequency of general or regional drought is over 90 percent. The distribution of annual precipitation is very uneven; in winter and spring it is no more than 18 percent of the annual amount, so spring drought occurs almost every year. According to statistics, the grain output of irrigated land in Shanxi is generally one to four times higher than that of unirrigated land. The grain output of irrigated land in a common year accounts for about 60 percent of the gross grain output of the whole province; such a proportion in case of drought years would be over two-thirds. Therefore, irrigation for the agricultural development of Shanxi Province is very important.

In 2005, the effective irrigation area in the whole province reached 18.85 million *mu*[2], accounting for 33 percent of the total cultivated area: 7.4 million *mu* (large- and medium-scale automatic flow irrigation);

[1] Director-General, Shanxi Water Resources Department, China.

[2] 1 *mu* = 0.06 ha.

3.12 million *mu* (similarly sized mechano-electric irrigation); 6.88 million *mu* (well irrigation); and 1.45 million *mu* (small irrigation projects).

After many years of research and experiment, Shanxi Province has preliminarily concluded a set of water-saving irrigation measures suitable for its natural conditions. With regard to irrigation water supply, the main measure is canal seepage control and for field irrigation it is low-pressure pipe irrigation. Currently, constructed canal length with seepage control is 60 000 km, accounting for 52.4 percent of the total length of fixed canals; the seepage control rate of main canals in large irrigation regions has reached 61 percent. We have developed a low-pressure pipe irrigation area of 6.43 million *mu*, as well as sprinkler irrigation and micro-irrigation areas of 2.6 million *mu*. Average use of irrigation water in the whole province has increased from a coefficient of 0.404 in 1990 to 0.474 presently; this is at the middle or higher level for usage nationwide.

3. Constraints and challenges

3.1 Development, utilization and management of water resources

(1) The water resource situation is serious and conflict between water supply and demand is intense. Average availability of water per capita in Shanxi Province is 381 m^3, about 17 percent of the national average. Since the 1970s, Shanxi has been experiencing particularly low water levels and according to the index for serious water deficit[3] , Shanxi has endured serious water shortages. Since 1980, in order to cope with national demand for energy, various industries in Shanxi have been developed rapidly; coal outputs, thermal power generation, chemical, steel and aluminium industries have proliferated. At the same time, domestic water usage in urban and rural regions and ecological water usage have risen quickly. Currently, the lack of water restricts the development of Shanxi and has become an important strategic issue.

(2) Regulatory and allocation capacity for water resources is low and the construction of water-related infrastructure has lagged seriously. Most of Shanxi is mountainous or hilly, so development projects are confronted by physical challenges, high costs and long construction periods. Since the late 1950s, Shanxi has constructed 730 reservoirs, with total storage capacity of 4.5 billion m^3. Sixty-three large- and medium-scale reservoirs were all constructed before 1976 and siltation has reached 1.2 billion m^3 after more than 30 years of operation. Because no new reservoirs have been built in recent years (only three reservoirs are now under construction), storage and capacity to control surface water has weakened (for reservoirs in the whole province this is less than one-fourth for river runoff, which is low). Because of inadequate water-related infrastructure, currently the average water supply per capita is only 180 m^3, about 44 percent of the national average. In this regard, Shanxi is ranked bottom among all provinces, cities and autonomous regions in China.

(3) Groundwater overexploitation is serious. Most of the river runoff is concentrated in the three months of the flood season and a flood often lasts for only several hours; thus runoff control and storage is difficult if there are no proper facilities. Most of the rivers rise in the watershed between the eastern and western mountains and cannot unite to form a major river with abundant supply until nearing the provincial boundary. Most locations suitable for the construction of large- and medium-scale reservoirs are distributed at both wings, which constrains the supply of water to the middle basin. Therefore, river flow optimization mainly uses the Fen, Sanggan and Su Rivers in the middle basin regions; the development and use of rivers in the eastern and western wings is only 5 to 15 percent. The average annual runoff flowing out of the province from 1956 to 2000 was 7.32 billion m^3, of which the Haihe River Basin accounted for 3.2 billion m^3 and the Yellow River Basin 4.12 billion m^3 respectively; total provincial outflow was 84.36 percent of river runoff. Even in low water periods from 1980 to 2000, provincial outflow had reached 4.8 billion m^3, about 65.84 percent of river runoff; only one-third of this amount could be used.

The water supply capacity of surface water projects is limited. After 1972, in order to meet demand for economic development, groundwater exploitation increased annually from 1.1 billion m^3 to nearly 4 billion m^3, and groundwater became the main supply. For a certain period, the situation became chaotic —

[3] UN International Population Action, 1993.

urban–rural rifts, multidepartment reviews and approvals, self-construction and self-management, open usage and uncontrolled exploitation. Annual exploitation of groundwater reached 0.7 billion m^3 over a total area of 11 000 km^2. Groundwater levels declined by 2 to 3 m per year on average. Most shallow groundwater layers have now dried up, and motor-pumped wells have become deeper and deeper, with corresponding physical disturbance; the depth of wells in some regions has even reached 1 000 m. The cost of irrigation for farmers is increasing too; they are barely able to afford water tariffs. Overexploitation has also generated environmental and geological problems, for example, some cities such as Taiyuan, Datong and Jinzhong have experienced land subsidence of approximately 1 100 mm.

The depth of basin groundwater has increased greatly. Consequently recharge by precipitation infiltration has been affected negatively. Thus the groundwater volume that crops and trees can utilize under natural conditions has diminished considerably; this further exacerbates adverse effects on the vulnerable ecological environment of Shanxi.

These problems are compounded by seepage of industrial wastewater and sewage which seriously pollutes river water. Most rivers in Shanxi are seasonal, so in the dry season water flow is reduced and sewage-bearing capacity is very low; river water quality is consequently poor.

(4) Coal mining has a negative influence on water resources. Coal resources in Shanxi are abundant and the province is a national energy base. Coal output in 2005 reached 0.6 billion tonnes, accounting for one-fourth of the total national output. Coal and water resources in Shanxi coexist in the same geological strata. Groundwater can be divided into three storage types: Coal formation, upper stratum covering the aquifer; coal formation, aquifer stratum; and coal formation, stratum underlying the aquifer. The first two are mainly “crack and cranny” aquifers and the latter is mainly a karst aquifer. Coal mining has resulted in cranny water discharge zones and caused dessication and leakage in the upper aquifer. Coal mining tunnels turn the coal seams into labyrinths and decompression draining during coal mining pollutes underlying karst water. What is even more destructive is surface damage: Cracks, subsidence and dessicated aquifers — water circulation via the natural chain of runoff, recharge and drainage is broken, which leads to the drying up of rivers and groundwater exhaustion.

According to expert research, on average, each tonne of coal mined in Shanxi Province will cost 2.48 m^3 of water. Considering the present mining scale, over 10 percent of current water resources will be affected.

3.2 Development of irrigation

(1) Water sources for irrigation purposes have declined and the actual irrigation area has been reduced. In recent years, owing to diminished surface water sources, decline of the groundwater table, ageing of irrigation projects and inconsistent management the actual irrigation area in the whole province has shown a descending trend, from 16.3 million to 12.2 million *mu*. Agricultural capability to resist natural disaster has been mitigated and stable agricultural development has been affected. During the 10th Five-year Plan, the highest annual grain output in Shanxi was 10.6 billion kg and the lowest was 6.9 billion kg, a difference of 35 percent. Areas that can be irrigated according to crop water demand account for 50 percent of actual irrigation areas; most of the other locations can only be watered once or twice a year.

(2) Investment in irrigation projects is seriously inadequate and there is no water conservancy policy. At present, investment in construction and reconstruction of agricultural irrigation projects is insufficient; many projects constructed in the 1960s and 1970s have deteriorated — they evidence high leakage, and progress in renovation and water-saving reconstruction has been slow. Because there is no water conservancy policy, especially with regard to initial water rights distribution and water rights transfer, farmers have not been motivated to invest in water conservancy and only the government is active.

(3) Irrigation water charges are not in place and management is inconsistent. The agricultural irrigation water price in most irrigation districts was calculated, checked and approved in the 1990s, and the approved water price, which only accounts for 50 to 80 percent of cost, cannot sustain normal operations, let alone expansion. Because of lack of funds and poor benefits, professional technicians have left many medium and

small irrigation districts so research on and promotion of advanced irrigation technologies and facilities has been seriously compromised.

4. Countermeasures to address challenges and problems

The Shanxi Provincial Committee of the CPC and the provincial government have placed considerable emphasis on problems such as exploitation, utilization, harvesting and protection of water resources. After in-depth investigations, they are adopting a series of important measures to accelerate the development of water conservancy throughout the whole province.

4.1 Firmly establish a water-saving society and effectively utilize water resources

In order to realize the target of provincial socio-economic development with extremely limited water resources, it is essential to implement strict water-saving measures and take the lead in establishing a water-saving society in China. Shanxi is planning the development of a water-saving society, which will be implemented thoughout the province after being approved by the provincal government. This development is divided into three phases: Phase 1 will preliminarily structure the system and mechanisms for a water-saving society by 2010 and build demonstration sites; this will target a decline of water usage per 10 000 yuan by 35 percent. Phase 2 will tentatively build up a water-saving society throughout the province by 2015. Phase 3 will finalize the establishment of a water-saving society by 2020.

At the core of establishing a water-saving society is framework development and establishing water use management systems that address control and allocation of total volumes. Other factors include developing water resource management systems based on water rights and water market principles, forming water-saving economic mechanisms, continuously improving use efficiency and generating resource benefits and promoting harmonized development in general.

By the end of 2008, Shanxi will have completed the distribution of initial water rights and established a water rights transfer and transaction system. Through government policy guidance and market price regulation, enthusiasm will be generated throughout society to invest in water harvesting and obtain appropriate returns; people will understand that harvesting water will yield benefits. Persons and communities who waste water and use it inefficiently will pay higher rates for their irresponsibility. In order to guarantee practical implementation of total volume control and micromanagement systems for allocation, Shanxi needs to accelerate the establishment of a monitoring and control network covering main water users. At the same time, we should promote advanced water-saving technologies through policy measures. Practice has proved that policy guidance, price regulation, mechanism promotion and science and technology are the main components for constructing a water-saving society.

4.2 Scientific development, realizing the sustainable use of water resources

When inspecting Shanxi in March 2006, Premier Wen Jiabao pointed out that (*sic*) "the maximal restriction factor for Shanxi Province lies in water, we should research the permanent policy to resolve long-term poorness of water resources". *Vis-à-vis* water resource evaluation and planning, with 17 basin areas as units, Shanxi has determined water resource carrying capacity and exploitation and utilization potential, identified future needs and evolved a water resource allocation scheme based on the characteristics of different areas. In the east and southeast where water resources are relatively rich and surface water exploitation is lower, we should strive for support from the Ministry of Water Resources and the State Development's Reform and Planning Committee to accelerate the construction of surface water control and storage projects to meet the needs of coal, thermal power and chemical industries and ensure national energy safety. For the middle basin region where water resource exploitation is higher and groundwater overexploitation and ecological problems are prominent, while adjusting industry structure to restrict the development of industries with high water usage, we will adopt measures such as water conservancy, pollution control and recycling. We will add water supply from the South Main Line of the Wanjiazhai Yellow River Diversion Project (including transport to the Fen River) and promote the construction of the North Main Line of the Yellow River Diversion Project, in an attempt to raise the water carrying capacity in this region. For external water diversion, we should arrange for certain areas to recharge overexploited groundwater to redress the natural balance; for the western loess hills and ravine regions where water exploitation and utilization are relatively worse, while controlling exploitation intensity and strengthening protection, we should encourage the excavation of wells to harvest rainfall and warp dam construction.

In the context of reservoir construction, we should determine project scale and not construct large reservoirs if medium-scale infrastructure is sufficient. Reservoir flood calculation should address the long term, while water supply calculation should address the short term, in order to avoid constructing large but unnecessary capacity. The targets of new water projects are mainly cities and industry and the guaranteed water supply rate is high (95 percent); we will advocate methods to streamline delivery and avoid extraction from a single reservoir. In reservoir planning, we will insist on moderate and rational exploitation of rivers.

4.3 Multiple investments, realizing the development of water conservancy in Shanxi Province

In order to change the passive condition of the construction of water conservancy infrastructure projects, we need to increase investment. We should completely change the original approach of simply depending on single governmental investment to finding multiple investment opportunities for the construction of water conservancy infrastructure. We should exploit the fact that the State Council is carrying out its sustainable development policy and experimentation in the coal industry to develop methods for restoring the natural environment degraded by coal mining and to resolve the problems of compensation and recovery.

4.4 Resolving ecological problems, adding scenic value to Shanxi Province

The Fen River is the mother river of Shanxi Province but the scenic value of her surrounding landscape has vanished. Objectively speaking, it is very difficult to maintain a favourable ecological environment in a province where the climate is dry, water resources are scarce and energy industries proliferate. In the North China scenario where rivers have dried up, water is polluted and water supply has drastically diminished, it is also unrealistic to expect to return the ecology to its former state *in toto* before the 1960s. Our proposal is to initially resolve ecological problems in major watercourses such as the Fen, Qin and Sanggan Rivers so that they can serve city perimeters. There are two core measures to restore and maintain healthy rivers: (1) treating sewage and wastewater entering rivers and (2) ensuring minimum loss of riverine assets. In June 2006, Shanxi Province began to implement the “Blue Sky and Green Water Project”; targets include restoring water quality upstream of the Fen River to potable standards, and water quality in the middle and lower river reaches to meet standards for agricultural irrigation. In September 2006, Shanxi Provincial People’s Congress decided to further protect Fen, Qin and Sanggan headwaters. Currently, the provincial water conservancy department is implementing this decision with relevant departments, cities and counties.

4.5 Retaining agricultural area and effectively raising irrigation quality

It is important to develop irrigation to ensure stable agricultural development, alleviate rural poverty and enhance farmers’ income in the context of developing rural areas. Our general strategy is to maintain the irrigation area in the whole province at 19 million *mu*, stabilize annual average water usage for agricultural irrigation at approximately 3.8 billion m^3 and focus on improving irrigation water quality while stabilizing the total volume. Major tasks include:

- Supplement the irrigation area by 3 million *mu* through renovation, infrastructure construction and regulation.
- Raise the utilization coefficient of irrigation water to 0.56 via water-saving infrastructure in irrigation districts and promoting advanced water-saving irrigation technologies. Saved water will be used mainly to add to the net irrigation water volume in fields and enhance irrigation assurance.
- For the region along the banks of the Yellow River in South Shanxi, develop 1 million *mu*, irrigated by diversion from the Yellow River, promote organic agriculture and high quality fruit bases and replenish overexploited groundwater in the Yuncheng Basin.
- In the Loess Plateau, develop 0.4 million *mu* via rainfall harvesting, construct 10 000 silting dams and add 0.5 million *mu* of irrigated area to help restore 2.5 million *mu* of cultivated sloping land.

4.6 Deepen reform and extend the development model of the Jiamakou Irrigation Scheme

To increase agricultural output, enhance farmers' income and facilitate operations under market economy conditions, Jiamakou Yellow River Diversion Administrative Bureau of Shanxi Province has deepened reform of the management system and devised the following approaches:

- Marketing of water supply management and implementing a contract system for water supply, with "water tickets" as the main component.
- Disseminating information on water supply management and establishing an irrigation information network system (from the administrative bureau to farmers) to enhance the transparency of water supply procedures.
- Instituting democracy in irrigation scheme management; establishing WUAs and a canal distribution management committee to carry out democratic management and supervision.
- Automation of project management; adopting advanced management methods and engineering measures to keep water sources stable and improve irrigation efficiency.

4.7 Research and extension on advanced irrigation technologies

Climate, terrain, soil and irrigation conditions in Shanxi Province are diverse so it is necessary to learn and acquire advanced irrigation technologies from abroad and combine them with indigenous practices for the modernization of irrigation. Since 2002, in this regard, Shanxi Province has carried out a number of projects in Jinzhong City and provided reference and highly effective water-use models for similar locations. Taiyuan City has acquired considerable experience on water rights distribution, water use allocation management and computation as well as monitoring for agricultural irrigation.

Currently, we are in the key phase of assessing water resources throughout the province and evolving policies and countermeasures. Hence, we are probing experts for advice to promote water resource management and irrigation modernization in Shanxi.

SECTION 3: SUBTHEME MEETINGS

SUBTHEME I:
OPTIONS FOR STRATEGIC AND POLICY INNOVATIONS AT THE RIVER BASIN LEVEL

Technical issues in modernizing farm irrigation systems: Some experiences in Mediterranean countries

Bruno Molle[1]

1. Introduction

In Mediterranean countries most available or accessible water resources are already exploited. Considering that the irrigated agriculture sector annually consumes up to 80 percent of water resources, and up to 90 percent in the peak demand period, every small decrease in this consumption will make more water available for other uses and reduce conflicts.

To promote this objective, governments are implementing policies based on tariffs and quotas, as well as modernization programmes to improve equipment and practices (Molle *et al.* 2004).

After years of massive investment in large infrastructures (Bouderbala 2004), governments now prefer to provide support to small private farms. Such support appears to be more cost effective per hectare, it allows farmers to become involved in the economic process, it helps to settle rural populations and it contributes to the development of local industry in rural areas while promoting extension service infrastructures dedicated to farmers (Gadelle 2002).

Moreover it appears that modernization policies that target farms are more successful when seeking step-by-step improvement, rather than through revolutionizing practices (Kay 2001). Participatory management systems that involve farmers give them a greater stake in system operations, which facilitates communication between the farmers and policy-makers (Loubier and Garin 2006). This implies creating farmer associations that allow end users, managers and political authorities to interface (Spadana 2004).

Modern irrigation techniques certainly have the potential to improve water and human power productivity. But their introduction is mostly driven by commercial stakes rather than water-saving concerns (Brabben 2001).

The financial and administrative tools employed to help manage irrigation systems have improved situations, but on-farm system durability remains too poor. To be effective, modernization policies should be based on an integrated analysis of current situations and practices, encompassing different levels of scale from farm, network to river basin (Vidal *et al.* 2001).

The farmers' priorities are often very different from what other stakeholders think. These differences may lead to conflicts or at best misunderstanding. The recurring problem is that farmers are not well represented, so their expectations are not considered by other stakeholders, or through the "filter" of other experts.

With this in mind, the Inco-Wademed Concerted Action was developed to: (i) Assess water management experiences in Maghreb countries, (ii) identify factors that hamper the implementation of water-saving measures and (iii) put forward recommendations for improving water demand management policies. To this end, a database of water management modernization experiences and their results has been created (www.wademed.net). A first workshop entitled "Modernization of irrigated agriculture" organized in Rabat, Morocco in 2004, focused on the exchange of experiences concerning technical issues. Recommendations

[1] CEMAGREF (a public agricultural and environmental research institute) France. Email: bruno.molle@cemagref.fr

proposed during this workshop are widely referred to, and commented on, in this paper. Two other workshops were organized on the same principle in Tunisia (2005) and France (2006) respectively on "Institutions and policy-making" and "Implementation of participative water management solutions".

In this paper, the modernization of farm irrigation systems will be assessed. The main focus will be on farmers and their interaction with water managers, policy-makers, equipment dealers, manufacturers' policy or product processors.

By modernization of on-farm systems we mean principally the conversion of farmers from traditional to supposed higher performance (i.e. modernized) practices and techniques. This is understood as the operation of water-saving technologies, most often the use of micro-irrigation, sometimes the implementation of irrigation scheduling. All of these factors should allow water to be saved provided a number of conditions are fulfilled.

2. Farmers and water management

Farmers expect the water manager to provide them with a reliable water supply in terms of volume and time scheduling. The modernization of irrigation systems usually involves adjusting water-application timing of irrigation equipment to plant water demand, both of which are linked to climatic and water supply conditions.

With unreliable water supply, precise irrigation scheduling methods cannot be properly implemented, even if the annual water volume at the farmer's disposal is sufficient. However the principal criterion used by water managers to evaluate their own level of service is more monthly volume supplied than daily or at least weekly supply, consistent with plant water requirements throughout the cropping season. Any insecurity in water supply will lead farmers to implement precautionary water management strategies that integrate variability in supply.

In pressurized systems, when the farmer is not sure about the next date of water delivery, he will maximize water application when water is available to fill the soil reservoir and wait for the next water distribution shift (see Plate 1). This will obviously lead to leaching or drainage and salt contamination of water tables. In Plate 1, the farmer's behaviour results in unreliable hydraulic parameters and jeopardizes good application performance with pressurized systems for those farmers who are more distant from the pumping station.

Plate 1. Filling up of a soil reservoir

The same issues affect gravity systems as irrigation techniques cannot be effectively improved when irrigation intervals are so long that the water holding capacity of the soil cannot provide enough water to plants between irrigations.

To secure water supply when possible, farmers operate private pumping facilities or storage, even if this water is saline. Thus, depending on the water supply schedule, networks will be considered as a mitigation solution (the coastal area of Doukala, Gharb, Tadla in Morocco). This may contribute to soil salinity and related water table depletion due to salt leaching.

If a reliable water supply is not guaranteed water supply cost recovery will become a problem. The farmer will hold the water manager responsible for his income decrease and he will not accept charges for a water service that does not allow him to obtain good production results.

Consequently the water manager will delay system maintenance, thus leading to lower levels of service and reduced cost recovery (Mouhouche and Guemraoui 2004). This vicious circle must be broken. The participatory path seems the more powerful and cost effective way to bring about changes, involving all stakeholders' representatives.

For the Tadla irrigation system (Morocco), the local water management company has developed dialogue with water users through Association Tadla de l'Irrigation Localisée (ATIL), a water users' association (WUA) that it helped to set up.

Thanks to good levels of water distribution, equitable water allocation practices partly rely on the development of private storage (Plate 2) and cost recovery is higher than 95 percent. The canal-based distribution system is able to provide a service approaching on-demand supply. Each farmer is allocated a yearly quota based on water available in the reservoir. Micro-irrigation users are allocated a higher quota than those using traditional techniques.

Plate 2. Private storage tank, Tadla, Morocco (for a 65-ha citrus farm)

An allocation system based on water order forms has been implemented through the ATIL. This lets farmers co-manage their access to water. They share local water distribution shifts that are based on individual requirements (micro-irrigation users have different water quality requirements to those of surface irrigation users) and private storage capacity.

The problem is that equity is not really achieved because:

- The WUA has been created by and for farmers operating drip irrigation.
- Priority in access to water is given to micro-irrigation users over surface irrigation users.

Such a policy intends to accelerate a switch to pressurized irrigation systems, but in fact it favours farmers with greater financial resources and may result in an increased rural exodus of poor farmers. An adapted financial support policy may prevent such an adverse effect from happening.

In the Moulouya irrigation system (Tizaoui 2004), the Mohamed V dam supplying water to the area is partly clogged with sediment, reducing its capacity to 45 percent of its original value. The water management company, in cooperation with the government, has helped farmers to design and manage private storage tanks that are geo-textile lined and to modernize their irrigation techniques. These tanks represent a major cost which doubles the total investment compared with that required for the plot distribution system alone. Subsidies amounting to 40 percent for individual farmers and up to 60 percent for a minimum of three associated farmers are provided. This operation has improved the scheduling of water supply to single farms. Lastly the more secure water supply provided by individual storage, along with the implementation of quotas and associated modernization of application techniques, has freed up approximately 30 percent of former volume, which can now be used by other users. This is mainly due to the decrease of precautionary practices (excess water application when available), increased water use efficiency and modern scheduling methods. The local water management company has created an extension service which is a key player in this successful modernization process.

In Tunisia, to improve poor farmers' access to modernization, the government operates cooperative measures such as higher subsidy rates (60 percent) for these farmers (Latiri 2004). Such cooperative solutions could be extended to all types of agricultural equipment providing a legal framework is implemented.

In areas without networks, management will concern the water table. Basin management authorities are responsible for such management. Pumping authorizations are delivered accordingly, but, due to overpumping or changes in management policy, new authorizations are no longer given. The consequence is an increase in unauthorized pumping (which is sometimes subsidized!) and greater difficulties in resource management. The basin authority will be forced to applying tougher regulations that may negatively impact profitable farming activities and may result in social unrest or prevarication by the authorities.

In 2002, in the valley around Damascus in Syria, overpumping by 20 percent over the last ten years has led many farmers to move away from their farms due to an increase in water table depth, which exceeds 100 m in some places. In 2006, the termination of pumping authorizations did not generate a reversal of the situation.

The same situation occurred in the Upper Barada Valley, close to the Lebanon border. The regional authority intends to create large wells and to use them as a means to control farmers' water withdrawals. These policies, which promote a "natural selection" process leading to the departure of poorer farmers, may allow the system to find a new balance, but generates considerable money wastage, firstly for farmers, especially when they have invested to modernize their irrigation systems, and secondly for the government when financial subsidies have been allocated. Even if conflicts fail to erupt, social tensions exist.

In Morocco, in the coastal areas of the Gharb Basin, private farmers have developed fruit and vegetable farms on sandy soils, pumping from the water table. Land is rented by "nomad farmers" who are not concerned about environmental sustainability. After ten years of major expansion, salt intrusion, nitrate and pesticide pollution are beginning to cause technical problems, along with pest pressure.

Local farmers have urged the basin authority to handle the situation, but the economic stakes have slowed down any initiative. The region is very economically dynamic and exports mainly to European countries.

3. Farmers and policy-makers

When access to water resources becomes difficult, farmers usually expect policy-makers to draft regulations aimed at fostering water allocation equity. Equity in allocation is one of the aims put forward by policy-makers, but it is seldom achieved.

3.1 Access to water

Generally when water becomes scarce or is inequitably distributed or when water distribution is unpredictable from public networks, wells dug without authorization multiply and governments stop delivering new pumping authorizations.

This situation was observed in Syria (Molle and Laiti 2003), where only one-third of the 180 000 existing wells were authorized. These wells irrigated about 65 percent of agricultural plots using one-third of the water resources of the country. Overpumping by 20 percent resulted in the drying up of one-quarter of the wells, which contributed, in a certain way, to pumping regulation — but it did not improve the situation. Volume uptake control may be the only way to manage water tables.

In the Parisian Basin in France, where the water table is under high pressure, every water withdrawal point is equipped with a water meter. Each farmer is allocated a yearly water quota. This management system requires knowing water table reaction to rainfall and withdrawals and good cooperation between all stakeholders. Withdrawals are declared annually by the farmer to the river basin authority, and are randomly verified.

This management method resulted in the preservation of the water table level, despite three successive years of rainfall deficit (2003 to 2005). A 25 percent reduction in water quotas did not generate a significant decrease in yield. These results are attributed to two factors: Quotas have been defined as comfortable and on-farm irrigation performance has progressed (AND-I, Cemagref 2006).

Landownership with regard to water access is also an important issue. Access to water resources is commonly linked to landownership which leads to numerous murky practices and related waste risks. In Syria (Molle *et al.* 2003) landownership is somewhat informal; many plots have been sold or inherited, without official registry to avoid paying taxes or administrative duties related to such transactions. Thus when farmers want to register their wells it is not possible, even if the previous owner had authorization. Consequently water uptake estimates are impossible due to lack of transparency.

When the farmer rents the plots he cultivates, and when contracts do not exist or are only yearly, the farmer will not be able to access water with transparency. In the meantime he will not attempt to adopt costly and complicated water-saving technologies and practices. This leads to uncontrolled water uptake and bad management practices, as mentioned previously for the coastal area of the Gharb.

Rules on pumping authorization should be clarified. Pumping authorization must be accessible for all farmers along with appropriate metering. This will make it possible to assess volumes with a minimum degree of accuracy. Once this is established, effective water management is possible through quotas or water pricing, which will have different impacts on irrigation technique modernization (Montginoul 2004).

3.2 Access to financial support

Developing modern water-saving techniques requires a minimum level of investment. Usually in developing regions, farmers have limited financial means, and will thus need access to subsidies or low rate credit to help finance modernization.

To gain access to credit, farmers have to be familiar with banks and their administrative processes. Only educated farmers possess this knowledge and smallholders need assistance. This was observable during the Syrian modernization programme in 2002, where less than 5 percent of available low rate credit was effectively used by farmers after two years of the programme.

When subsidies are offered the problem remains the same; the first candidates are those who do not really need such support. The smallholders apply later in the process and in some cases cannot gain access because of attribution rules.

We have observed this in Morocco and Tunisia (Molle *et al.* 2004), where subsidies were allocated to farmers modernizing their systems (40 percent of cost). Subsidy policy is framed in such a way that under 5 ha, projects are not cost effective. In Morocco, during the first 15 years, the average size of subsidized projects was 16 and 12.5 ha respectively for micro-irrigation and supplemental irrigation projects (AGR 2003). Then the government decided to allocate subsidies to complete systems (storage, pumping, distribution) and the average surface area decreased to 7 ha in 2005.

Observing that smallholders could not access these subsidies, the Tunisian Government decided to increase the rate of subsidy by 60 percent when at least three farmers present a joint subsidy application. This was successful thanks to the help of extension services (CRDA) in designing consistent and cost-effective projects.

Another point of concern regarding modernization subsidies is cost recovery. Support for modernization is often considered by farmers as a gift and not as an opportunity to help build a cost effective and productive production system. This results in neglected equipment and maintenance as noted later.

The help of extension services is the key to reaching sustainable modernization. They are very active in Tunisia as well as in Morocco. In Algeria now that the political situation has become more stable they are being progressively re-opened.

Extension services help farmers' decision-making on project dimensioning, they validate dealers' sales propositions, suggest changes in system design and participate in project inception. Their agreement is needed before subsidy allocation.

The extra work required for such a verification mechanism should be recognized and financed by the modernization programme.

Such subsidies and technical support policies have allowed Tunisia to increase the total surface covered by micro-irrigation in 2003 to 22 percent of the irrigated area. But these subsidies and support also cover other modern irrigation techniques whether pressurized (sprinkler: 27 percent) or not (surface irrigation: 25 percent). Water losses have decreased enormously; Vidal *et al.* (2001) cited up to 50 percent decrease in such losses in citrus production areas.

In Morocco the subsidy policy extension to private storage tanks decreased the pressure on public networks and created a water resource buffer capacity close to the areas of consumption. In Tadla management area it represents 4 percent of annual volume used by pressurized systems and gives an autonomy of ten days.

Where water distribution shifts are too long, such solutions helped achieve resource reliability.

Plate 3. Combined irrigation system to produce wet bulbs in the soil

3.3. Consequences of modernization: Identifying policy priorities

The **definition and conditions of subsidy allocation for modernization** are keys to reaching policy objectives. We can identify three priorities in modernization policies, generally given in the following order:

1. Decrease water use: The water-saving objective is always given first, even if it is rarely met. It justifies a clear preference of policy-makers for micro-irrigation solutions compared to more traditional sprinkler or surface systems, even if modernized. Scheduling methods are seldom considered by policy-makers. But the main point of concern is when micro-irrigation is chosen and developed, water consumption does not decrease (Molle *et al.* 2004); farmers simply re-allocate the water saved to other plots. Water savings originating in a switch to micro-irrigation can only be achieved if water supply is restricted through quotas (Tizaoui 2004; Molle *et al.* 2004).
2. Increase water productivity: This is usually considered as a regional economic objective and is always reached, at least in initial years. The problem remains that it is not linked to water saving — better

water productivity often results in increased water demand from modernized farms, and may result in market saturation.

3. Increase social welfare in rural areas: This is a logical consequence of modernization and incomes of the associated farmers increase. But the selectivity of governmental support may contribute to the deterioration of smallholders' conditions and facilitate rural exodus. On the other hand when analysing the consequences of modernization policy, the impact on the regional economy and employment may contribute to the increase of regional productivity and profitability. In France, the rate of direct employment for the production of open field-irrigated vegetables is one employee for 30 ha, while for dry cereal production this rate is 1/100 ha. Considering indirect employment, the rates are 15 ha and 100 ha respectively (AND-I, Cemagref 2006). In Southern France where greenhouse horticulture and vegetable production are developed the rates are one direct employment for 7 ha and one indirect employment for 2.5 ha.[2] In developing countries the rates may even be higher.

Modernization of irrigation techniques may result in considerable changes in the existing balance of the hydraulic system. Where traditional irrigation methods are modernized the existing beneficial losses will drop to zero. Increasing water use efficiency increases net water consumption, decreases leaching and associated water transfers to downstream users (Molle *et al.* 2006). Depending at what scale water use efficiency is considered, modernization of plot irrigation can be considered either good for the individual farmer or bad for the balance of the aquifer.

Lastly the sustainability of modernization policies should be questioned at all scales from farm to regional level, considering employment, incomes, rural activity and social welfare to achieve regional sustainability.

As mentioned previously the help of WUAs will allow modernization to become more consistent and integrated. To be sustainable these WUAs should have financial and decision-making autonomy; this implies an appropriate legal status and matching rules.

Numerous tools exist to help such processes, such as Olympe (Le Grusse 2001; Carmona *et al.* 2005) and can be used in participative analysis before any policy decision.

4. Farmers' expectations of irrigation equipment manufacturers and testing laboratories

4.1 Quality and durability

When governments actively support farm irrigation modernization policies, an expansion in the number of local dealers, installers and manufacturers usually follows. For example in Syria in 2002 approximately 140 irrigation manufacturer were registered, for an irrigated surface area of 1.35 million ha of which 0.2 million ha were under pressurized systems.[3] This is definitely excessive, and results in intense competition, which often leads to bad commercial and manufacturing practices.

Manufacturers will lower irrigation product quality to reduce production costs. As most equipment is manufactured from plastic compounds, they will buy low-cost raw materials, use low quality recycled plastics and save money on additives.[4] Product durability will thus be reduced.

Such situations will weaken "good" manufacturers because of unfair competition and generate considerable money wastage that may be fatal to smallholders with limited financial means.

The first step required to improve irrigation product quality is the development of a testing policy that establishes real performance characteristics within an independent laboratory using standardized protocols.

[2] Total irrigated surface area: 162 000, 25 000 and 75 000 ha direct and indirect employment. Source: Bouches du Rhône, Regional Authority, Marseille.

[3] The same numbers were reported in 2006 during the symposium.

[4] Protecting plastics from oxidation.

The government plays a key role in developing such laboratories and promoting quality verification mechanisms linked to modernization policies.

In Morocco between 2002 and 2004, the simple fact that testing of products to be subsidized was made compulsory resulted in an increase in dripper quality (Laiti *et al.* 2004): The highest quality class represented 60 percent of tests in 2002 and 72 percent in 2004.

Such a policy, conducted on new products after standardized sampling, is to be extended to products taken randomly from the field after installation to avoid any discrepancy between products evaluated in the laboratory and located in the field. Testing, which can be very simple, could be conducted by regional extension services at a very low cost.

4.2 Standardization and testing

Implementing a standardization process will help involve manufacturers more heavily in this quality policy. It provides a framework that allows all stakeholders to reach a consensus on different technical aspects of irrigation. This process is managed by a standardization committee comprising all stakeholder representatives. This committee should be balanced, as achieved in Morocco (Molle *et al.* 2005), and not monopolized by one category of stakeholders. It can be further consulted as a reference group on evaluation of modernization policy in a totally transparent way.

Moreover the standardization committee is in a position to help identify regional technical stakes and define R&D needs, bridging the gap often observed between field evaluation and academic research concerns.

The standardization process relies on references obtained by independent laboratories which verify the levels of performance of irrigation systems or products with those put forward by manufacturers. These laboratories should be public to avoid commercial pressure. A small amount of modernization programme funds could be put aside for this purpose. From our experience creating independent irrigation testing laboratories is a cost-effective water-saving initiative, provided they are closely associated with the modernization programme.

These laboratories should have resources to operate tests and integrate an international network for benchmarking. This is what INITL[5] is attempting through cross-testing, information, sample and methodology exchanges (INITL 2005). Recently this network was recognized as a key partner by the International Commission on Irrigation and Drainage (ICID) and also by ISO SC18 “irrigation techniques” for standardization processes. The results obtained in the framework of a cross-test on sprinklers (11 laboratories in the world) were integrated in the new revision of ISO 15886-3 on sprinkler testing.

With regard to the development of regional laboratories, they should take advantage of close cooperation with universities to develop staff skills through R&D cooperative studies in association with local manufacturers or dealers.

4.3 Quality in manufacturing and installation processes

As most irrigation products are manufactured from imported plastics, manufacturers should create their own quality assurance processes to verify the characteristics and quality of compounds they will use in their manufacturing processes. The implementation cost of such verification laboratories requires a minimum manufacturing plant size to be effective. It can be externalized provided that it is justified by market demand. In Syria in 2002 negotiation between manufacturers and the Damascus Chamber of Commerce was initiated to create a small private laboratory dedicated to plastic material testing. In 2006, without any willingness from the government to operate a quality policy, nothing had been made.

This will certainly contribute to cleaning up the market, reduce the number of manufacturers in Syria based on quality and performance criteria but it will also contribute to saving considerable amounts of private as well as public money and people’s energy.

---

[5] International Network of Irrigation Testing Laboratories: 21 members in 2006 (CENTEC Australia, Brazil, Canada, China, Egypt, France, India, Italy, Israel, Japan, Republic of Korea, Malaysia, Mexico, Morocco, Portugal, South Africa, Spain [2 laboratories], Syria, United States, Zimbabwe).

The competition among dealers to provide cheap solutions for poorly educated farmers will inevitably lead to lower system quality. In Morocco and Tunisia the government has linked subsidy attribution to equipment or system design quality verification for field systems. Subsidies are given to systems verified by regional extension services (from water management companies or regional agricultural authorities) and after system installation in the field.

Such verification processes have been very effective in Morocco in support of subsidy policy for farm irrigation systems. They lead to better system design (as illustrated further) and reduce the number of incompetent system installers.

4.4 Technology transfer

Equipment modernization is generally associated with more complicated operational processes. It requires specific skills that farmers may not possess. The consequence is often that the dealer must offer an extension service role when selling his equipment.

To avoid such distortion, the government should link the allocation of a share of its subsidies to technology transfer as it is an integral part of the modernization process. The implementation of a technology transfer framework should be managed by the national laboratory in cooperation with extension services. Technology transfers will be needed for the field operations of modernized systems and subsequently for maintenance of the systems.

It is the responsibility of the dealer to tell farmers how to maintain their systems so that a satisfactory level of durability is attained. Documents to this effect should accompany system delivery in addition to hardware. In Morocco, subsidies are not attributed if these documents are not provided.

In micro-irrigation systems for example, if maintenance is satisfactory, system durability should be more than ten years. In France the average value is often lower than five years. The main reason for such poor durability is bad filtration characteristics and incorrect maintenance which lead to partial clogging of drippers. When the farmer is not aware of the deterioration of system distribution performance, observing locally grown plants showing evidence of scarcity, he will consider applications to be insufficient and increase irrigation duration. In Tunisia, Mailhol *et al.* (2005) measured water efficiency under three-year-old dripper systems and discovered that 50 percent of them were less efficient than some traditional surface systems.

A long-term reference study conducted in South Africa (Reinders 2003) on 42 plots showed that after the second year of operation, 67 percent of pressure regulating drippers and 42 percent of non-regulating drippers were clogged (i.e. the flow rate had changed by more than 20 percent). A training programme for farmers that focuses on maintenance processes is now underway and managed by the national laboratory of ARC in Pretoria.

4.5 Appropriateness of modernization policies

To ensure that modernized irrigation options are adapted to local conditions (water quality, reliability of supply, availability of spare parts, farmers' skills, farmers' financial capacity), a thorough investigation should be carried out prior to any modernization of field irrigation systems. The national laboratory will prepare guidelines for modernization in different contexts based on existing experience. Such a process has been successfully implemented in Morocco to prepare guidelines on field irrigation systems' design and their field installation. These guidelines are to be used by extension services and are being standardized in Morocco. This could easily be applied in countries with similar climate and water supply conditions.

If the modernization of farm irrigation systems is supposed to be subsidized the rates applied must be fitted to the local financial conditions. The objective is to obtain an important lever effect by attenuated financial incitation apropos irrigation cost. In France irrigation costs represent approximately 20 percent of the total cropping costs, among which 50 to 70 percent represent equipment cost for centre pivots or hose reel guns. As a consequence subsidies applied to equipment will incite renovation of equipment, representing a small part of the investment; this can have an enhanced effect on the productivity of the system and on water productivity. The degree of incitation will depend on the proportion of the subsidy related to the cost of equipment, the maximum amount per project and the technical rules applied to access the support.

Finally the modernization policy should be evaluated periodically and revised if required. A set of indicators is needed to evaluate changes in farm performance in terms of water and more generally input productivity, incomes and cost recovery. Indicator ranking will comply with modernization policy priorities.

The use of actor models (Le Grusse 2001) can be very helpful for identifying gaps in modernization processes as well as anticipating the consequences of policy decisions at the farm scale, and then at the small region scale in terms of production, productivity, income and employment.

5. Processing and marketing of farm products

The priority of the farmer is to assure a minimum level of income for his family and venture. His production strategies are subject to this objective. Small family farms prefer to ensure daily income, while bigger farms will seek credit for investment to obtain higher profits and to meet longer term objectives.

Small farms will diversify production to ensure regular incomes (producing milks, poultry, eggs and vegetables for example) while bigger farms will focus on making profits.

Generally the small farms are connected to local markets and not to industrial or export networks. Production is usually variable in terms of quality and quantity. These farmers are not organized, are subjected to the constraints and fluctuations of the market and are unable to secure their production process.

They may grow some specific crops to access water. For example in Morocco sugar (beet or cane) or milk production allow access to water rights (notional strategy). Part of this water is then diverted to other more cost-effective crops.

These farmers mostly use traditional surface irrigation techniques. They will convert to modern techniques if they are obliged to. This occurred in Moulouya (Morocco) and in Tunisia for water scarcity reasons, or implementation of quotas.

On the other hand, larger farmers or dual activity farmers will specialize production and contract with the food-processing industry based on quality and quantity requirements. They are contractually obliged to implement specific production processes and techniques, including irrigation. Irrigation is considered a prerequisite for access to such markets as it is considered important for quality and production regularity. These farmers will be very receptive to any modernization programme that improves the reliability of their production system and that secures their incomes. By grouping with others, they try to maintain maximum levels of added value of their production on the farm — storing, sorting, packing and conditioning products — as seen in European countries.

Modernization policies should promote such cooperative solutions for groups of farmers based on shared management of equipment.

Modernization of irrigation techniques will always result in production increases and may result in local market price decreases, unless no market organization is anticipated. Cooperative organizations will help farmers become stronger, but some technical assistance is needed to promote such a process. It will result in better production control to adapt to existing markets and in farm income increases, while keeping rural populations in place.

Such cooperative organization allows better irrigation and cropping technology transfer and may contribute to water savings (dissemination of scheduling techniques, deficit irrigation methods). The WUAs can be a first step in achieving this new form of organization. These associations should be designed to initially promote water-oriented cooperative initiatives and then to become multipurpose.

6. Farmers and water conservancy

6.1 Productivity issues for farmers

As mentioned previously farmers are primarily focused on land productivity by trying to maximize the gross profit margin per hectare (Montginoul 2004). They will extend their irrigated surfaces and re-allocate the water saved by the modernization of the distribution system to new plots. Water productivity is not a priority issue, except when water becomes scarce or volumes limited. If the water price increases, water is considered as an input and managed accordingly on the farm. It will be allocated where cost return is the highest. In both cases scheduling methods must be part of the modernization process; water saving may be a secondary achievement.

When farmers develop private pumping they will favour this solution instead of a public network. It is generally more reliable, does not require any anticipation (water shifts) and in some (many?) cases, unauthorized pumping is left unpunished. When water shifts are too long, it is the only way to gain access to modernization, anticipate irrigation scheduling and thus save water.

Private pumping is not considered expensive by the farmer when equipment has already been purchased; direct operating costs (energy) will be regarded as the only cost.

In addition, pumping often provides water of better quality in terms of suspended material, making it easier to filter for micro-irrigation. When salinity increases in water tables, water from the public supply will be used to mitigate salinity.

6.2 Cost effectiveness of modernization

Modernization is generally cost effective during initial years because of production increases for an equivalent amount of water.

For example water productivity has been increased by a factor of 2 in the Doukala management area for different drip-irrigated vegetable crops (Majouj and Akartit 2004; Plate 4) compared to traditional hand moved sprinkler systems subject to leakage, sprinkler ageing, plugged or worn out nozzles, inappropriate spacing, pressure variations and losses due to drift and evaporation.

In olive tree production in the Damascus region, a farmer visited in 2002 has paid back his micro-irrigation system after the first campaign thanks to production increases.

Plate 4. Private pumping for potato production, Doukala, Morocco

As mentioned previously to be cost effective a modernization project must attain a minimum surface scale. Farmers are often reluctant to group with neighbours to operate equipment in common. Nevertheless, the need for heavy equipment and infrastructure in modern agriculture requires a minimum surface area to be cost effective.

For instance, in Northern France, vegetable production (potatoes, beans, spinach) is considered to be cost effective from 100 ha. Farmers group to form CUMAs (Cooperative for Shared Use of Agricultural Machinery) which provide a solid framework for the management of such associations. The CUMA allows the sharing of equipment and infrastructure for seeding, planting, cropping, processing and conditioning of vegetables, and thus decreases its cost per hectare.

Under the same legal framework, there are examples of groups of farmers managing a centre pivot. The principle of the WUA with extended purpose can be applied for such an activity too.

Modernization policies should facilitate cooperative solutions that are cost effective, more equitable and reduce the numbers of smallholders who abandon agriculture.

6.3 Efficiency of farmers' practices

In modernized areas, farmers still use practices inherited from the past. In micro-irrigation they only stop irrigating when water begins to pond. When they see head loss increases they often remove the filter cartridge (Plate 5), fail to replace it when torn, are unaware that some drippers can be cleaned (Plate 6), and when a part of the plot appears dry, they increase total plot application. When performance decreases too much, they simply keep the pipes for improved basin irrigation (Plate 7). After such failure these farmers are very reluctant to modernize their practices and in addition, they discourage their neighbours from switching to other water-saving techniques.

Plate 5. Filter cartridge

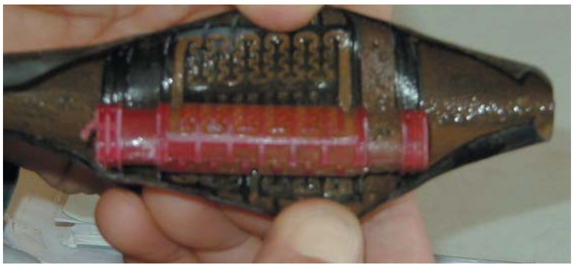


Plate 6. Drippers can be cleaned

Plate 7. Improving basin irrigation

This is widely observed, except in areas where extension services exist. They assure technology transfer, and make transition more feasible. Where no technical support is proposed, the dealer will be the technical reference — even if many are honest and do not take advantage of the situation, they may not be competent, especially in recently modernized areas.

On the other hand farmers usually purchase the cheapest equipment, disregarding its performance and durability. They consider that it will always be better than former surface techniques.

Very often small farmers cannot afford to purchase the equipment, even when subsidized. Many dealers wait for the first yield to be paid; such a "service" has a price which has to be paid back somehow. When price competition is very tough, dealers will buy cheaper products. This results in constant changing of brands and models which makes it complicated to find spare parts when they are needed.

Dealers should commit to a minimum service follow-up for provision of spare parts lasting at least five years to keep equipment durability consistent.

Finally, when speaking with farmers in areas under modernization they preferred a step-by-step modernization strategy to allow minds to adapt to the changes involved, instead of a complete overhaul of methods and practices. Farmers appear to be very conservative especially when they do not understand the process — whether it be political or technical in nature.

Modernization policies should also promote improvement of traditional methods and practices, instead of a complete system overhaul that will often frighten away poorly educated farmers.

7. Conclusions and recommendations

To be effective, modernization of farm irrigation requires a global approach to the problem. The consequences of any irrigation system modifications on water consumption and on farm economic performance must be properly assessed.

During the planning of the modernization policy, all stakeholders should be involved. In particular, this participatory planning has to reserve a prominent place for farmers on whom the success of the process heavily depends. This involvement could be made through a steering committee which will have to work initially on the definition of the modernization policy framework, and then estimate yearly its consequences for revision purposes.

The points on which the policy steering committee for modernization will have to focus are:

- Access to water and water supply: Reliability of water supply and access to water are decisive factors for the farmer when organizing his water volume or quota management strategy. The farmer will first try to secure his water resource before optimizing its use. Then he will firstly anticipate modernization of his equipment to optimize water application; secondly, he will think about changing his scheduling practices to increase land and water productivity. Water productivity is not necessarily associated with water saving at farm as well as regional levels.
- Water saving at the farm scale will benefit other farmers if water use is limited. If it is not, water saved will be re-allocated to other plots.
- Transfer of technology: On a regional basis, the whole technical environment must be improved (farmers, extension staff, dealers). The dealers often tend to sacrifice equipment quality to decrease prices. To avoid a decline in system performance and durability, a regulation process should be set up to define the minimum technical characteristics of products (parts) and field systems. A standardization process can meet this requirement, reaching consensus on technical issues through a participatory process. The standardization committee will serve as a reference body for the work of the policy steering committee for modernization.

- Once modernization is underway, its success depends heavily on good technical assistance. Such support is required over two to three years, through frequent visits to farmers and the establishment of farmer-managed demonstration sites.
- In developing countries, where numerous farmers have limited financial means, access to subsidies or loans will allow modernization to reach the smallholders. The definition of a subsidy policy that provides a powerful modernization policy control mechanism will have to focus on equity of allocation between the farmers to limit any social risks associated with the industrialization of agriculture.

As the modernization process is long and complex, and involves numerous stakeholders, periodic auditing, managed by a policy steering committee for modernization, is necessary. The efficiency of modernization policy must be questioned and analysed using performance indicators to appreciate:

- The level of modernization development (surfaces concerned, techniques used, regions involved, size of projects, proportion of collective projects).
- The cost–benefit ratio of the modernization process: Cost of cubic meters saved at local and regional scales, the evolution of water productivity and the evolution of the volumes applied per hectare — including negative effects on water management areas and water distribution equity.
- The equity of modernization and its social impact: Size and number of farms concerned, employment impacts at local and regional scales and average farm income.

Numerous activities on this subject should be adapted for awareness campaigns and used for regional analysis of irrigation modernization stakes. It is one of the objectives of the Wademed European programme and of the Sirma[6] programme supported by the French Government (2003–2007).

Bibliography

AGR. 2003. *Suivi des aménagements hydro-agricoles réalisés par le secteur privé avec l'aide financière de l'etat. Etat d'avancement au 30 Septembre 2003.*

AND-I, Cemagref. 2006. L'irrigation sur le Bassin Seine Normandie, etat des lieux et perspectives. Expertise report for Parisian Basin Water Authority.

Bouderbala, N. 2004. *Institut Vétérinaire HASSAN II, Rabat (Maroc). L'aménagement des grands périmètres irrigués: L'expérience marocaine.* Cahier Options Méditérranéennes. Rabat (Maroc), CIHEAM.

Brabben, T. 2001. *Affordable irrigation technologies for smallholders in South Africa.* Mission report August 2000.

Carmona, G., Le Grusse, Ph., Le Bars, M., Belhouchette, H. & Attonaty, J.M. *Construction participative d'un modèle d'aide à la gestion collective de la ressource en eau. Application au cas du Bassin Aveyron-Lère.* Paper presented at the symposium "Territoires et enjeux du développement régional", Lyon, 9–11 March 2005.

International Network of Irrigation Testing Laboratories (INITL). 2005. Draft report of sprinkler distribution measurement results collected from 10 laboratories in the world (available from B. Molle).

ISO. 15886-3 irrigation equipment — irrigation sprinklers — Part 3: Characterizing of distribution and test methods.

Kay, M. 2001 *Smallholder irrigation technology: prospects for sub-Saharan Africa.* Knowledge Synthesis Report No. 2, March 2001. FAO/IPTRID.

Laiti, A., Penadille, Y. & Chati, T. 2004. *Action des laboratoires d'essais dans un processus de modernization des irrigations.* Wademed workshop 1, April 2004, Rabat, Morocco.

Latiri, R. 2004. *Les efforts de modernization de l'agriculture irriguée en Tunisie.* Wademed workshop 1, April 2004, Rabat, Morocco.

Le Grusse P. 2001. *Du "local" au "global": Les dynamiques agroalimentaires territoriales face au marché mondial. Quels instruments d'aide à la décision pour l'élaboration des stratégies territoriales?* Cahier Options Méditerranéenne, Série B, Etudes et recherches, 32.

6 Systèmes Irrigués au Maghreb.

Loubier, S. & Garin, P. 2001 Strengths and weaknesses in long-enduring irrigation institution management. *Agricultural Water Management,* 2006. In press.

Majouj, M. & Akartit, A. 2004. *Promotion des techniques d'irrigation à économie de l'eau dans le périmètre des Doukkala.* Wademed workshop 1, April 2004, Rabat, Morocco.

Molle, F., Wester, P. & Hirsch, P. 2006. River basin development and management. Chapter 17 of the Comprehensive Assessment of Water Management in Agriculture. http://www.iwmi.cgiar.org/Assessment/index.htm. Draft version.

Molle, F. & Turral, H. 2004. *Demand management in a basin perspective: is the potential for water saving overestimated?* International Water Demand Management conference, June 2004, Dead Sea, Jordan.

Molle, B. & Laiti, A. 2003. *Establishing an irrigation standardisation process in Syria.* Report for FAO/UNDP, Project SYR/02/03: Support to the Development of National Standards for Locally Manufactured Modern Irrigation Equipment. Cairo, Egypt, FAO Regional Office for the Near East.

Molle, B., Chati, T., Laiti, A., Lévite, H., Latiri, R. & Yacoubi, S. 2004. *Quels enseignements tirer des politiques de soutien à la modernisation de l'irrigation à la parcelle?* Wademed workshop 1, April 2004, Rabat, Morocco.

Molle, B. & Belabbes, K. 2005. Technical aspects of irrigation systems modernisation: experiences in Mediterranean countries. ICID congress, Beijing. Question 52: "Policy options for water saving in agriculture".

Montginoul, M. 2004. *Les instruments économiques de gestion de l'eau, entre concurrence et complémentarité.* Economie des équipements pour l'eau et pour l'environnement. Cemagref.

Mouhouche, B. & Guemraoui, M. 2004. *Réhabilitation des grands périmètres d'irrigation en Algérie.* Wademed workshop 1, April 2004, Rabat, Morocco.

Reinders, F.B. 2003. *Performance of drip irrigation systems under field conditions.* ICID 20th European Regional Conference. Workshop on "Improved irrigation technologies and methods: research, development and testing". Montpellier, France, September 2003.

Spadana, J. 2002. *Promoting farmers networks for water sector reforms.* INPIM: www.inpim.org, Farmers Networks.

Tizaoui, C. 2004. *Promotion de l'irrigation localisée dans le périmètre irrigué de la basse Moulouya.* Wademed workshop 1, April 2004, Rabat, Morocco.

Vidal, A., Comeau, A., Plusquellec, H. & Gadelle, F. 2001. *Case studies on water conservation in the Mediterranean region.* IPTRID–FAO report.

Wademed. www.wademed.net

Integrating urban and rural plans and promoting the development of rural areas

Zhang Zhongfa[1]

1. Guidelines for new rural development

The central government's proposal for rural development has received considerable interest nationwide. In particular, experts and government officials have explored innovative ways to adjust measures to local conditions and prepare suitable guidelines. For instance, the land can be divided into three sectors: "Developed", "intermediate" and "undeveloped" areas. Using economic zones as bases for further disaggregation, they can be split into, *inter alia*, grain, cash crop, forest, prairie and fishery zones. On the basis of topography, classifications can include plains, hills and mountains.

State compartmentalization into three administrative divisions will facilitate the promotion of different policies to support development projects: Primary administrative villages (villages in cities); secondary administrative villages (villages that are merged); and tertiary administrative villages. Tertiary villages are part of the land that will not be urbanized over a relatively long period of time. With the transformation of the old institution into a new system, the adjustment of economic structure and the policy of liberalization, such land will experience a transition in the context of agricultural modernization. As such, the basic characteristics of rural development in China will feature four agricultural "modernizations" and four "transformations".

1.1 Four agricultural modernizations

Modern agriculture will have the following major characteristics: (1) Agricultural production will intensify; (2) the market mechanism will govern agricultural production; (3) science and technology will affect production, processing and marketing of traditional agricultural products through farm mechanization, upgraded water conservancy and automation of associated equipment; (4) urban–rural integration (reduction in disparity between urban and rural areas, narrowing of the division between agricultural and industrial profits and parity in income between farmers and city residents).

1.2 Four agricultural transformations

(1) Agriculture is transformed from purely traditional agricultural production to modern agriculture in which the economy, society and ecology develop in juxtaposition; (2) the rural economy is transformed from a township collective to a diversified economy (including industry); (3) rural society is transformed from the bifurcation of urban and rural areas to a modernized new countryside with coordinated development of urban and rural areas; (4) farmers are transformed from traditional small producers to empowered and artisanal workers.

2. Overall planning of urban and rural areas: General guidelines for rural development

- Scientific planning and structured layout.
- Deepened reform and solving the problems associated with rural development.
- Gradually establishing a governmental system that serves new rural development.
- Improving comprehensive agricultural productivity and assuring grain safety.
- Developing a comprehensive rural economy and steadily increasing farmers' income.
- Addressing new farmers and strengthening the status of the developed countryside.

---

[1] Research fellow, Ph.D. Tutor, Development Research Center of the State Council, China.

3. Overall planning of urban and rural areas, the focus of rural development

The main elements will be: Overall planning of urban and rural areas as well as the acceleration of urbanization, information dissemination, industrialization and farmers' enrichment.

With farmers' increase in income, we should also expedite the development of modern agriculture and the adjustment of rural economic structure.

3.1 Establish the state infrastructure mechanism

- Strengthen the development of comprehensive agricultural production capacity.
- Address the issue of marginalized farmers' living facilities.
- Enhance rural infrastructure construction.

3.2 Accelerate the development of a rural society

- Promote the balanced development of urban–rural compulsory education.
- Re-inforce the provision of rural public health and basic medical service facilities so farmers can access doctors easily.
- Gradually explore rural security systems.

4. Water conservancy in new rural development

The 11th Five-year Plan is a critical period for the creation of a more affluent society and is an important time for rural development; it will also be instrumental in enhancing the construction of water conservancy infrastructure through "democratic management"[2] and by "fostering civilization".[3]

Water-saving infrastructure (WSI) is essential to: (1) Increase capacity for disaster prevention and reduction; (2) promote the development of agricultural production; (3) improve farmers' living conditions; and (4) improve the ecological environment.

Construction of rural WSI to "improve living standards" will introduce new requirements for rural irrigation and drainage projects and water supply projects. "Improving the overall cleanliness of villages" necessitates new techniques for soil and water conservation, developing rural hydroelectric power, water conservancy in pastoral areas and harnessing water resources.

4.1 Water conservancy progress in China

The trend of continuously deviating from on-farm water conservancy has been contained and key projects have made a good start. Obvious results have been achieved in flood prevention and drought relief; losses caused by disasters have been mitigated. Each administrative area pays more attention to research on and the launching of related water conservancy policies.

4.2 Main constraints *vis-à-vis* water conservancy development

Many farms still lack basic water supply facilities and the safety of supposedly potable water cannot be assured. Farmland irrigation and drainage facilities are weak, which seriously constrains enhanced agricultural productivity. Soil erosion problems, grassland degeneration and water source pollution are prominent and the deterioration of the ecological environment has not been effectively checked.

---

[2] The need for new management approaches to rural water conservancy.

[3] The introduction of new technologies and standardized management for rural water conservancy.

4.3 The main tasks for the development of rural water conservancy

Safe drinking water is the most important objective. Other tasks include: Irrigation and drainage facility reconstruction with water saving as the focus; promoting soil conservation and reducing soil erosion, thus increasing the area of basic farmland; developing hydroelectric power; encouraging water conservancy in pastoral areas and irrigating grazing land.

4.4 The basic ideology for farmland water conservancy

There are three concepts to facilitate rural development:

- Transform from traditional to ecological water conservancy and establish the concept that humans and the environment can co-exist in harmony.
- Exploit the potential for harnessing floodwater; enhance flood prevention and disaster mitigation.
- Develop a water-saving and environmentally friendly society; ensure the sustainable development of water resources.

Five strategies

1. Guarantee potable water — provide regular supplies.
2. Eliminate potentially dangerous and unstable reservoirs — continue with the mandate.
3. Enhance rural water use efficiency and grain productivity — continue to expand the renovation and water-harvesting capacity of large- and medium-scale irrigation areas.
4. Improve production, living conditions and the ecological environment in soil erosion-prone areas — vigorously develop small basins.
5. Expand the replacement of fossil fuel by small hydropower stations — scientifically develop rural hydroelectric power supply.

4.5 Policies and measures for the promotion of water conservancy

Multiple factors constrain the development of rural water conservancy in China. Problems are related to knowledge, investment and management. In particular, project construction investment has been low over the long term and there has been an overall decline in recent years. This is because in the current situation, where the comparative benefits of agriculture have changed, farmers' roles have been established and farmers' democratic consciousness is growing. Consequently we can no longer depend on administrative measures only to develop rural water conservancy so we must accelerate the establishment of effective new mechanisms and measures. Specific suggestions are provided hereunder.

4.5.1 New measures for the basic development of farmland water conservancy

There is a need to fine-tune:

- Organization and leadership.
- Government inputs.
- Farmers' participation.
- Management development.
- Government investment.
- Management rights.
- Water pricing and water-harvesting rewards.
- Protection of regional grain safety.

With regard to the last measure, grain productivity in China is insufficient. In future, grain production will also be subjected to the "one increase (people) and three reductions (land, water and planting area)" policy. The annual increase of grain yield should increase to 1.8–2.6 percent from 0.9 percent in the past ten years.

This will be very difficult. We must consolidate WSI, disseminate agricultural science and technology and improve comprehensive agricultural productivity to a new level in order to guarantee grain safety. Currently for the construction of WSI, increasing investment is the major bottleneck. According to expert estimations, the annual cost of maintaining existing water conservancy facilities for farmland nationwide amounts to approximately 240 billion yuan. To realize further development, several trillion yuan will be needed but only 22 billion yuan is available. The state should address this issue and establish a diversified input system with the state playing the major role and the active participation of farmers. Rural water conservancy for farmland, reconstruction of large- and medium-scale irrigation areas and the development of large-scale commercial grain bases are key factors at the moment.

4.5.2 Responsibilities and rights and rethinking farmers' labour contribution

WSI serves "weak" agriculture; it is also the basis for ensuring grain safety and so has very strong societal interest. In this context it should be the major objective for state financing and investment should mainly come from the state. This is the case for developed countries (e.g. United States and Japan) and upper bracket developing countries (e.g. India and Turkey). Infrastructural water supply has a certain commercial quality, so farm households who benefit from it should assume certain responsibilities for maintenance after the completion of projects and during the construction of small projects. With state funding, we should adopt operation by local people but subsidization by the state. Farmers should undertake the construction of tertiary canals and field distributions and be involved in small water conservancy projects. We should formulate detailed rules for farmers' labour contribution. Different government levels should be responsible for the funding of farmland water conservancy. Now that township level financing has been removed, county level financing has been experiencing widespread difficulty. So the central government and provinces (autonomous regions) should assume more responsibilities. As state financing is not bottomless, we should encourage farmers to contribute their labour for water conservancy activities.

4.5.3 Accelerate reform on water infrastructure investment and management modes

Currently multiple departments participate in the development of water infrastructure for agriculture. However integrated planning is absent, subsidies are not uniform and the abundance of many players in one programme discourages investment in and the uniform management of water resources and projects. The state should further define the responsibilities of every department and underscore the uniform management of water conservancy technology by one department. We should accelerate reform on water infrastructure investment and management modes. In this context, WUAs can play an active role in mobilizing farmers' enthusiasm and empowering them.

Developing water conservancy projects for agriculture is not straightforward and requires strong supporting policy. In particular, owing to the rapid development of industrialization, urbanization and modernization, government leadership needs to be stiffened. Enhancing comprehensive agricultural productivity is not easy; it requires further inputs and government funding, farmers' enthusiasm and manifold construction of appropriate infrastructure.

4.5.4 Substantially increase government investment in rural water conservancy

In the past, building relevant infrastructure in China, in particular, small schemes, mainly relied on farmers. The thinking has been that "farmers should handle their own affairs". Problems included: Low construction standards, no subsequent maintenance and no exploitation of benefits. To adapt to the new rural development trend, we must find new solutions to addressing rural water conservancy inputs based on local characteristics and governmental responsibilities. Government assistance should be increased substantially and a diversified input mechanism with government investment taking the lead should be established with voluntary inputs from farmers as the foundation and auxiliary social inputs as supplements.

Firstly, the scale of central financing should be boosted. In 2005, central financing's special fund for small-scale water conservancy development was 0.3 billion yuan; in 2006 this climbed to 0.6 billion yuan. We suggest that the 2006 subsidy should be increased to three billion yuan in 2007 and by further increments year by year. Each province should also increase the scale of financial subsidies. Secondly, we should adjust the investment structure of the state's comprehensive agricultural development funding system and increase the investment proportion for key projects in medium-scale irrigation areas. At present, such investment is approximately 0.15 billion yuan every year. At this rate we will need 70 years to complete tasks related to key projects. We suggest that the amount be increased to one billion yuan every year. Thirdly, we should increase similar investment for key projects in large-scale irrigation areas. In recent years, the central government has set aside 1.5 billion yuan annually for this, which can only support a small number of projects and mitigate hazards that are present. Meanwhile annual investment remains very unstable. According to the current level, it will take 30 to 40 years to complete the reconstruction of key projects. We suggest that in this case investment should be increased to 3 billion yuan.

4.5.5 Highlight the uniform planning of rural water conservancy in counties

We should arrange for uniform planning of WSI under the leadership of county governments; they will be guided by water conservancy departments, with related departments participating. After planning has been completed, it should be approved by higher authorities. Such planning, after approval, will apply to the whole county, not single departments or units. All related departments and units should strictly implement the agenda with no interruptions or changes. Through planning, we can better understand conditions, standardize outputs, provide coordination, integrate investment and improve efficiency with regard to deployment of funds.

4.5.6 Formulate and launch early regulations on rural water conservancy

We suggest that a state law on "Rural Water Conservancy" be formulated; *inter alia*, this will stipulate investment, construction and management mechanisms and operational modes for rural water conservancy as well as responsibilities for different governmental and departmental levels. As launching this law at present is difficult, we advocate initial research first to formulate "Regulations on Rural Water Conservancy".

4.5.7 Indices for rural water conservancy infrastructure

WSI is implemented to ensure enhanced farmers' income, improvement in living standards and development of production. Farmers must be guided by various indices. As geographic conditions, economic development and human factors differ from place to place, we should formulate evaluation indices according to local realities and should not make uniform requirements. The author suggests that evaluation indices address aspects related to infrastructure investment and living standards. We should evaluate infrastructure investment through seven indices: (1) The average annual sedimentation rate of ditches and ponds in a village is lower than 1.5 percent; (2) the execution of ancillary structures on fields per *mu* is over 65 percent; (3) the proportion of losses generated by floods and drought in the GDP is less than 2.5 percent and the average loss rate per *mu* is lower than 3.5 percent; (4) the use of tap water is over 90 percent; (5) the quality of ecological water is over 70 percent and surface water quality exceeds Class III; (6) the standardized discharge of sewage is over 50 percent; (7) the average input into WSI per capita is no lower than 200 yuan.

Living standards are evaluated through four indices: (1) Water surface area per capita is greater than 8.6 m^2; (2) water resources per capita are no lower than 600 m^3; (3) household water per capita is 80–120 litres/day and the quality is 100 percent; (4) ambient air quality exceeds grade 11.

5. Conclusions

The development of WSI is an important programme for national progress, affording peace and security and constructing a harmonized society. It is the foundation for agricultural and rural development. We should not forget major disasters and subsequent problems that emerged; view water conservancy development from the overall socio-economic perspective; fully understand the importance, protracted nature and difficulties involved in constructing such infrastructure today; protect, guide and generate enthusiasm among farmers; and inculcate each tier of society to strengthen and promote this programme nationwide.