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SRA Final Report

Small Research Activity

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Abbreviations and acronyms

ACEDP	Australia China Environment Development Program
ACIAR	Australian International Centre for International Research
ACWF	All China Women's Federation
ADB	Asian Development Bank
ATDH	Agricultural Technology Demonstration Household
ATEC	Agricultural Technology Extension Centre
AusAID	Australian Agency for International Development
CAAS	Chinese Academy of Agricultural Science
CAS	Chinese Academy of Science
CA	Conservation Agriculture
CATEC	County Agricultural Technological Extension Centre
CIDA	Canadian International Development Assistance
CT	Controlled Traffic
DfID	Department for International Development (UK)
EC	Extension Centre
EOI	Expression of Interest
FFS	Farmer Field School
GAAS	Gansu Academy of Agricultural Science
GFGP	Grain for Green Program
ID	Irrigation District
ISWC	Institute of Soil and Water Conservation
MATEC	Municipal Agricultural Technological Extension Centre
M&E	Monitoring and Evaluation
MEP	Ministry of Environmental Protection
MLR	Ministry of Land Resources (Chinese)
MOA	Ministry of Agriculture (Chinese)
MOF	Ministry of Finance (Chinese)
MOST	Ministry of Science and Technology (Chinese)
MWR	Ministry of Water Resources (Chinese)
N	Nitrogen
NDRC	National Development and Reform Commission (Chinese)
P	Phosphorus
PADO	Poverty Alleviation and Development Office (Chinese)
PATEC	Provincial Agricultural Technological Extension Centre
R&D	Research and Development
R,D&E	Research, Development and Extension
SEPA	State Environment Protection Agency (Chinese)
RHCRS	Rural Household Contract Responsibility System
SRBMB	Shiyang River Basin Management Bureau
SFA	State Forestry Administration (Chinese)
TATEC	Township Agricultural Technology Extension Centre

TOR	Terms of Reference
WRDMAP	Water Resources Demand Management Assistance Project (UK)
WTO	World Trade Organization
WUE	Water Use Efficiency
ZT	Zero Tillage

1 Acknowledgments

The team of consultants would like to acknowledge and sincerely thank the large number of Chinese scientists and government rural development officials who assisted with the study, and participated in the workshops to finalise the recommended strategy. The team also wishes to record their thanks to ACIAR's Beijing-based staff who assisted by organizing travel and meeting agendas, and for their support throughout the two missions to China.

2 Executive summary

2.1 Introduction

The Australian Centre for International Agricultural Research (ACIAR) contracted a four-person team to visit China with the overall objective of reviewing the effectiveness of past ACIAR work and scoping options for future investments into water use efficiency (WUE) and conservation agriculture (CA) in north-west China.

The mission followed an internal ACIAR "Water Use in China" workshop in August 2007 at which key ACIAR Australian co-operators presented progress reports on their current China projects.

In summary, the terms of reference (and therefore the objectives) were to:

- Undertake an evaluation of the opportunities and constraints for research and development investment into increasing agricultural water productivity in north-west China
- Synthesise the information from (a) into recommendations to ACIAR for investment priorities and project design principles to develop a coherent and effective cluster of projects to increase the productivity of agricultural water in north-west China
- Document the information obtained from addressing the detailed terms of reference in a report to ACIAR in a format suitable for publication as an electronically down-loadable PDF file.

ACIAR has decided to focus its future Land and Water Research projects on irrigated and dryland WUE in north-west China, and Gansu in particular. This strategy intends to build on ACIAR's suite of past projects which have focused on water-saving, and to support the Government of Gansu in their quest to develop and extend water-saving technologies which are essential for the very survival of irrigated and dryland agricultural production in the Province.

2.2 The mission

The mission spent two weeks in China in November/December 2007 and during that time held meetings and discussions with more than 30 agencies, institutions, farmer groups, individual farmers, and various levels of government.

The mission was able to collect and collate considerable information, suggestions and proposals for future collaborative research and development work; and at the same time identify a number of issues and constraints which have either impacted on the outcomes from past projects, or which needed to be taken into account when formulating any new investment strategy. The meetings with staff at local research institutions and stations (and with individual farmers) provided the mission with strong evidence to back-up some of the earlier conclusions from prior meetings with agencies and institutions which have mandates to engage directly with farm families and deliver new technologies and supportive training.

In March/April 2008, the team conducted workshops in Lanzhou and Beijing with stakeholders to discuss the Interim Paper published in late 2007 and refine its recommendations. The three workshops involved a total of 23 people who represented the main stakeholders visited during the first mission in 2007.

2.3 General conclusions

By the end of the two missions to China it was apparent that:

- Gansu Province is facing a major crisis in terms of water supplies for irrigation. For example, Minqin County in Wu Wei City used to have about 1.0 billion m^3 of water available for irrigation, but now only about 0.15 billion m^3 (15%) are available, when the minimum demand is reported to be about 0.6 billion m^3 and the water table is falling by up to 1m/year in critical areas[1]. This has lead to a program of well closures (500 in 2007) and a ceiling on the area of land which can be irrigated (3 mu/family). Another 1,600 wells will be closed over the next five years. There are also policy issues related to the balance of water use within the catchments and the protection of downstream oasis developments.
- China's (and Gansu's) response to this situation has been rapid and decisive, especially in terms of saving irrigation water by lining distribution canals and commencing water allocation, quota and payment systems. Unfortunately this response has not always been supported with wide-spread on-the-ground application of existing and proven on-farm water use efficiency technologies; such as smaller irrigation bays, retention of crop residues on the surface to prevent evaporation, and decision making based on the farm management technique of maximising returns to limiting resources. However, programs which include government subsidies for technology such as plastic film for mulching are being well adopted. There have also been large government-supported programs to collect water in dryland areas and to use this for greenhouse vegetable production and supplementary crop irrigation.
- Pasture management programs in China's north-west focus on the use of deep rooted perennials such as lucerne as a WUE method, and as a source of animal feed. There is also considerable use of trees to replace cropping and grazing on some land types for degradation control, and programs such as Grain for Green are very obvious. However, there is very limited consideration of total watershed water input and output balances which would lead to the consideration of water allocation to its highest value uses.
- ACIAR's program is highly regarded by those stakeholders who are directly involved, but the program is virtually unknown outside this small circle of people. In addition, the R&D findings are being used by very few extension officers. ACIAR's project results are often not incorporated into government programs for the relevant county because appropriate stakeholder linkages have not been well developed. Technology for government-funded extension generally comes though government sources rather than directly from "outside" sources such as universities and academies. Some linkages are developing but these are very much a result of individual efforts.
- There are many opportunities for future ACIAR-funded research projects to assist the Government of Gansu to improve on-farm WUE. Some of these should be based on existing and known technologies which are "sitting on the shelf" and simply need efficient and effective extension systems for dissemination to irrigation and dryland farmers.

[1] *Note: one of the main reasons for this decline in the availability of irrigation water is the decision by the Yellow River Commission to allocate Inner Mongolia (and specifically the lower reaches of the He Hei River) an annual flow of about 950 million m^3.*

2.4 Specific findings – key issues

- Many national and provincial level agencies and institutions are involved in WUE and CA. In addition, a number of other research and development agencies have a role in WUE through their policy, research, planning, consultancy, and environmental protection mandates. However, conflicting institutional mandates, responsibilities, priorities and policy objectives seem to be limiting R&D into sustainable land and water resource management, as well as the effectiveness of efforts to increase WUE.

- The lack of an integrated institutional framework for the various WUE plans and programs has resulted in: (i) each sector setting ever increasing targets; (ii) an expansion in the number of potentially conflicting development policies and water management regulations; (iii) poor coordination among line agencies resulting in wasted resources and duplication of effort; and (iv) insufficient attention being given to creating an enabling policy and legislative environment. In addition, opportunities have been missed to achieve synergies between WUE, land degradation control, biodiversity conservation, and climate change mitigation. These could be achieved through the adoption of integrated ecosystem management approaches.

- The impact of improved WUE on accompanying poverty could have been increased if a more coordinated approach had been used. However, in Gansu Province the Poverty Alleviation and Development Office's (PADO's) role in addressing rural poverty reduction seems to have been discounted in terms of the Office's ability to engage with poor farmers and their families, and to assist with the transfer of appropriate WUE technology. Similarly the All China Women's Federation (ACWF) runs impressive and relevant projects in the poorer counties in Gansu.

- There are poor linkages between ongoing projects which focus on WUE and CA, and poor knowledge of the results from completed projects. For example although ACIAR has supported projects to assess fertilizer use efficiency (Hebei LWR/1996/164 and Shanxi LWR/2003/039), very few agencies and institutions in Gansu knew of these projects or realized that the findings were directly applicable in Gansu's irrigated areas. In fact the significant results from the Hebei project were published in ACIAR Proceedings Series No 123 based on an ACIAR Workshop in Beijing (2005) and yet the Gansu branch of the Chinese Academy of Science (CAS) is proposing to conduct similar research.

- Effective extension is a critical component of any R, D&E project, but has been a missing element in many of ACIAR's past investments. Although the agencies and institutions with mandates to improve WUE through improved irrigation practices have access to a range of technologies which will achieve this national objective, these technical packages are only being used by a few farmers because of the failure of the extension system to transfer the technology. As with much of China's agricultural technology, numerous solutions to problems seem to be "left on the shelf" because the county and township extension stations only respond when specific and top-down programs direct that a certain piece of technology be extended to a selected group of farmers. Understanding how to engage and maintain the involvement of appropriate extension agencies must be a key aspect of future ACIAR investments.

- The Grain-for-Green-Program (GFGP) has achieved some very impressive targets, and reportedly reduced run-off and water erosion and land degradation. However, some sites could have achieved these objectives by applying cheaper technologies, such as planting grasses and pasture species rather than mono-culture trees. In addition, some of the GFGP sites do not appear to have been subjected to land-use planning exercises before officials decided how to change landuse.

2.5 Specific findings – subsidiary issues

- There are ongoing problems with zero/reduced tillage planters – mainly blockages due to poor straw flow between tynes. The mission suspects that the main reason for reduced yields in the early years of zero/reduced tillage trials could be reduced germination, seedling vigour and establishment. This means that some of the results could have been compromised, the outcomes interpreted incorrectly and opportunities lost for more wide-spread promotion of this technique.
- Poor farmers use animal draft power for cultivation and retain mixed herds as alternative sources of income in bad years, and as "standing banks". These families also tend to used crop residues for heating and cooking, and as livestock feeds, and in some areas crop residues are sold for manufacturing purposes. This means that at best very little organic matter is returned to the field in the form of retained crop residues. The consequences are declining soil organic carbon levels, stable but low crop yields, over-reliance on artificial fertilizers, and ongoing wind- and water-caused soil erosion.
- The mission's terms of reference refer to WUE in irrigated and dryland agriculture systems. However, the Chinese focus is mainly on irrigated crop production systems. This priority is understandable given the huge volumes of water used to flood-irrigate wheat and maize. However, there are substantial Chinese research data to show that these volumes of water could produce more grain if spread over more land, based on using optimal WUE criteria, or used for supplementary rather than total irrigation.
- The application rates of N and P inorganic fertilizers on irrigated wheat and corn crops in Gansu are extremely high by world standards. This leads to decreased farm gross margins and subterranean pollution of aquifers.
- The national objective of maximizing grain production (at any cost per unit area of land) is probably over-shadowing the more economically rational (and sustainable) approach of allocating public and private agricultural resources on the basis of their highest marginal returns.
- The disciplines of farm management analysis (financial analysis), and economic and environment analyses are not well-understood by many of the agencies and institutions with mandates for rural development in north-west China, and are rarely used to add value to the scientific results.
- The issues listed above are all reasonably complex in terms of how they operate and impact in the field. It is only by involving extension staff in the design and analysis of relevant R&D that they will be able to understand the issues and transfer this knowledge to farmers. The current practice of only disseminating results at the end of a project does not effectively utilise ACIAR's investment to achieve goals in WUE, CA or poverty alleviation.

2.6 Conclusions and recommendations

- The range of partners in recent ACIAR programs has not been sufficiently broad, given the land and water issues and the stakeholders in north-west China. Past programs have resulted in some good capacity building within Chinese research institutions but they have not always resulted in multi-discipline research and have often not lead to the adoption of technology as the appropriate extension agencies were not initial partners. Future investments by ACIAR will need to address the issue of technology transfer, and use a more integrated watershed approach to sustainable land and water management. This can only be achieved if a wider and more appropriate range of stakeholders is engaged.

- The current “passive” approach by ACIAR to R&D in China is not effective in delivering recognisable benefits in WUE or poverty alleviation to a substantial number of farmers. In most cases, the recognition and uptake of the technology resulting from these investments has not been significant or ongoing, as it has not been “accepted” by agencies undertaking extension and therefore its direct influence on farmers has been very small.
- Becoming involved in projects in large river basins where there are already large ongoing investments would not allow an ACIAR focus and would not result in the development of technology that was replicable in other areas. There is also evidence that such involvement would not be welcome by water authorities except in a few small cases where knowledge gaps might exist.
- **The main recommendation is that ACIAR should operate a technically directed program in a geographic location** (preferably a small catchment) in Gansu Province which is not currently being substantially impacted on by large-scale national, provincial or bilateral aid or development support. Such a direction and/or location could be nominated by ACIAR to potential partners, or be agreed on as part of a bidding process (see [f]).
- This recommendation is expected to result in larger and more multi-disciplinary R, D&E programs for ACIAR to fund, in conjunction with their counterpart stakeholders in Gansu. A bidding process should be used to plan new R, D&E programs which focus on specific catchments in Gansu Province and comply with design criteria which can be identified from the mission’s findings.
- The bidding conditions and processes would generally follow internationally accepted procedures, although ACIAR and relevant responsible partners should jointly reserve the right to “re-package” bids if the process does not reveal a consortium which proves that it is able to comply with all the bid selection criteria. It is expected that bidding consortia would include ACIAR’s current partners in Gansu, and other agencies and institutions which are considered to have the skills and experience to enable the consortium to be able to comply with essential bid criteria. This approach should result in more multi-disciplinary consortia because of the need for a greater focus on farmer participation and the on-farm delivery of research results.

3 Introduction

In November 2007 the Australian Centre for International Agricultural Research (ACIAR) contracted a four-person team[2] to visit China with the overall objective of reviewing the effectiveness of past ACIAR work and scoping options for future investments into water use efficiency (WUE) and conservation agriculture (CA)[3] in north-west China.
The mission followed an internal ACIAR “Water Use in China” workshop in August 2007 at which key ACIAR Australian co-operators presented progress reports on their current China projects[4]. After this workshop Dr. Christian Roth (Research Program Manager, Land and Water Resources Program, ACIAR) prepared terms of reference for the China mission.

In summary, the terms of reference (and therefore the objectives) were to:

- Undertake an evaluation of the opportunities and constraints for research and development investment into increasing agricultural water productivity in north-west China

[2] The team comprised Mr. Philip Young, Team Leader and Agricultural Economist/Program Planner; Mr. David Marston, Natural Resource Management and Water Use Specialist; Professor Wang Jinxia, Agricultural Economist; and Professor Li Xiande, Policy Specialist.
[3] In this report the term CA refers to the application of reduced or zero tillage and the retention of at least some crop residue on the surface.
[4] Mr. Philip Young also attended the workshop and presented a paper on the financial, economic and environmental analysis of dryland conservation agriculture in northern China.

- Synthesise the information from (a) into recommendations to ACIAR for investment priorities and project design principles to develop a coherent and effective cluster of projects to increase the productivity of agriculture water in north-west China
- Document the information obtained from addressing the detailed terms of reference in a report to ACIAR in a format suitable for publication as an electronically downloadable PDF file.

Initially the mission intended to visit Beijing and the Provinces of Shaanxi and Gansu. However, as the program was finalised by ACIAR's Beijing office it became apparent that Gansu was prepared to contribute more time and resources to the mission so a decision was made to limited the visit to Shaanxi to one major potential collaborator – the Institute of Soil and Water Conservation (ISWC). In retrospect this was a good decision as it allowed the mission to focus on the key issues across one province in some detail, and to complete an informative field trip which confirmed many of the preliminary conclusions following consultations with cooperative agencies and institutions.

The mission spent two weeks in China during late 2007 held meetings and discussions with more than 30 agencies, institutions, farmer groups, individual farmers, and various levels of government. Most of the more formal meetings were structured around the following points and questions:

- An introduction to China's rural water supply and utilization crisis, with a particular focus on the use of declining quantities of irrigation water in dry and arid areas for food and cash crop production
- An overview of the agencies'/institutions' current mandates in relation to land and water resource management (and WUE where appropriate) in north-west China
- A summary of the agencies'/institutions' relevant research and development projects – past, present and planned; and an over-view of how these research results were extended to farmers
- If appropriate, a summary of relevant policies, laws and regulations; and plans included in the current 11th Five-Year Plan[5]
- A summary of completed and planned ACIAR-funded projects, and an assessment of the agencies'/institutions' understanding and awareness of past and present ACIAR-funded projects
- A summary of the main water-related issues and problems which need to be solved if north-west China is (in the longer-term) to continue to be a major producer of food and cash crops
- A general discussion on priority research programs and projects which ACIAR might support with the objective of increased WUE and wider application of CA.

The mission was able to collect and collate considerable information, suggestions and proposals for future collaborative research and development work; and at the same time identify a number of issues and constraints which have either impacted on the outcomes from past projects, or which need to be taken into account when formulating the new strategy. The meetings with staff at local research institutions and stations, and individual farmers provided the mission with strong evidence to back-up some of the earlier conclusions from prior meetings with agencies and institutions which have mandates to directly engage with farm families and deliver new technologies and supportive training.

In March/April 2008, the team conducted workshops in Lanzhou and Beijing with stakeholders to discuss the Interim Paper and refine its recommendations. The three workshops involved 23 people who represented the main stakeholders visited during the first mission in late 2007.

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[5] *This information was difficult to collect from informal meetings and therefore the mission assigned Professor Li Xiande to prepare an over-view of relevant policies, programs and projects which are included in the current 11th Five-Year Plan. This information is detailed in Appendix 1.*

This report is based on changes to the Interim Paper and covers the mission's terms of reference. It includes chapters on:

- Introduction and mission purpose
- The context and settings for the new strategy
- The main findings
- Relevant Chinese policies and programs which guide strategy formulation and implementation
- A summary of recent, current and future WUE research topics
- Comments on on-farm extension and technology transfer issues
- Analysis of the "drivers of change" for improved land and water management in target area/s
- Options for future ACIAR-funded research on WUE and CA in north-west China.

4 Context and setting

4.1 China's national water management objectives

The policy of the Government of China on *"Scientific Outlook for Development"* which is presented in the 11th Five-Year Plan heralds a shift in China; by changing the national goal from economic growth to economic development, and for the first time recognising the importance of protecting the environment at the expense of economic development. This has been described as the "Scientific Outlook on Development"; shifting the goal of China's development from economic growth which exerts large pressures on water and the environment, to economic development through innovation in order to improve living standards for all. The targets which the 11th Five-Year Plan has set for China's water sector are[6]:

- Water consumption per unit of industrial added value to be reduced by 30% from the 2005 value (conversely the value of water used by industry to be increased by 40%)
- Irrigation efficiency to be raised from 45% to 50%
- Main pollutants discharge to be reduced by 10% from the 2005 value
- Forest cover ratio to be increased from 18.2% to 20%.

During implementation of the 11th Five-Year Plan the vision and goal of the Ministry of Water Resources (MWR) are to:

- meet the water demand for socio-economic development and promote a change in the approach to economic growth
- ensure sustainable socio-economic development through sustainable use of water.

The MWR will contribute to this goal through strategies and plans for managing the most important water issues in China, which are:

- "Excess Water", i.e. flooding due to changing land use and climate change
- "Shortage of Water", i.e. drought due to excessive use of water, and climate change
- "Dirty Water", i.e. pollution of water due to agricultural, urban and industrial development
- "Muddy Water", i.e. high sediment loads of rivers due to unsustainable land use in up-river catchments.

[6] *Further details are provided in Appendix 1 of this discussion paper.*

The foregoing means that China is emerging from an era when water shortages were addressed solely by increasing the supply of water (although major strategic inter-basin water transfers are still under construction) to an era of a "water saving society". This new water saving society will aim to address water shortages through increased WUE and effectiveness, and through the promotion of industrial restructuring to reduce the social and environmental costs of economic development. The immediate objectives of the water saving society are:

- At the micro-level, to achieve efficiency by reducing the water consumption per capita and per unit output
- At the medium-level, to achieve effectiveness by increasing the value creation per unit of water consumed
- At the macro-level, to achieve environmental sustainability by abstaining from water resource development at the expense of important eco-systems and the environment.

4.2 Water-saving agriculture

Developing water-saving agriculture is an important first step in the better utilization of water (see Appendix 3 for more details). Water saving agriculture has been a Chinese objective for some time but as one scientist reported "it has not delivered the results required due to a tendency to focus on engineering solutions". Water saving agriculture in this Chinese context includes irrigated crops, the use of plastic for rainfed field crops, as well as the local collection and use of run-off rainfall in greenhouses. More recent discussions and policies are focusing on water use efficiency.

China is now implementing its Water Law 2002. This law requires policy in the water sector to rely less on supply led approaches and to use the principles of Integrated Water Resources Management (IWRM). These IWRM principles and management tools are as listed in Table 1.

Table 1: IWRM Management Tools (adapted from IWRM Toolbox[7])

No	Management Tool	Description
1	Water Resources Assessment	Understanding water resources and water demands
2	Planning for IWRM	Combining development options, resource use and human interaction in water resources planning
3	Efficiency in Water Use	Using direct controls to manage demand and supply
4	Regulatory Instruments	Managing demands by administrative allocation and limitations on water use
5	Economic Instruments	Using the value and price of water for improved efficiency and equity of water use
6	Social Change Instruments	Encouraging water awareness in society
7	Conflict Resolution	Encouraging sharing of water and managing disputes
8	Information Exchange	Sharing knowledge for better resources management

Water saving and WUE are two terms used in China that are not always well differentiated and are often used in the wrong context. Water saving is an older term used in the Chinese context and refers to operational practices and or physical systems that reduce wastage in the collection or supply processes. These methods can improve the efficiency of the supply system and reduce the cost of supplying water. Water saving also refers to practices of water harvesting in dryland areas. This is simply a practice to use more of the rainfall (or runoff) in the upper part of the watershed for local benefit and its impact on downstream users is not often considered. To determine the efficiency of this practice it is necessary to consider how the water is used; the efficiency will vary between uses such as horticulture in greenhouses or supplementary irrigation of rainfed field crops.

[7] *Global Water Partnership (GWP) Toolbox for IWRM (www.gwpforum.org)*

WUE is a more recent term in the Chinese context and reflects international usage. It refers to a range of practices and management decisions that can be used to ensure that available water is used to produce the optimum quantity of produce per unit of water applied. It includes practices such as the method of applying water to the crop (flood versus drip or spray irrigation), water application at various times of the day or under various wind conditions, the use of plant types or varieties which require varying amounts of water to produce a unit weight of harvestable product, and in some cases the multiple use of water between when it is supplied to an area and when it is disposed of as drainage from the area. WUE is about increasing the benefits generated by a unit of water after is it supplied.

Many of the irrigation methods currently used are inefficient at best. Whereas in developed countries the WUE is as high as 70%, the rate in China's main irrigated areas is only about 40%. This is being addressed by reducing supply losses through the lining of irrigation channels but this is a major task. Other system losses result from shallow storages and other evaporation losses during lengthy supply routes.

Across all of China food output is only 0.8 kg/m^3 of water (it is as lows as 0.5 kg/m^3 of water in parts of Gansu) compared with about 2 kg/m^3 in Israel. In much of northern China's irrigated areas water use is three to five times the actual water needed by crops, resulting in an annual waste of about 1,000 x 10^8 m^3. Therefore it is imperative for China to develop water-saving irrigation application practices and to utilize water resources more efficiently. This involves understanding plant water requirements, supplying water as required (not necessarily when available), plant selection, reducing in-field waste, drainage and reuse systems.

China has made good progress in terms of developing water-saving irrigation practices, and some progress with dryland farming techniques which conserve rainwater in situ. The country now has many internationally proven (and some China-specific innovations) which have the potential to save huge volumes of rainfall and irrigation water. For example in Gansu the Water Resources Bureau has lined many of the main and subsidiary irrigation canals and introduced water allocations, water quotas and water payment systems. However, the application of conservation agriculture techniques in non-irrigated areas is minimal and more needs to be done to conserve rainfall in these poor and marginal areas. The Government of Gansu is receiving considerable national, multilateral and bilateral support for the programs referred to above and therefore the question has to be asked: "if solutions are available, why haven't these been extended across the Province?" Some of the answers to this question are discussed in Section 5.

There is now a program to consider "water saving for the environment" in which water for downstream environmental flows is being sought through incentives or compensation to operators and users in order to:

- reduce losses in physical storage and supply structures
- eliminate wasteful practices by all users
- increase water use efficiency in agriculture.

4.3 Water in north-west China

By any standard water shortages in China, particularly in the north-west, are very serious[8]. This region, which includes Shaanxi, Gansu, Ningxia, Xinjiang and western Inner Mongolia, accounts for 32% of China's area but only has about 8% of the nation's total water resources. The mean annual rainfall in the north-west is less than 250 mm (and even less in the desert areas) whereas the annual evaporation is about 1,500 mm (and up to 2,500 mm in the desert areas). Annual surface water availability in north-west China is only 220 billion m^3 and with groundwater reserves of 65 billion m^3, the total water resource only amounts to 285 billion m^3 which is about 10% of the national total.

[8] *This information is taken from a range of documents presented to the mission by agencies and scientists.*

Moreover, water supplies are distributed unevenly through space and time, and water pollution is significant.

Climate change has the potential to change the quality and quantity of these water resources but no impact scenarios were presented to the mission. Some stakeholders saw this topic as a research opportunity to predict impacts while others wanted to ensure that future R&D considered the impacts of resource changes on water availability, WUE and the overall catchment ecosystems.

Overall irrigation efficiency is about 40% and typically irrigation water productivity is about 0.5 kg of product/m^3. Excessive irrigation in many areas has a significant impact on downstream water users, particularly along the Yellow River both in terms of the quantity and quality of water available. The frequency and severity of dust storms, sourced from desert areas and bare cropping lands have been increasing every year. This has been accompanied by an increase in the desertification of large areas. This situation increases the conflict between the supply of and demand for water, compounds the issues of environmental management, and constrains economic development.

An example is the Hexi Corridor which is located in central-western Gansu where the climate is classified as semi-arid. During the past 100 years, and especially during the last half century, human activities in the Corridor have caused a series of detrimental environmental impacts including water environment changes, land desertification and salinisation, and vegetation degeneration. Changes in the water environment include a decline in the volume of surface water, a decline in surface water quality, continuous lowering of groundwater tables and degradation of ground water quality. Vegetation in the lower reaches is seriously degenerated, resulting in land desertification, salinisation and dust storms. Ground water tables are falling (on average) by about 0.5 m per year (and often by up to 1.0 m per year). The mean annual rate of groundwater resource decline in the Wuwei and Minqin sub-basins ranges from 1.1% to 4.0%. The annual groundwater deficit is reported to be 452.6 x 10^6 m^3 and if no effective measures are taken to control the use of irrigation water this figure is expected to increase to 672.8 x 10^6 m^3 by 2010.

Water resources are now under great pressure to support increased dryland and irrigated agricultural production in arid regions. The short-term situation in terms of the availability of irrigation water is expected to decline as the demand for water for domestic, industrial and environmental flow purposes, increases. Therefore understanding the relationships between water and the environment (and water and development) and recognizing how to apply sound water management practices, is crucial for sustainable agricultural production and healthy environments in Gansu Province and the rest of north-west China.

A number of large water supply and management projects are operating or being implemented. These include new or changed water storage and supply systems, irrigation channel lining to reduce losses, metering of irrigation supply to improve management efficiency, and more efficient water application methods such as raised beds and sprinklers or dripper systems. Water harvesting in dry landscapes is also being promoted to support greenhouse development, supplementary irrigation of crops and household or animal use. Government programs also operate to support the use of plastic film to mulch dryland cash crops and the use of deep rooted perennial pasture species.

An example of a large water supply and management project is the “North West Water: One Large Consultant Project”. This project was funded by the State Department and organized by the Chinese Engineering Academy in 2001. The project leader was Professor Zhengying Qian and there were 35 academicians and about 300 experts involved in the research.

The research team has published a comprehensive final report entitled "Water Allocation, Establishment of Ecological Environment, and Sustainable Development Strategy in North West China" in which there sections dealing with:

- "status and problems in the north-west of China
- an harmonious development strategy between humans and nature
- rational arrangements for ecological environmental construction
- establishment of an efficient water saving and water pollution controlling economy and society
- rational allocation of water resources
- strategies and measures."

The report proposed ten key strategies to improve the use of water in north-west China:

- "strengthening integrated water resources management
- vegetation establishment in the dry and semi-dry areas to change cultivated land to forestry or grass land
- desertification control on degraded former cultivated land, grassland and forestry land
- strengthening the financial input for agriculture development
- ensuring a balance between food supply and demand
- developing industry and promoting urbanization
- controlling pollution while developing the economy
- implementing population planning programs and eliminating poverty
- preparing the western route of the South-North Water Transfer Project
- establishing agency coordination mechanisms for ecological environmental establishment."

4.4 Agricultural setting

The landscape of Gansu is dominated by the Loess Plateau and the agriculture that it supports. There are large areas of dryland farming where cropping and/or livestock are practiced. The rangelands are primarily native pastures with low stocking potential for sheep and cattle. The rainfed croplands (40,000mu) are low in fertility and yields are limited by rainfall. Erosion by wind and water occurs over large areas and this is often accelerated by removal of plant cover by grazing and cultivation. Desertification is a major problem. Rainfall decreases from east to west and from south to north and ranges from 50mm to 1000mm. This influences the patterns of grazing or cropping and the types of dryland crops such as wheat, barley and potatoes.

Water is sourced from rivers, surface storages and aquifer systems and this enables irrigation in defined irrigation schemes. The infrastructure associated with many of these schemes is old and not very efficient. System supply losses of water are large and drainage reuse is not a usual practice. Both of these situations, together with poor irrigation application practices, are leading to salinisation of many irrigation areas. Irrigation water is mainly used for grain production with some being used for cash crops such as cotton, lucerne, oilseeds and horticulture. Irrigated lands amount to 20,000mu but there are programs that aim to increase this area.

Agriculture is by far the largest water user in the province and gradual reductions in the resource volume and quality is a major concern. The need for environmental flows in rivers is recognised and is adding to the problems of water over use. These water problems are critical in the inland river areas of Gansu.

Gansu Province is not an exporter of grain because production is not high and the policy is to produce sufficient for local consumption. Hence there is constant demand for new cropping land (based on irrigation) and new technology to increase productivity. An increasing amount of vegetable production is being undertaken in plastic greenhouses in dryland areas using water harvested locally from roofs and roads.

A number of major government programs (national and provincial) managed by a range of agencies (see Section 6) impact on current and future agriculture (see Section 7 of this report and Appendix 1). These include: (i) “Water Saving Society” for collecting more water and using water more efficiently; (ii) “Yellow River Commission”, “Tou Li River Basin Authority” and “Water Law 2002” for changes in water allocation and charges; (iii) Hexi Corridor development plans for irrigation supply development, water use efficiency and allocations to Inner Mongolia; (iv) programs to support the use of plastic mulch for water saving and WUE in rainfed and dryland cropping; and (v) ecological restoration of rivers, grazing land and programs such as Grain for Green.

All of these programs have large budgets, set targets and often short timeframes which, together with their potentially overlapping or counter objectives can result in unreal expectations, a very changeable environment for the operation of RD&E, and confounded outputs on the ground. In an environment where government agencies have separate targets and programs for increased production to meet growing population and economic needs, it is possible to have conflicts of interest in the area of sustainable natural resource management. This is a major challenge for the objectives of an ACIAR investment.

5 Main findings

5.1 Key and subsidiary issues

The main issues identified by the mission have been categorised into two broad groups – those which are considered to be **key issues** and therefore need to be addressed before the objective of increased WUE in Gansu can be achieved; and the **subsidiary issues** which if over-come would increase the impact from over-coming the key issues. Many of the key and subsidiary issues are inter-linked and complementary. This suggests the need for a much more integrated approach when designing and implementing research and development projects which focus on WUE and CA. Section **10** contains an outline of this suggested strategy.

5.2 Key issues

5.2.1 Agency and institutional coordination and engagement

Many national and provincial level agencies and institutions are involved directly or indirectly in WUE and CA, notably: (i) Ministry of Water Resources (MWR); (ii) State Forest Administration (SFA); (iii) Ministry of Agriculture (MOA); (iv) Ministry of Land Resources (MLR); (v) Ministry of Environmental Protection (MEP) (formerly the State Environmental Protection Agency); (vi) Ministry of Finance (MOF); (vii) National Development and Reform Commission (NDRC); and (viii) the Ministry of Science and Technology (MOST). In addition, a number of other research and development agencies have a role and interest in WUE through their policy, research, planning, consultancy, and environmental protection mandates. However conflicting institutional mandates, responsibilities, priorities and policy objectives seem to be limiting R&D into sustainable land and water resource management as well as the effectiveness of efforts to increase WUE.

The problem is that ecosystem elements are currently treated in isolation from each other, in line with the mandates of the concerned institutions. As a result there is no strong understanding of area-wide ecological systems and how to address these in a coordinated, systematic and integrated manner. For example, water is treated differently depending on whether it is managed for livestock needs, irrigated agriculture, forestry purposes, industry or domestic consumption.

Another example is for CA because the drivers that influence a farmer to adopt CA vary from labour saving to the availability of subsidised machinery to WUE or erosion control, and these are the responsibility of a range of agencies. These agencies also have different drivers for promoting CA which range from policy to environmental benefits to increasing yields. There are also now some negative drivers such as the increasing promotion of biomass for energy production. All of this means that unless the governments' approach to all aspects of R,D & E are coordinated, the development of appropriate technology and the message to farmers will be confused and adoption rates will be low.

The level at which agencies are involved is not simple and has to be considered in the context of the likely impacts. Engagement at an appropriately high level is important to engender support at lower levels (particularly if financial resources are required) but engagement at too high a level may add to confusion and not actually provide any practical assistance. Clearly a project that aims to influence major policy in water management such as water allocation between agriculture and the environment in a river that crosses provincial boundaries will need national and provincial level stakeholder support (Task Forces established under the Sandification Prevention and Control Law may be a mechanism for this). However, a project which is considering WUE in various crops or landscapes within a province will need provincial and county level stakeholder support (County Vice-Governors responsible for agriculture and natural resources are often a suitable mechanism for this). This is an issue which project proponents need to consider at the early stage of project identification so that the relevant stakeholders are involved in the design process.

5.2.2 Linkages with policy makers

This lack of an integrated institutional framework for the various WUE plans and programs of the concerned agencies has resulted in: (i) each sector setting ever increasing targets for its own technical responsibilities; (ii) an expansion in the number of potentially conflicting development policies and water management regulations; (iii) poor coordination among line agencies resulting in wasted resources and duplication of effort; and (iv) insufficient attention being given to creating an enabling policy and legislative environment for resource users to take primary responsibility for improved WUE, and uncoordinated (and even duplicated) R&D.

In addition, opportunities have been missed to achieve synergies between WUE, land degradation control, biodiversity conservation, and climate change mitigation that could be achieved through the adoption of integrated ecosystem management approaches. The lack of any clear authority and coordinated institutional control over the exploitation of the north-west region's natural resources (soils, vegetation, water and biodiversity) is the primary reason why past efforts to increase WUE seem to have had a limited impact on improving crop production efficiency and the environment. Even if the governance structure requires such a sectional approach, there is no reason why R&D investments should not provide an integrated ecosystem approach.

5.2.3 Linkages with agencies responsible for poverty reduction

In addition, the impact of improved WUE on the accompanying poverty could have been increased if a more coordinated approach had been used. However, in Gansu Province the Poverty Alleviation and Development Office's (PADO's) role in addressing rural poverty reduction seems to have been discounted in terms of the Office's ability to engage with poor farmers and their families, and to assist with the transfer of appropriate

WUE technology. PADO's work in Gansu (with considerable support from World Bank loans) is very impressive and the Office has developed an excellent participatory planning and implementation approach which enables small and poor farmers to become involved in the identification, selection, adaptation and use of a wide range of existing and new production and environmental protection technologies. PADO should have a role in all projects/ programs which aim to increase on-farm WUE and improve CA practices.

Similarly the All China Women's Federation (ACWF) runs impressive and relevant projects in the poorer counties in Gansu. In the past these projects have understandably focused on the provision water for domestic and livestock production. However the Federation's experience working with poor female household heads is directly relevant to the need for ACIAR to improve the delivery of new technology to poor farmers. This is because many women are now household decision makers and primary operators for much of the year due to their husbands gaining off-farm employment.

5.2.4 Extension and technology transfer systems

This important topic is discussed in detail in Section **8**. Effective extension is a critical component of any RD&E project and it has been a missing element in many past investments. Understanding how to engage and maintain the involvement of appropriate extension agencies will be a key aspect of future ACIAR investments.

5.2.5 Linkages with and knowledge of other projects

One of the mission's main findings was poor linkages between ongoing projects which focus on WUE and CA, and poor (or no) knowledge of the results from completed projects. For example although ACIAR has supported a project to assess fertilizer use efficiency (LWR/2003/039 – Improving the management of water and nitrogen fertilizer for agricultural profitability, water quality and reduced nitrous oxide emissions in China and Australia) very few agencies and institutions in Gansu knew of the project or realized that the findings were directly applicable in Gansu's irrigated areas. In fact similar research is still being undertaken and excessive (non-efficient) rates of water and fertilizer are being routinely applied to maximise grain yields per unit area rather than optimising yield per unit of water or fertilizer input, even though these resources (not land) are the scarce resources.

Another more pertinent example of this issue is that the Dingxi County Agriculture Extension Station Director was not aware of ACIAR's CIM/1999/094 project (Improving the productivity and sustainability of rainfed farming systems for the western Loess Plateau of Gansu Province), even though the project was implemented in Dingxi County over a period of five years. The outcome of such a situation is that "technology sits on the shelf" for years and in some cases is never accessed for on-farm development.

AusAID's recently launched Australia China Environmental Development Program (ACEDP) could result in considerable opportunities for ACIAR and its future partners to leverage additional funds for specific components of projects which address WUE and the environmental impact on agricultural land. ACEDP uses a bidding process to allocate funds for: (i) pilot studies and projects that demonstrate the integration of social, economic and environmental parameters to improve natural resource management; (ii) study tours, training courses, conferences, work attachments, exchange programs and scientific cooperation to foster people-to-people linkages and understanding; and (iii) policy dialogue mechanisms across jurisdictions to strengthen environmental policy formulation and implementation at all levels. An example of successful coordination between ACIAR and AusAID is the Seeds of Life project in East Timor.

There are major projects funded by UK, Canada and Japan that could provide collaborative opportunities for future ACIAR investments. No future ACIAR project proposal should be considered unless it contains a comprehensive review of past, current and future R&D knowledge, and investment collaboration opportunities.

5.2.6 Current irrigation practices

Although the agencies and institutions with mandates to improve WUE through improved irrigation practices have access to a range of technologies which will achieve this national objective, these technical packages are only being used by a few farmers because of the failure of the extension system to transfer the technology. In addition, quite simple technologies such as irrigation border check systems and simple land levelling, and drainage reuse arrangements seem to be ignored. As with much of China's agricultural technology, numerous solutions to problems seem to be "left on the shelf" because the county and township extension stations only respond when specific and top-down programs direct that a certain piece of technology be extended to a selected group of farmers.

Although not an R&D issue, the use of inappropriate targets of maximum production per unit of land rather than per unit of water is a major limitation to the adoption of known WUE technologies. Policy changes and reworking existing data to demonstrate benefits in terms of increased WUE and reduced poverty, while at the same time maintaining total production in an administrative region, are the actions required to overcome this situation.

This focused agricultural extension process has been effective in extending intensive green-house vegetable production technologies and associated water-saving systems. However not every poor farmer with irrigated land will be able to adopt this production system (because of market over-supply issues, especially for vegetables and fruits), and unless all farmers who irrigate have access to water-saving technologies the objective of increasing WUE across all of China's irrigated land will not be achieved.

The mission noted a tendency for some research institutions to not release new water-saving technologies before they had been through prolonged research station testing and analysis. This approach means that on-farm testing and adaptation are delayed, often until "perfect" solutions or results are achieved. A better approach would be to try and identify some "best bet" options and to fast-track their on-farm adaptation and testing. A good example is the use of raised beds to reduce the number of irrigation events and the amount of water applied during each irrigation. ACIAR's project LWR/2002/094 (Promotion of conservation agriculture using permanent raised beds in irrigated cropping in the Hexi Corridor, Gansu) has already identified some simple and "best bet" technologies which (in the opinion of the mission) are ready for on-farm testing and verification.

5.2.7 Grain-for-green program

The Grain-for-Green-Program (GFGP) has achieved some very impressive targets, and reportedly reduced run-off and water erosion and land degradation. However, some of the sites in Gansu could have achieved these objectives by applying cheaper technologies, such as planting grasses and pasture species rather than mono-culture trees that are often the wrong species for the local area. In addition, some of the GFGP sites do not appear to have been subjected to simple land-use planning exercises before officials decided how to change landuse. This deficiency has (in some cases) lead to forestry-type trees being planted on flat land which perhaps should have been used for economic forestry (fruit trees) and pastures for livestock.

5.3 Subsidiary issues

5.3.1 Problems with zero-tillage seeders

The mission was surprised by the number of references (by scientists and leading farmers) in Gansu to ongoing problems with zero/reduced tillage planters – mainly blockages due to poor straw flow between tynes. There is no firm evidence, but the mission suspects that perhaps the main reason for reduced yields in the early years of zero/reduced tillage trials could be reduced germination, seedling vigour and establishment, especially when compared with traditional practices. This means that some of the results could be compromised, the outcomes interpreted incorrectly and opportunities lost for more wide-spread promotion of this simple technique which has the potential to revolutionize dryland agriculture in China, and to increase WUE in all annual cropping systems.

Given that China has been testing and developing zero/reduced tillage planters for many years (with considerable assistance from Australia - through ACIAR and other institutions) and the availability of such machines in other parts of China and from countries such as India, Pakistan and many South American countries, there are no valid reasons why this problem should not have been resolved some time ago. As the Department of Agriculture Machinery Mechanization (within MOA) has a role in ACIAR's project LWR/2002/094, this issue should be immediately afforded a high priority.

Furthermore, there appears to be research situations where rigid agronomic parameters (row spacing, time of sowing, plant density, etc.) take priority over the enormous potential benefits of developing a practical system for residue retention with its benefits in WUE (rainfed), soil conservation and dust reduction. Working more closely with end users (farmers) is likely to refocus the development of suitable machinery.

5.3.2 Breaking the organic matter cycle

Poor farmers (both irrigated and dryland) use animal draft power for cultivation and retained mixed herds of cattle, sheep and goats as alternative sources of income in bad years, and as "standing banks". These families also tend to used crop residues for heating and cooking, and for livestock feed, and in some areas residues are sold for manufacturing purposes (paper, etc.). This means that at best very little organic matter is returned to the field in the form of retained crop residues. The consequences are declining soil organic carbon levels (e.g. from 1.0% to 0.3% in Tianshui in south Gansu); stable but low crop yields, over-reliance on artificial fertilizers (see Section 5.3.4), and ongoing wind- and water-caused soil erosion.

Farmers' reasons for using their scarce organic matter for non-cropping uses are logical and rational. However, when the opportunity costs of using crop residues for non-cropping purposes are taken into account it becomes apparent that there are strong arguments in favour of "breaking the organic matter cycle" even if this requires special extension support and subsidies (particularly zero-tillage machinery subsidies) from all levels of government[9]. The following figures, sourced from an ADB-Dryland Farming Project, support this argument:

- One tonne of crop residue has a value of about Y780 - this is the value of the incremental crop yield generated by leaving crop residue on surface and using zero tillage
- The financial opportunity cost of 1 tonne of crop residue is about Y150/tonne - this is an average for a range of non-cropping uses
- Conclusion – the best financial use of crop residue is as the basis for CA; not for livestock fodder, paper production, house-hold fuel, gasification, and power generation.

5.3.3 Increasing rainfed agriculture WUE

The mission's terms of reference refer to WUE in irrigated and dryland agriculture systems. However, the Chinese focus is mainly on the irrigated crop production systems. This priority is understandable given the huge volumes of water used to flood-irrigate wheat and maize (e.g. in Gulang Village in Xiao Man Township, water use for winter wheat and summer maize is 558 and 817 m^3/mu, respectively, over three to four

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[9] *Note: the proposal submitted to ACIAR by the University of Adelaide entitled: "Improving farmer livelihoods through efficient use of resources in crop-livestock farming systems of Western China" is designed to try and break this cycle.*

irrigations) and the disastrous consequences of not being able to use a declining supply of irrigation water far more efficiently. The irony here is that there are substantial Chinese research data to show that this volume of water could produce more grain if spread over more land, based on using optimal WUE criteria, or used for supplementary rather than total irrigation.

There are large areas of annual cropping land in Gansu which are either 100% rainfed or which rely on a combination of rainfall and supplementary irrigation – for example in Dingxi County. This situation means that there should be good opportunities to increase WUE in these more marginal areas through practices such as CA. There are considerable R&D trials or demonstrations in these dryland areas of the use of plastic film to harvest rainfall, channel this water to row crops and use the plastic as a mulch to reduce evaporation. This is another example of where many agencies are undertaking similar work but under different funding programs and without much exchange of information.

Water saving programs operate in these areas to collect rainfall and runoff for greenhouse production of vegetables using drip irrigation. There are also government subsidised programs to convert land to perennial pasture or trees to improve WUE and reduce degradation relative to current annual cropping systems.

5.3.4 Fertilizer use

The application rates of N and P inorganic fertilizer on irrigated wheat and corn crops in Gansu (and many other parts of China) are extremely high by world standards[10]. This leads to decreased farm gross margins and subterranean pollution of aquifers. For example, in Yong Chang Township in Wuwei City, farmers reportedly use the following quantities of fertilizer:
Urea – 43.5kg of urea/mu (20 kg of elemental N/mu and 300 kg of elemental N/ha); and
Phosphorus – 17.5 kg of elemental P/mu (263 kg of elemental P/ha).

These levels of fertilizer are being applied to soils which reportedly have 40-60 (and up to 80) ppm of P, similar levels of N, and a pH of 8.0 to 8.4. Irrigated yields are reportedly 6t/ha of wheat and 8t/ha of corn and with no fertilizer application yields are about 4.5 t/ha for wheat and 6.0 t/ha for maize. Given that 1 tonne of wheat/ha removes about 3 kg of elemental P/ha and 23 kg of elemental N/ha, the recommended Chinese application rates, even for the reported very high yields, are extremely high.

One explanation of the continued use of very high rates of N and P fertilizer is the national objective of maximising grain production, rather than optimizing farm-level profits and the returns to marginal public and private resources (e.g. irrigation water and farm labour, respectively). This observation is further discussed in Section 5.3.5.

5.3.5 Maximization rather than optimisation

A literature review, particularly ACIAR's Proceedings No. 123 "Agricultural Water Management in China" and discussions with scientists and technicians confirmed the mission's conclusions that the national objective of maximizing grain production (at any cost per unit area of land) is probably over-shadowing the more economically rational (and sustainable) approach of allocating public and private agricultural resources on the basis of their highest marginal returns.

This current national strategy is rationalized through the importance of wheat and maize as subsistence and cash crops in north-west China[11], but now that China has substantial

[10] However none of the scientists from the Gansu Academy of Agricultural Science and the Gansu Academy of Science knew of ACIAR's work on nitrogen use efficiency in Shanxi (LWR/2003/039).
[11] Particularly given the sharp increase in international grain prices in the past 12 months, e.g. wheat futures on CBOT have increased from about US$4.0 to US$9.0 per bushel. Whilst farm gate prices for wheat and maize in north-west China have increased by 40% and 33%, respectively, the import parity price of purchased wheat is probably about US$500/t.

international reserves and a booming economy, it is probably time to consider a new strategy which aims to maximize farmer and public returns to farm inputs. This gross grain production target-driven approach predominates at the lower levels of government but makes it even more critical for such agency personnel to be involved in the design and implementation of research and development for a new approach to WUE.

A good example of how this approach might complement completed and ongoing research on WUE and related issues can be found in ACIAR's Proceedings No. 123 "Agricultural Water Management in China", pp 13 (Groundwater use and potential implications for water conservation in the North China Plain), Tables 5, 6 and 7. These tables list: (i) irrigation times and number of irrigations; (ii) total irrigation water applied; (iii) total water used by the wheat crop; (iv) grain yield (kg/ha); and (v) WUE (kg grain/mm/ha). These analyses would be more useful as decision making tools if the RMB returns to the marginal mm of irrigation water had been calculated. For example Table 7 shows than an additional 80 mm of irrigation water resulted in a decline in wheat yield of 358 kg/ha, and a fall in WUE from 16.49 kg/mm/ha to 14.51 kg/mm/ha. The question is: "what do these figures mean in terms of gross margin per ha and gross margin per mm of irrigation water", for various rates of irrigation? The results presented in is report would have been far more useful in terms of extending the results to farmers if some basic farm management analysis had been completed with the objective of maximising the marginal returns to water, fertilizer, farm labour, etc.

5.3.6 Application of financial, economic and environmental analytical techniques

This finding follows on logically from the finding discussed in Section 5.3.5. The disciplines of farm management analysis[12](financial analysis), and economic and environment analyses are not well-understood by many of the agencies and institutions with mandates for rural development in north-west China, and are rarely used to add value to the scientific results. Few agencies and institutions have these in-house skills particularly at the county and township levels[13].

Examples of how the application of these techniques could change decisions by farmers and government officials on how to allocate scarce resources (in this case the relevant resource is crop residues) to increase incomes and protect the agricultural environment, are given in Section 5.3.2. In the context of increasing WUE in north-west China, the opportunity cost of increasingly scarce irrigation water, and the economic and environmental returns from this resource, should be considered in future research and development programs which focus on water and land management.

Past ACIAR research projects have often not included these analyses, but relied on straight technological improvements to convince farmers to adopt the new methods. This is usually not adequate in a society where change is not easily accepted. Information on financial benefits may have prompted adoption as the risks could be better understood.

5.3.7 Integration of issues for better understanding

The issues raised in sections 5.2.1 to 5.3.6 are all reasonably complex in terms of how they operate and impact in the field. It is only by involving extension staff in the design and analysis of relevant R&D that they will be able to understand the issues and transfer this knowledge to the farmers. The current practice of only disseminating results at the end of a project does not effectively utilise ACIAR's investment to achieve goals in WUE, CA or poverty alleviation.

[12] *Analyzing farms as a business even if they are very small and off-farm income is important for family livelihoods.*

[13] *This finding is supported by outcomes from the ADB's Capacity Building to Combat Land Degradation Project. Two mission members worked on this project during 2005-2007 with the objective of improving the financial and economic analytical skills needed to analyze options to address land degradation across north-west China. The main finding from this project was that these skills are not as well developed as technical skills and that this major deficiency is leading to inappropriate decisions on how to allocate resources to address land degradation.*

5.3.8 Partnership base

The range of partners in recent ACIAR programs has not been sufficiently broad, given the land and water issues and stakeholders in northwest China. The programs have resulted in some good capacity building within Chinese research institutions but they have not always resulted in multi-discipline research and have often not lead to the adoption of technology as the appropriate extension agencies have not been partners.

Future investments by ACIAR will need to address the issue of technology transfer and a more integrated watershed approach to sustainable land and water management. This can only be achieved if a wider and more appropriate range of stakeholders are engaged. In particular there will need to be more involvement with bureaux from the Ministries of Water, Agriculture, Forestry, Environment and Poverty Alleviation. This should result in a broader range of capacity building in all aspects of RD&E as well as greater on-farm adoption of sustainable land and water management practices.

6 Policies and programs guiding land and water management

6.1 Overview

Generally speaking there are three levels of laws or policies which guide scientific research, including research on WUE in China. The first level is the national laws, regulations and policies or plans which set the framework for important issues in China's economic and social development; the second level is the policies and plans at ministerial level which provide more details on the issues under their jurisdiction; and the third level is the provincial policies or plans. Normally local governments formulate their policies and plans according to the national laws, and ministerial regulations or policies.

Sometimes one issue comes under the responsibility of a sole ministry or department, but in many cases one issue is addressed by several ministries and departments (see Section 5.2.1 for details). In terms of WUE in agriculture, MWR and MOA are the agencies with general responsibility, but this critical issue is also addressed by NDRC, MEP, SFA, MOST, etc.

The following two sections contain lists of relevant national and provincial (Gansu) levels of the laws, policies and projects related to WUE in China. Full details on these policies and programs over the next five years, and in the longer term, are tabled in Appendix 1.

6.2 National-level laws, policies and projects

- Outline of the 11th Five-Year Plan for National Economic and Social Development
- 11th Five-Year Plan for Western Development
- MOA's 11th Five-Year Plan for Rural Economic and Social Development
- MOA's Agricultural Science and Technology Development Plan (2006-2020)
- NDRC's Modern Agriculture Demonstration Project Construction Plan (2007-2010)
- MWR's Water Law for the People's Republic of China (2002)
- State Council Management Regulations on Water Permits and the Collection of Water Fees
- National Water Saving Office - Outline of the National Water Saving Plan (2001-2010)
- NDRC's and MWR's 11th Five-Year Plan for Water Conservation Development

- National Guidelines for Medium- and Long-term Plans for Science and Technology Development (2006-2020)
- MOST's National 11th Five-Year Plan for Science and Technology Development
- National 10th Five-Year Plan for Science and Technology Development: (i) key special research projects; and (ii) new products research and development of modern water saving agricultural technology systems
- SEPA's 11th Five-Year Plan for National Environmental Protection
- SFA's 11th Five-Year and Middle- and Long-term Plan for Forestry Development
- NPC's Sandification Prevention and Control Law of the People's Republic of China
- Decision of the State Council on Further Strengthening Sandification Prevention and Control
- Circular of the State Council on the Perfection of the Policy of Grain-for-Green.

6.3 Gansu-level laws, policies and projects

There are a number of major policies and programs operating in Gansu that provide some direction to future investments in RD&E by ACIAR. Details of these are provided in Appendix 1.

- Gansu People's Congress Outline of the 11th Five-Year Plan for Gansu's Economic and Social Development;
- Gansu Department of Agriculture and Animal Husbandry 11th Five Year Plan
- Gansu Department of Science and Technology - Guidelines for Medium- and Long-term Plans for Science and Technology Development (2006-2020);
- Gansu Department of Science and Technology - Opinions on the Implementation of Modern Agricultural Science and Technology Innovation Action in Gansu Province; and
- Gansu Department of Water Affairs - 11th Five-Year Plan for Gansu Water Conservation, Development and Reform.

It is clear that RD&E in sustainable land and water management is very important but it is equally clear that there are major investments (recent and current) in some locations and topics that indicate aspects that are inappropriate for further investment to the level that ACIAR can provide. These Chinese and/or international investments are such that ACIAR's potential program would be 'swamped' or unable to identify a clear niche.

7 Past, current and future research on WUE and CA

7.1 Overview

Investigation by the mission identified a large range of research topics which are relevant to land and water resource sustainability, and related agricultural production. A complete listing of these research projects and programs, the main institutions and partners, the geographic and landscape locations, key technology issues or development, and comments on the extension processes used, are presented in Appendix 2.
From a reading of Appendix 2 and through discussions with the major stakeholders in cooperating institutions (particularly in Gansu and Shaanxi) it is clear that most research topics have been or are being covered. Of course some topics such as irrigation water quantities for specific levels of crop production, and the use of plastic mulch, are more intensively covered than topics such as optimum water use for crop and fruit tree production with associated productivity optimisation. The issue of optimisation is discussed in more detail in Section 5.3.5.

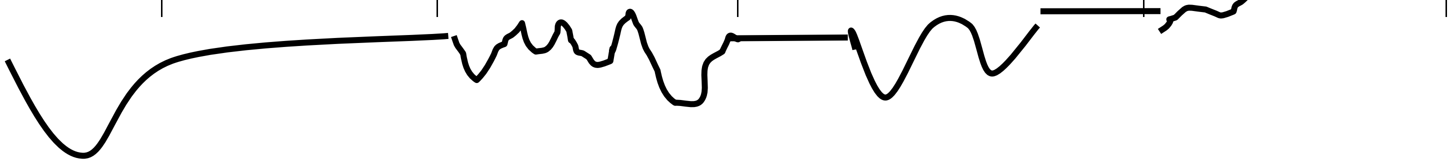
Many R&D topics are being or have been recently addressed by a number of research bodies and a major concern is the apparent lack of coordination or even knowledge of related R&D by other researchers. There are large numbers of R&D projects in water use, plastic film, fertiliser use, and tillage systems that do not appear to relate to, or benefit from, similar work at different locations or in different institutions. This duplication and failure to communicate and share information and resources is a concern as it wastes scarce research investments.

Similarly the lack of use of practical R&D information in extension programs, and the poor evidence of technology transfer from R&D projects to farmers, is also a concern as the outcomes of research investments are not available to the end user or stakeholder. It is reasonable to suggest that many of the solutions to many sustainable land and water resource management problems are known but are not being used by farmers, and certainly “best bet” options could easily be developed from the existing knowledge database. This is not to say that there are not some knowledge gaps, as discussed in Section 7.3. Section 8 further discusses the issue of extension of R&D results to on-farm application in more detail.

7.2 Assessment against land and water management issues

The mission developed Figure 1 using the 44 relevant R&D projects identified by the mission. These are listed in Appendix 2. The objective was to indicate where these R&D topics might fit into a typical landscape, and to identify areas of overlap. A review of Figure 1 illustrates that technology is available to improve the sustainable use of land and water resources in most sections of a typical watershed (or basin or catchment). Observations during field trips and discussions with stakeholders indicate that this knowledge is not being used on farms, particularly for some aspects of irrigation supply management, WUE, landuse suitability, fertilizer usage, and grazing impacts on land degradation.

Figure 1: Fit of Past and Current R&D across the Landscape

General R&D	Applicable to total watershed; 1, 8, 12, 17, 23, 25, 29, 30, 31, 39, 40					Climate 6, 10, 12, 27, 32, 41
R&D specific to landscape	1, 8, 11, 12, 14, 17, 20, 21, 22, 23, 28, 31, 35, 39, 43	4, 9, 10, 11, 12, 13, 20, 21, 22, 23, 26, 27, 28, 30, 32, 34, 35, 36, 37, 38, 40, 43, 44	2, 4, 5, 6, 7, 15, 16, 18, 25, 29, 33, 41	2, 4, 5, 12, 15, 16, 18, 24, 25, 26, 27, 28, 29, 30, 32, 33, 34, 41, 42, 44	2, 7, 8, 18, 19, 29, 30	
Landscape profile						Desertification and remediation of any landscape unit 2, 19, 29
Landscape name-→	River	Flat irrigation land	Dissected grazing land	Rainfed crop and grasslands	Forestry and grassland	Closed mountain
Land and water use	Water supply quality and quantity Allocation Policy	Irrigated crops Field Fodder Horticulture Green houses	Pastures Fodder Grazing and stall fed	Field crops Some local water harvesting Green houses Grasslands and grazing in mixed farming	Rehabilitation Afforestation Grazing	No grazing

7.3 Relationships between R&D projects and land and water management issues

Table 2 presents the information on relevant R&D projects (see Appendix 2) against bio-physical categories and again indicates the spread of knowledge, and the "depth" or concentration in some topics. This is a general analysis and does not indicate the impact of various projects on the land and water management topics, as the R&D projects vary in scope and depth of research into the nominated topics.

Table 2: Spread of R&D Projects against Land and Water Management Topics

Land and Water Management Topics	R&D Projects which Address Topic (Numbers relate to listing in Appendix 2)
Availability of water in watersheds – change in quality and quantity over time	1, 8, 11, 13, 17, 20, 23, 28, 31, 39
Environmental water requirements in watersheds	1, 17, 25, 30, 31, 39, 40, 41
Landuse planning based on assessment of suitability and capability	13, 16, 29, 30, 41
Ability to grow rainfed crops and pastures	3, 4, 5, 15, 25, 33, 41
Water saving techniques	20, 21, 23, 24, 33, 41, 42
Water allocation, pricing and property rights	1, 14, 17, 20, 21, 23, 31, 40
Irrigation system supply efficiency/losses	13, 20, 21, 23, 24
Efficiency/effectiveness of field irrigation application techniques	11, 20, 21, 23, 28, 30, 35, 36, 41, 42, 44
Field crop water requirements	10, 21, 23, 24, 25, 30, 34, 36, 37, 41, 42, 43
Horticultural crop water requirements	30, 37, 44
Drainage, re-use and salinity	11, 21, 22, 23, 28, 35, 41, 43
Crop and soil fertility requirements, and rotations	3, 10, 24, 26, 27, 32, 34, 36, 38, 41, 42, 43
Conservation agriculture techniques for crop production and erosion control	3, 9, 15, 16, 26, 27, 29, 33, 34, 36, 41, 42, 43
Conservation agriculture machinery	3, 9, 15, 26, 42, 43
Sustainable livestock feeding systems including crop residue, fodder and pasture	4, 5, 7, 15, 16, 18, 30, 33, 42
Forest development and management	30
Rehabilitation of degraded land and monitoring of socio-economic and ecological benefits	2, 8, 18, 19, 29, 33, 41
Poverty alleviation	2, 3, 5, 7, 15, 17, 26, 40
Climate change, greenhouse gasses and carbon	6, 10, 27, 32, 41
Water and watershed management policy	1, 8, 12, 13, 14, 15, 16, 17, 18, 19, 20, 23, 25, 26, 31, 39, 40

The conclusions which can be drawn from Table 2 (and related details in Appendix 2), together with stakeholders' comments during the mission's visit to China, are:
The development of field crop technology is very extensive and detailed. In terms of the scientific knowledge of how to grow crops under varying conditions, there is no shortage of information. This is the situation for all the major annual grain and cash crops. However, as reported elsewhere the major constraint is not a lack of knowledge but an inadequate system to transfer this technology to poor and risk adverse farmers. There are some exceptions to this general statement and these are listed below in (b) and (c);
Information on horticultural water requirements and efficiency is limited although the infrastructure technology is available (and used in demonstrations) to improve WUE in horticulture using micro-irrigation;

There are considerable unknowns in afforestation and management as well as methods to monitor and quantify the ecological or environmental benefits of large investments in these topics;

- Despite some projects in environmental water requirements, most of these focus on using the data in models, rather than in determining requirements for various ecosystems
- The technology and skills for landuse planning based on suitability and capability of the resource base are not well developed, even though there are systems for such planning and these are being used in FAO, World Bank and ADB programs in China
- The efficiency of irrigation supply systems is understood and considerable engineering work has and is being undertaken to improve this, but the aspect of providing water at appropriate times and quantities for irrigation scheduling at the farm level is not being promoted or discussed
- There are several major projects aimed at the principles and practices for water allocation, pricing and property rights
- Research is commencing into aspects of climate change and carbon sequestration
- While there are considerable data on crop yields for various water and fertiliser inputs, this is all used to drive maximum yield per unit of land (which is not the main limiting factor) rather than optimising yield per unit of scarce (or expensive) resources, such as water and fertiliser
- Farm management economics is rarely considered as a basis for determining the allocation of scarce natural resources (water, fertilizer, and in some cases arable land) or the optimisation of outputs
- There is poor quantification of the interaction of cropping, pastures and livestock in integrated systems where water is the limiting resource
- Extension of information for use by farmers and policy managers is not given adequate consideration in the development or operation of research projects.

A major issue is that the concept of optimising water use across all uses – agriculture, environment, human, and industrial - within a landscape and for multiple benefits is not being promoted or properly considered. In reality, much of the basic information is available but it is not being used to develop policies or practices. A major reason for this is that most government programs at provincial and county levels aim to maximize inputs and outputs per land area (mu). This concept is supported by the conclusions from ACIAR Project ADP or LWR/2000/120 - Institutions and policies for improving water allocation and management in the Yellow River Basin, China. How such information (and other project findings) can be fed into the policy development process remains a serious question for future ACIAR investment in China. A similar question needs answering in terms of the use of ACIAR’s project results in the Chinese agricultural extension system to enable farmers to utilise the new technologies.

7.4 Comments on proposed projects

The mission was presented with information on three possible projects to be considered for future ACIAR investment. Two of these relate to studies of inland basins and the other relates to crop-livestock farming systems. The mission’s task was not to critically review these proposals as the required information was not available and time was limited. However, an assessment of the proposed projects is helpful to illustrate aspects of a strategic direction for future R&D funded by ACIAR.

All future water-related projects should be consistent with the developing operation of Water Law 2002. China is implementing this law from policy to practice within the field of Integrated Water Resources Management (IWRM). The IWRM principles and management tools that are reflected in the Water Law were explained to the mission by the Gansu Department Water Resources, and are as listed in Table 1.

7.4.1 Inland basins in the Hexi Corridor

There are three basins in the Hexi Corridor of which the Shiyang and Hei are the largest. As indicated in Appendix 2 there are, and have been, extensive R&D projects in these basins. Both river basins have low to medium water availability and experience regular and severe water shortages due to agricultural and industrial development and population growth, which have created water demands which approach or exceed the available water resources. In both basins the present and future demands for water must therefore be met by a combination of more efficient use of water, reallocating water amongst users and by an overall reduction in water use. Further details on the extreme problems in Shiyang are provided by Huang Gaobao (August 2007) in his proposal "Research on Water Resources Allocation and Management under Ecological Safety in Shiyang River Basin" and by CAREERI in their presentation on "Water Issues in the Black River Basin".

The DfID-funded "Water Resource Demand Management Assistance Project" (WRDMAP) 2005 to 2010 is undertaking a comprehensive set of case studies in the Shiyang Basin. The three case studies are being implemented at different levels of government from river basin authority under provincial government to municipal, county and community levels in order to demonstrate the principles of management at the lowest appropriate levels, as indicated by the following quotation from the DfID Project Documents, Annex G (2004):

> "Case Study Gansu 1: IWRM planning for Shiyang River Basin (G-1) will apply the IWRM principle of water resources management in the context of a river basin. The planning process will be used to develop the mandate of the newly formed Shiyang River Basin Management Bureau (SRBMB) and strengthen its organisation. The case study will introduce international practices for river basin organisations, build commensurate capacity in water resources planning and management at the river basin level, and encourage communication with Wuwei and Jinchang Municipalities.
>
> "Case Study Gansu 2: Water saving societies in Wuwei and Jinchang (G-2) will assist Wuwei and Jinchang Municipalities, which are the principal administrative units within the Shiyang River Basin, to regulate water use within their administrative boundaries in order to achieve a long term sustainable balance between the available water resources, the current use of water and the projected future demands for water.
>
> "Case Study Gansu 3: Shared water management in Minqin (G-3) will assist Minqin County Water Resources Bureau and Water User Associations in selected rural communities to develop a model for increased community and user participation in the management of water resources and water delivery as close to users as possible".

Therefore, it would appear inappropriate for ACIAR to undertake any work in the Shiyang River Basin until the results of the DfID-funded work can be assessed and any new or remaining R&D topics have been identified. Most of the issues identified in proposals for R&D are the same in both basins and the results will generally be transferable, at least at the level of principles and water management practices, even if not in terms of actual water quality and quantity management.

MWR and SFA are jointly involved in the development of a RMB 5 billion Shiyang River Basin Plan to be implemented over a period of 10 years. Planning is under the control of

NDRC. The Gansu Bureaux of Water Resources suggests that the technology for the plan is available and that the plan is generally appropriate, except for the aspect of ecological monitoring. Ecological monitoring is a major focus of a new CAREERI study in the Black River Basin.

Hence ACIAR funded R&D in these inland basins of the Hexi Corridor should be postponed. The reasons for this are:

- The large government expenditure programs in these basins are changing the water resource base such that new supply systems, water rights and pricing will alter the viability, costs and benefits of irrigated cropping systems
- The expenditure on engineering and extension systems would swamp any ACIAR investment and make evaluation of the investment difficult
- The basins are unique in terms of their natural resources, infrastructure development and political characteristics such that transferability of results to other areas in north-west China would be unreliable
- It would be difficult to find a unique but important research aspect that would not duplicate other work
- Existing stakeholder arrangements would make it difficult to develop appropriate partnerships for new investments.

The one exception to this suggestion relates to the topic of optimising crop water use efficiency. There are considerable data on crop water use and related yields (even for varying fertiliser regimes) but it seems that this information has not been used to determine optimum return per unit of water applied. This is a critical factor for sustainable water use and is discussed in more detail in Section 5.3.5. However, such work would have to be based on the situation when current infrastructure changes are complete so that the new water delivery and availability regime is known. Given that this will take time, and other locations are available for such work, these basins are not ideal areas for investment by ACIAR in the near future.

7.4.2 Crop livestock farming systems

A major concern for future projects in this area is the fact that results of past research are not well known to extension agency staff and the systems developed are not being widely used by farmers. Unless future projects are developed with end-users as key stakeholders these investments will not address ACIAR's objective of poverty alleviation (see more discussion in Section 8).

Again it could be argued that most of the component information about production requirements is known but it is the systems approach and optimisation of resource inputs that are the factors that need to be demonstrated rather than researched. In fact the issues are more about appropriate resource assessment and landuse planning than about detailed agronomy, soil science or animal husbandry. The capacity building challenge in these area of R, D&E is to develop skills in systems-based sustainable resource use demonstrations.

8 Extension and technology transfer issues

8.1 Introduction

Appendix 4 is a detailed description of China's public agricultural extension system and covers the following topics:

- evolution of the public agricultural extension system in China
- characteristics of the public agricultural extension system in China
- existing problems of the public agricultural extension system
- reform of the public agricultural extension system.

This appendix should be read as background information to the following discussion on the issues related to the transfer of technology results from R&D programs to farmers (and extension staff), with some examples from Gansu Province.

8.2 Specific comments on agricultural extension

The primary interface between farmers and new technology in China is the Extension Centres (ECs) which operate at the county and township levels. ECs are supported by budgets from County Bureaux of Agriculture and Animal Husbandry, Water Resources, Forestry and others, depending on local circumstances. ECs employ technicians who are often part time farmers or who have farming backgrounds. Under such arrangements their primary task is to implement programs which are determined by these bureaux, or other tasks assigned by township governments to meet their operational plans. As such there is very little scope for these technicians to work on technology transfer topics which are not supported directly through this government hierarchy. It is also common for agricultural technicians to operate on health or welfare programs (for at least part of their time) if these are a township or county priority.

Hence for technology developed by universities, the Chinese Academy of Science (CAS), the Chinese Academy of Agricultural Science (CAAS) and foreign projects to be extended through ECs it is necessary for the technology to be accepted by the bureaux and preferably to have accompanying budget. It also helps if the technologies have been developed in a program that has the appropriate bureaux as initial stakeholders and that staff of these Bureaux are involved in research design and management. In fact, working with the extension agencies of MOA, MWR and SFA is the only way to guarantee that technology transfer will have the support of government and the status that this brings with it. A useful starting point would be the National Agro-Technical Extension and Service Centre of MOA.

Involving farmers in the research and extension processes is even more likely to lead to adoption and successful technology transfer. This is a fairly standard methodology for any adult education and training hierarchy to support outcomes, but one that the mission found missing or incomplete in much of the land and water management R&D reviewed.

The mission found a surprisingly low level of recognition of ACIAR's research projects by management and staff from the extension services, and even by other research organizations. This later point was common across all R&D organisations with very few staff having an understanding of parallel or competing work by other institutions. A major fault in sustainable land and water management appears to be the isolation of R&D between research providers and end users, and the subsequent limited transfer of skills and knowledge to policy makers, extension program managers and their staff, and ultimately to farmers or even private sector agri-industry.

Further information on the barriers to R&D extension and technology adoption is presented in Appendix 4. Analysis of past and current ACIAR projects indicates that most do not have adequate involvement of technology transfer or extension organizations in the project design stage. Most involve a few farmers in small field plots but contain no mechanism to transfer the relevant technical information beyond this level. The publication of scientific papers is not an extension mechanism; it does not even transfer the information into the policy arena or into bureaux operational programs[14]. Government extension programs tend to be based on technology approved by (and usually generated by) the agency rather than information from “outside sources” such as universities or academies.

ACIAR’s R&D providers need to engage (as stakeholders) with end users and extension organisations for all existing and future projects as a matter of urgency if there is to be any reasonable degree of adoption of results and ideas. ACIAR’s R&D providers also need to develop much stronger working relationships with other R&D projects operating in similar areas to avoid duplication and isolation. Both of these factors are reducing the outcomes and value of ACIAR past and current investments. All potential new projects need to substantially improve in these areas prior to submission and/or approval.

The mission concluded that the largest impediment to increased on-farm WUE and improved small-scale CA practices is the inability of China’s rural extension systems to engage with farmers and to transfer relevant technology. The mission encountered numerous examples of sound WUE and CA scientific results which had not been tested on-farm and adapted to local conditions, let alone extended to farmers. Such a situation is in effect a failure of the **D**evelopment and **E**xtension segments of the “**R**esearch, **D**evelopment and **E**xtension” system. The mission concludes that the **R** part of this equation is working well, the **D** part is partially effective, and the **E** part is almost non-functional. This means that in future ACIAR will need to ensure that all elements of this equation are included in the project design stage and appropriately resourced, either though direct budget support or by engaging with a partner/s who can provided these essential D&E services.

Illustrative box on tillage

Over the past 15 years ACIAR has invested considerable funds in China in various aspects of conservation tillage (CT). Researchers have been nationally recognised and the work is attributed as assisting with the development of a policy to support CT in China.

However, the Chinese partners on some current ACIAR projects are apparently unaware of some details of the work in similar ACIAR projects in other provinces, and of related R&D funded by other donors.

One ACIAR project is operating in association with the Agricultural Mechanisation Department of the MOA, yet staff in the Agricultural Extension Department of the same Bureau are not aware of the work and are not extending the information to farmers; while staff in the Water Saving and Soil Conservation Department of the same Bureau are conducting separate research on the use of mulch for water conservation. Part of the problem is that the Agricultural Mechanisation Department has separate extension sites and activities. However this situation should have been identified during the design stage of the project.

[14] A warning bell sounded when the Agricultural Extension Bureau in a county where there was an ACIAR project were not using its findings, even though the topic was regarded as a priority for farmers in the county and a few farmers had been involved in field trials.

An impact assessment of ACIAR Projects LWR2/1992/009 and LWR21996/145 (Vere 2005) presents a comprehensive economic assessment and reports very favourably on the projected economic benefits. The report comments on the policy impacts and on capacity building for researchers. Whilst it does not comment on the actual adoption of CT technology by farmers, or on the actual use of the R&D findings beyond the life of the project, there is evidence that in Shanxi, where the ACIAR projects were located, there has been good uptake and that the Shanxi Agricultural Mechanisation Bureau is actively pursuing a program to further refine CT. Neither does this study comment on any actual local or regional technology transfer, although it would be worthwhile to investigate the reasons for the comparatively high level of uptake in Shanxi as opposed to other Provinces, including Gansu.

Given the reported success of these two projects, the mission was surprised to find that a current ACIAR tillage project is still having some problems with CT machinery in some raised bed and maize-wheat systems. Also surprising was that researchers are not actively seeking out possible solutions from other parts of China or internationally where small plot CT machinery is reported to be operating very successfully and functioning as the key to the wide-spread use of CA technology.

Clearly there are regional and location specific differences for some soil/crop systems but current and future CT projects should be more about applied D&E with extension services, farmer associations and commercial operators rather than continuing to undertake basic research with academic institutions in this topic. Ensuring that farmers and all appropriate extension providers are consulted as partners at the design stage should reduce these problems.

The situation described in the box is common to many developing countries, and to other parts of China. However if the outcomes from ACIAR's projects are to be more widely disseminated across thousands of small irrigated and dryland farms in Gansu and other provinces, there is an undeniable and essential need for ACIAR (in the future) to engage with partners who can provide improved D&E services.

One such partner is PADO, see Section 5.2.3. Of all the agencies and institutions interviewed by the mission, PADO had the best understanding of the extension techniques which are now accepted as best practice, in China and throughout the world. These are based on farmer participatory techniques which allow groups of farmers to select new technologies from a prescribed "menu of options" for on-farm testing in their own fields. The use of Farmer Field Schools (FFSs) has also proven successful in China's north-west provinces. FFSs are key elements of World Bank, Asian Development Bank, Canadian, UK and AusAID projects so the question has to be asked: "why are they not essential components of ACIAR's investments"? Another potential partner in this process is the ACWF, see Section 5.2.3.

Although research into extension and farmer learning/training techniques may be outside ACIAR's mandate, the mission suggests that attention to these topics will be essential if the results from ACIAR's R&D program are to be successfully adopted by resource-poor and small-scale farmers. In addition and as suggested above, in future it will be essential for ACIAR and their cooperating Chinese partners to ensure that farmer extension and training programs are designed into their projects from the beginning, and not considered as an "after-thought".

In addition ACIAR should engage with MOA, MOST and other relevant agencies and institutions to ensure that this major constraint to rural development in China is addressed by key policy-makers. There is a current initiative under-way to address this lack of coordination between those parts of government and research agencies which have responsibilities for increasing farm incomes. ACIAR should become familiar with this development and as such it needs to interact more regularly with the appropriate departments within MOA and MWR.

Greatly improved partnerships with extension providers (County and township), farmer associations and the private sector (eg, machinery contractors and product processors) are essential for the effective operation of the future ACIAR program. Past and current technology developed by ACIAR investments is not being widely communicated or adopted and this is often a deficiency in project design and operation. The pathways through which farmers obtain technical information on WUE and CA are still reasonably clear and identifiable in China but they function by responding to available information rather than seeking it out (see Appendix 4). Therefore, to ensure adoption impact, ACIAR projects need to involve these extension providers at the concept stage of a project and then throughout its implementation.

Involvement of this broader, but relevant range of stakeholders in early needs analysis of all partners and gap analysis of current knowledge will ensure that the research hypotheses are relevant and the methodologies lead to practical recommendations or technologies.

9 Drivers of change in water and land management

9.1 Overview

Significant developments in the Chinese economy; and how agriculture adjusts to these changes, to world trade and to global/regional/domestic environmental issues, are increasingly influencing the operating and investment environments for rural land and water management, particularly in areas which are reliant on declining supplies of irrigation water. Some of these changes have been incorporated into water management regulations and policies, as described in Section 6 and detailed in Appendix 1. Others are secondary consequences to local economic development such as the cost and availability of labour; and others come through society's concern about environmental issues. Therefore it is necessary to consider the drivers of change from both the perspective of natural resource management and then from the perspective of the end user; in this case the farmers. For each case there are internal and external drivers of the change process.

9.2 Natural resource managers

Land and water are scarce resources in China and there is increasing pressure to manage these resources efficiently and sustainably, both from an environmental and farm profit point of view.

9.2.1 External drivers

The Water Law 2002 sets obligations for basin-level water managers, system supply providers and local water authorities to appropriately and efficiently allocate and supply water for the competing needs of rural, urban and industrial users. This involves the need for a range of physical allocation data sets and procedures, the application of "property right" concepts, and the operation of pricing systems for cost recovery.

At each level in the water administration system these drivers are set by the management level above. There may be a need to establish policy and operational parameters at each level, but information to assist with this process is often limited.

A major change is necessary in this arena because as water becomes increasingly scarce or more expensive, it becomes the major factor limiting agricultural production, rather than land. Policies and processes to optimise production per unit of water become far more important than the past driver of maximising production per unit of land.

The Sandification Prevention and Control Law and related Ministry programs provide a framework for retiring grazing land, reafforestation and the development of improved dryland cropping. The mechanisms of this law provide for coordination arrangements at the provincial level which may well be a mechanism for securing multi-agency coordination for watershed based RD&E.

Drivers for changes in landuse are also changing as central government regulations and policies ensure the retention of agricultural land around urban areas and convert “marginal” land from cropping to forestry under the GFGP. Both of these factors drive local land allocation and use, but good resource capability data are needed to ensure appropriate and sustainable landuse planning.

9.2.2 Internal drivers

Competing needs are the biggest drivers affecting sustainable natural resource management. That is, there are generally more potential uses for land and water than there are resources to allocate. However, R&D developments which focus on improved resource understanding and new technology for sustainable resource use are assisting managers to understand and meet these competing demands.

As in most countries “political objectives” can make sustainable resource allocation difficult. For example, land should be assessed for its sustainable cropping potential before being mapped for conversion to forestry. Another example is that water should be allocated to the highest optimal use rather than following traditional practices which result in lower production per unit volume of water. However, technology and bio-physical and socio-economic data are becoming available to assist managers to determine sustainable resource use and allocation.

Water scarcity in local areas is driving considerable R&D and large scale physical works programs. It is important to ensure that these are bounded by knowledge of the integrated resource and the potential off-site impacts. For example, increasing groundwater usage or water diversion to other catchments can have major impacts on local sustainability due to salinisation and loss of ecosystems. Again data are becoming available which can assist with the determination of these trade-offs when allocating scarce and integrated resources.

9.3 Farmers, herders and foresters

These resource users are all facing an increasingly important set of external and internal drivers which influence how they use their natural resources to maintain sustainable, equitable and acceptable life styles.

9.3.1 External drivers

These include:

Allocation of land and water rights

User rights for state land have been allocated for some time in most parts of China, particularly for arable crop land and increasingly for the more marginal grazing areas. However the allocation of water rights and associated fixed irrigation water quotas (m^3/mu/farmer/year) are recently established external drivers which have the potential to radically change how farmers use this increasingly scarce resource. The understandable “imposition” of these new drivers will need to be accompanied by large technology transfer programs if farmers are to maintain a reasonable standard of living. Simply decreeing changes in the availability of irrigation water and then waiting for farmers to adjust their crop production systems will not work – this process must be supported with substantial public expenditure on agricultural extension programs.

Water pricing and timing of availability from supply authorities

As with (a), the decision to charge more for irrigation water (RMB 0.07/m^3 for water used on farms in a village in Zhangye City), and for local water management authorities to begin to install irrigation scheduling equipment will be powerful drivers of change, provided they are supported with appropriate farmer education and training programs.

Effective operation of water user associations (WUAs) or other production-based groups

The allocation of land and water rights, and the introduction of water pricing, must be undertaken in association with effective extension programs which need to be understood by and have the support of WUAs and farmer production groups. The objective of increasing WUE and CA practices will not be achieved without the full involvement of rural communities and the provision of support for changed production systems. Appendix 3 contains more details on the evolution and operation of WUAs in China.

Level of technology support and/or incentives through government agencies or the private sector

Without support from this external driver, and in association with driver (c), the influence of the “imposed” drivers (a) and (b) will be limited. In addition, the role of the emerging private sector cannot be ignored, particularly in terms of marketing and the provision of crop production inputs.

Determination of landuse through programs such as GFGP conversion to forest, or bans on grazing animals

This massive, nation-wide program has already had a marked influence on farmers’ livelihoods, at least in the short-term. Throughout north-west China farm families in their millions have elected to receive annual payments of varying durations, depending on the types of land surrendered and the replacement crops/trees grown. GFGP has reportedly now reached its peak in that the rate of expansion will slow down in future as the cost of contracted periodic payments has escalated (recently it was reported that this program has been “suspended” indefinitely due to “over-success”, particularly in the north-east of China). However there is no doubt that the Program has had a profound and broad-scale impact on changed landuse in China’s more marginal agricultural areas.

Markets and prices for products increasing influenced by world trade situations

Since gaining accession to the World Trade Organization (WTO) China has begun to liberalize its agricultural trade and to expose its rural producers to international prices and costs. This process is expected to continue and therefore even in provinces as remote as Gansu (in terms of its distance from sea ports - which determines import and export parity prices and costs) farmers’ terms of trade and therefore their standards of living will be determined by drivers which are beyond their control. For some products, e.g. wheat, this could mean increased farm-gate prices as the world’s stocks of coarse grains continue to fall and international prices respond positively. In the case of Gansu, the import parity price (shadow price) of wheat could reach US$500/tonne and in food deficit areas this should mean that farm-gate prices should rise well beyond the current level of about US$285/tonne. It is reasonable to assume that over time the Chinese Government will allow timelier and more accurate international price signals to influence small farmers’ crop selection.

- Availability of local contract services operations such as zero-tillage. The provision of private sector services (such as contract zero-tillage planting services offered by local entrepreneurs who set up businesses based on the 30% government subsidy) will be important drivers of change which impact on WUE, and the environment through the use of CA. Most small farmers cannot afford the capital outlays to purchase small zero-tillage seeders and tractors, but financial modelling (see Section 5.3.2) and discussion with officials and farmers indicate that the rate of adoption of this important and proven technology would be increased if the machinery constraints (planting efficiency and local availability – see Section 5.3.1) could be over-come. Ensuring that CA machinery for contractors and for individual farmers is available is an important objective for a relevant CA program.
- Availability of credit. Farmers often have to use credit for purchasing inputs such as seed and fertilizer for crops, or for the purchase of livestock. The availability of credit and the lending conditions can influence the scale of an enterprise or a farmer's willingness to accept the risk of new technology. The cost of new machinery and the availability of government subsidies or loans for purchase are factors which influence the uptake of CA practices.

9.3.2 Internal drivers

These include:

Available farm labour if household members seek off-farm employment

The national policy of encouraging members of poor farming families to seek off-farm employment in China's larger cities has lead to the situation where, in some areas, there is a shortage of farm labour at certain times of the year. This policy has also resulted in many female-headed farm families. The promoters of new agricultural production systems need to consider these demographics, and to adjust/adapt their technical messages, CA machinery and extension techniques to suit local situations.

Households' age structures and life style goals

Similarly, the promoters of new technology need to consider the impact of aging farmers and changing life style objectives. Past methods to encourage changes at the farm level are probably no longer appropriate.

Funds to implement technology changes which may involve a personal outlay

For example, a percentage of the cost of participating in government-sponsored programs where the balance of the funds is a government subsidy, such as for plastic film for early maize, and greenhouses. Some of the poorer farmers do not have the financial resources to be able to participate in such programs and therefore there may be a need for other sources of short-term finance.

Ability to understand and manage new technology

Such as reduced/zero tillage, irrigation scheduling and greenhouse production. Some farmers find the challenge of changing their traditional production systems (e.g. deep ploughing followed by repetitive harrowing before winter - for spring wheat) particularly daunting. This means that technical and extension staff need skills, not only in the new techniques themselves, but also in human education and adult learning techniques. In some areas the recognition of "model farmers" provides an incentive to change and is a source of "champions" for technology extension.

10 Options for future research strategy

10.1 Introduction

The mission considered various options for ACIAR's future China cooperative research program including:

- continuation of the current strategy which is passive and based on accepting proposals and suggestions from Australian research partners, provided they comply with ACIAR's current project selection criteria and with Chinese agency or ministry strategies
- a greater focus on "big picture items" such as the large river basin studies which were flagged to the mission by Chinese agencies and institutions as being critical to the success of identifying and extending water saving technologies
- a refinement of the current strategy with the objectives of increasing the on-farm impact of ACIAR's past and current research, and expression of the complementarities between ACIAR's and other research projects which focus on WUE and CA.

The mission's finding is that the current "passive" approach is not effective in delivering recognisable benefits in WUE or poverty alleviation to a substantial number of farmers. In most cases, the recognition and uptake of the technology from these investments has not been significant or ongoing as it has not been "accepted" by agencies undertaking extension and its direct influence on farmers has been very small. The mission also found that becoming involved in large river basins where there was already large ongoing investments would not allow an ACIAR focus and would not result in the development of technology that was replicable in other areas. There is also evidence that such involvement would not be welcome by water authorities except in a few small cases where knowledge gaps might exist.

Therefore, the recommendation is that ACIAR should operate a technically directed program in a geographic location (preferably a watershed) in Gansu Province which is not currently being substantially impacted by large scale national, provincial or bilateral aid or development support. Such a direction and/or location could be nominated by ACIAR to potential partners or be agreed as part of the bidding process discussed in Section 10.2 from suggestions made by potential partners.

Such a directed approach should enable ACIAR to:

- provide a targeted program approach to the objectives of improved WUE by all water managers and users (including the use of CA) and poverty reduction on farm, rather than the current individual (and often isolated) project approach
- concentrate its efforts in an area or watershed where is should be possible to measure the direct impact of ACIAR's R, D&E efforts and avoid the confounding effect of other projects and programs
- build on past results from relevant ACIAR-funded research (with the objective of increasing the returns to historical expenditure)
- capture the outcomes and subsequent benefits from Chinese-funded R&D which are relevant to the targeted watershed, and therefore extend "technology which is on the shelf" and/or improve the extension of applied technology

- link with national and provincial programs promoting sustainable land and water management to ensure the correct operational context for future RD&E so that it is complimentary to, but not consumed by, government activity
- use participatory research methodology to involve appropriate extension staff and farmer associations in the design stage to adequately address the drivers for all stakeholders for the topic concerned
- ensure that any investment is coordinated with and uses existing data from any relevant R, D&E projects supported by other countries such as Canada, UK, EU and Japan
- bring together all relevant R&D outcomes in one area (preferably a small watershed) where it should be possible to generate complementary outcomes between past R&D programs which are relevant to different sections of a watershed, (e.g. ADP/2000/120, ADP/2002/021, LPS/2001/094, CIM/1999/094, LWR/2002/018, LPS/1998/026, LWR/2003/039, and LWR/2002/094)
- consider WUE for agriculture (dryland and irrigated) in association with environmental water needs in the watershed
- use gap analysis with stakeholders to identify missing links between these and planned projects with the objective of being able to extend a full range of development options which are applicable over an entire watershed for sustainable land and water management
- develop stronger and more strategic linkages with relevant bi- and multi-lateral projects such as AusAID's ACEDP, EU's River Basin Program and World Bank or GEF projects which have a far greater ability to influence policy
- develop appropriate multi-discipline teams so that integrated natural resource management outcomes are developed and extended to resource owners and users
- enable improved and earlier engagement with agencies which have mandates for village development - not just the technical agencies and bureaux, but also the social and poverty alleviation agencies such as the ACWF and PAD
- ensure that appropriate communications and engagement plans between all collaborators and the beneficiaries are developed, maintained and reviewed regularly across the life of the investment.

This directed approach is recommended for ACIAR's strategy so that:

- past R, D&E deficiencies are over-come or avoided
- future research programs build on past results and complement outcomes from relevant but independent research and development programs and projects
- a critical mass approach is used with the overall objective of maximizing the impact of R, D&E at the farm-level
- extension agencies and farmers are key participants from design to finalization
- projects address all aspects of sustainable land and water resource management
- the approach recognizes, and avoids if necessary, the geographic areas in which large national, provincial or bilateral projects are planned, or are currently being implemented that could confound either research conditions, extension processes or adoption rate
- a broader base of Chinese and Australian partners is engaged in all aspects of R, D&E and possibly with an increased level of investment contributions.

10.2 A bidding process

10.2.1 Overview

The preferred option outlined in Section 10.1 is expected to result in larger and more multi-disciplinary R, D&E programs for ACIAR to fund, in conjunction with their counterpart stakeholders in Gansu. If ACIAR accepts the mission's recommendations, one outcome could be the need to allocate increased internal ACIAR and Country office management time to the processes of new R, D&E program identification, assessment and planning. However given that this suggestion is probably not acceptable to ACIAR, the mission suggests that a bidding process be used to plan new R, D&E programs which focus on specific watersheds in Gansu Province and comply with design criteria which can be identified by reviewing the points listed in Section 5 and extracting specific criteria which are considered to be essential for successful new R, D&E programs.

The bidding conditions and processes would generally follow internationally accepted procedures, although ACIAR and relevant responsible partners should jointly reserve the right to "re-package" bids if the process does not reveal a consortium which proves that it is able to comply with all the bid selection criteria. It is expected that bidding consortia would include ACIAR's current partners in Gansu, and other agencies and institutions which are considered to have the skills and experience to enable the consortium to be able to comply with essential bid criteria. This approach should result in more multi-disciplinary consortia because of the need for a greater focus on farmer participation and the on-farm delivery of research results.

10.2.2 Bidding steps

Following acceptance by ACIAR and its key partners of the recommended new strategic direction and an agreement between ACIAR and key partners on how any proposed new project would be jointly managed[15], the following steps will need to be completed:

- Agree on essential bid criteria which will be used to select a conforming consortium, with the proviso that ACIAR and key partners have the right to "re-package" non-conforming bids in order the achieve the desired outcomes. Such criteria should include:
    - evidence of agreements with the county and township governments and village committees (as appropriate) for their cooperation and support, and a clear statement of the resources to be provided to support the project
    - a list of cooperating agencies and institutions, a nominated lead agency or institution, and a clear description of each agencies'/institutions' roles, responsibilities and contributions
    - statements of support from the relevant ministry departments responsible for R&D as well as those responsible for extension as these are usually separate
    - evidence that the county, township and village agricultural extension stations and personnel have agreed to support the project, and an agreed list of the resources and budget to be provided from these sources
    - a review and gap analysis of relevant past and current research programs, so that the new projects build on and complement past results

[15] *It may be necessary for ACIAR to fund and appoint two Program Coordinators, one based in Lanzhou and one in Australia, at least for the first two years of (say) a five-year project. As the number of projects in China reduces over the next year or so, there is potential for the Country office to take on some of this responsibility.*

- a detailed description of the project's objectives, components, and the logic of how activities address objectives with key performance indicators at each level to enable a fully defined M&E plan
- budgets for each component which clearly list "who will pay for what and when", including contributions in kind and possible compensation payments to cooperating farmers in the event that a trial or experiment fails
- a description of the production linkages between the project components, and of the linkages which may need further research in order to allow an integrated watershed management approach to "D&E"
- evidence that appropriate land and water resource allocation and regulatory managers are involved as stakeholders, and the linkages of how R&D information will be used to address policy issues in China and Australia
- a description of how outcomes will benefit the targeted poor farmers, and how the outcomes might be of use in Australia[16]
- a description of the proposed linkages and cooperation arrangements with relevant bilateral, national or local projects as appropriate
- a plan to engage with local farmers (during the project design and implementation phases) in a participatory way to ensure their commitment from the outset including needs analysis which can lead to early identification of key farmers and champions
- a clear "D&E" plan to deliver new and past research results to poor farmers, and to extend the results to other watersheds with similar characteristics, i.e. out-reach programs
- a description of the M&E system which will be used to measure progress and impact, including mechanisms for project revision as necessary, and a description of the proposed reporting program on project results and outcomes
- M&E to include financial, environmental and social impacts
- a description of the "clearing house" to be used to disseminate the project's achievements and results to other agencies and institutions which might be interested in using these outcomes for their own programs
- an outline of the over-all capacity building program (including specific in- and out-country training) and associated conferences and workshops.

• Finalise the selection criteria for a watershed in Gansu which has the following characteristics[17]:
  - in a PADO-recognised poor county, but not in the Hexi Corridor
  - contains 3-5 townships in one county (or two counties at most to reduce administration complexities)
  - contains representative landuse systems: e.g. closed land, grazing land, sloping land which is suitable for forestry and economic forestry, land suitable for terracing, dryland cropping areas, and irrigated areas

[16] This requirement could prove to be a "stumbling block" for the suggested strategy as initial assessments indicate that the direct benefits to Australia's farmers from such an approach may be limited.
[17] The actual selection may be undertaken by ACIAR and Chinese agencies prior to the bidding process or it may be undertaken as an integral step at the EOI stage of bidding using information provided by potential partners, based on the selection criteria.

  - is not “cluttered” with previous research and development projects and programs that have competing objectives or where these investors are not going to become partners in the new RD&E
  - is not an area where large infrastructure projects are planned for the future as these will change water and land allocation arrangements, irrespective of the outcomes of the proposed R, D&E
  - has reasonable all-weather access
  - topographical, soil and water resource and current land-use maps are preferably available.
- Promote the bid opportunity across all past and potential ACIAR Chinese and Australian partners to engage a broader partner base and enable selection of the most appropriate RD&E providers for each situation. This will also ensure that all potential partners understand ACIAR’s principles and concepts so that unreal expectations of support are not created
- Facilitate a two stage process where[18]:
  - Stage 1 is an expression of interest (EOI) only and ACIAR selects the EOIs which are worthy of full development, those EOIs which would benefit by being combined for full development, and those EOIs which do not meet the selection criteria or priority ranking such that their full development is not warranted; and
  - Stage 2 when full proposals are submitted and assessed. It may be appropriate to provide some resources to the EOI proponents that are selected to develop a Stage 2 full proposal so that they can adequately engage all stakeholders in the development of the proposal. This will probably require a workshop in the proposed location with all stakeholders, including ACIAR, Chinese agencies, and representatives of RD&E proponents and end-users. This cost to ACIAR will enable the development of a more efficient and effective project proposal and should lay the foundations for successful implementation.
- Assess, revised bids against the agreed criteria
- Sign contract and commence implementation
- Manage the investment based on regular M&E reports using standard ACIAR evaluation procedures
- Negotiate revision of projects if required to address issues identified during evaluations.

[18] *This 2 stage process is used by a number of R&D corporations in Australia so the development of procedures will not be difficult.*

11 References

Appendix 2 contains a complete list of references

12 Appendixes

12.1 Appendix 1: Policies and programs related to WUE

Note: the information in this table has been translated from Chinese

Document	Issued by and timing	Goals and Objectives	Policies or Programs
National Level			
Outline of the 11th Five-Year Plan for national economic and social development	NPC (proposed firstly by CCP); released in March 2007	Five year plan is a grand blueprint and guiding document for China's economic and social development, which clarifies national strategic intention, identifies government work emphasis, and guides market behaviour. **Goals:** GDP growth rate 7.5%; urbanization rate to 47%; both urban employment and migrant agricultural labourers will increase by 45 million; Urban and rural development growth is to be balanced; R&D expenditure will increase to 2% of GDP; Arable land will be maintained at 120 million ha. Main pollutant discharges will be reduced by 10% and forest coverage rate will reach 20%; rural resident per capita net income will grow by an annual rate of 5%. New rural cooperative medical care coverage will reach over 80%. The efficient use of resources is given special attention: Energy consumption per unit of GDP is to decrease by 20%. Water consumption per unit of industrial added value is to decline by 30%. Irrigation water use efficiency is to increase from 0.45 in 2005 to 0.50 in	**I. Building a new socialist countryside** The outline proposes to retain developing agricultural productivity as the primary task, maintaining grain production growth and increasing its production capability to around 500 million tonnes. It also proposes to up-scale the agricultural value chain to let farmers benefit more from the agricultural diversification and develop farm produce processing, preservation, storage, transportation and other services. It suggests to accelerate implementation of rural water safety project, basically realize connection of all towns by cement roads, perfect rural power grid, basically connect all the villages with telephones and provide internet access in every town, complete rural healthcare and medical aid system. **Important programs:** Large scale grain-cotton-oilseeds production base and high quality grain program; fertile soil program; plant protection program; continuous construction and renovation of large scale irrigation irrigations; rural safe drinking water program, etc. **II. Building a resource-saving and environmentally friendly society** **1. Saving water and water management:** Shift in water resource management from mere flood control to flood management and scientific utilization of the rain; from the exploitation and utilization of water resource to water-saving, water protection and optimal allocation. **Measures:** Developing the water-saving agriculture; promoting the rainfall harvesting (collection); constructing the feed production base with water-saving irrigation; improving the water use efficiency and realizing the zero growth of the total amount of irrigation water. Strengthening the unified management of water resource; unifying the arrangement of water uses for living, production and ecological purposes; rational allocation of water resource between upstream and downstream river basin and between surface water and underground water; controlling the exploitation of underground water; improving the water-taking permit system and payment-based use of water resource; implementing the system of the combination of total quantity control of water use and quota management; perfecting the management

		2010. Industrial solid waste recycling and conserving rate is to grow to 60%.	system of water resource of the combination of basin management and regional management; establishing primary national water right distribution system and the water right transfer system, etc. **2. Protecting and restoring the natural ecology** The foci of the ecological protection and construction should shift from the *ex post* management to the *ex ante* protection; from the artificial construction to the natural recovery. In the natural forest protective areas and important water source areas, establishing the important ecological function zones and promoting the restoration of natural ecology. **Environmental protection programs in the 11th Five-Year Plan:** **(1) Natural forest resource protection**: effective management and maintenance of 94.18 million hectares of natural forest and other forests; afforestation of 5.79 million hectares in the upper reaches of Yangtze river and upper and middle reaches of Yellow river. **(2) Retiring the farmland to forest and to grass**. In the Yangtze and Yellow river basins as well as the dust and wind affected North China, continuing to implement the policy “Retiring the farmland for forest and for pasture”. **(3) Retiring the rangeland for grass**. Four areas: East inner Mongolia; West of inner Mongolia, Ningxia and Gansu; East Qinghai-Tibet Plateau; North Xinjiang. **(4) Beijing-Tianjin dust and wind origin management**. **(5) Protective forest system**. **(6) Wetland protection and restoration**: establishing 222 wetland protection areas, recovering the important wetlands through rational allocation and management of water resources. **(7) Ecological protection of Qinghai Three-Rivers-Origin natural protective area**: “retiring the rangeland for grass” 6.44 million hectares; “retiring the farmland for forest and for grass” 6,500 hectares, management of black lands, desertification control, forest reservation and wetland protection 0.8 million hectares; harnessing of water and soil erosion 50,000 hectares. **(8) Water conservancy engineering**: increasing the control of water and soil erosion on 19 million hectares; implementing the integrated management of Shiyang River Basin. **(9) Integrated management of stony deserts area**: mainly through vegetation protection, retirement of farmland to forest, planting grass to raise animals, rational exploitation and utilization of water resources, land management and water conservancy, change of farming system, establishment of rural biogas and migration for poverty alleviation, etc. **III. Promoting balanced regional development** The overall strategy for regional development is to advance the western development, rejuvenating old industrial bases in northeast China, promoting the rise of the central region; and encouraging development of the east first. The outline further proposes to give overall planning to population distribution, economic deployment, land utilization and urbanization pattern in light of the carrying capacity of resources

			and environment, existing development density and potential, so as to classify the land space into four categories: optimized development, key development, restricted and banned development zones.
Eleven Five-Year Plan for the West Development	NDRC and "West Development Office of the State Council". March 2007	Guiding principles and blueprint for West China's economic and social development in the next five years. **Challenges**: enlarging gap between western China and other regions; the infrastructure lags behind, serious shortage of water resources in NW China; higher incidence of poverty; heavy ecological stress; high proportion of restricted and banned development zones in the total land area, etc. **Goals**: constructing a set of important programs on the exploitation and saving utilization of water resource; making important progress on the water-saving agriculture, unit irrigation water use reduced greatly, and zero growth for total amount of irrigation water. The proportion of water and soil erosion in total land area decreasing by 2%, control of the degraded rangeland 110 million hectares; the forest coverage rate in the national ecological protection and restoration area increases by more than 2%, and pollution discharge reducing by around 10%.	**Measures:** Strengthening farmland and rangeland water conservancy construction; actively developing the dryland farming water-saving agriculture. Increasing water-saving irrigation area by 2.67 million hectares, irrigation water use efficiency in agriculture is to increase to 0.5. Adjusting agricultural production structure. **Important programs** **I. Agriculture:** Basic farmland for ration grain program (NW China 2 mu per capita; Southwest China no less than 0.5 mu per capita); Commercial grain base program (Shaanxi, Ningxia, Inner Mongolia, Hexi corridor of Gansu, etc); Special and advantageous agricultural product base program; Water-saving demonstration program (extension of advanced water saving techniques, such as the pipe irrigation, lining channels, drip irrigation; support of the purchase of the water saving equipment; and the construction of the small scale rain collection facilities); Rural safe drinking water program; Rural road; Rural energy; Ecological migration for poverty alleviation; Demonstration of agricultural science and technology; Rural labour transfer. **II. Water and environment:** Strengthening the construction of water conservancy facilities. Promoting the saving, protection and optimal allocation of water resource. Fastening the construction of rural middle and small scale water conservancy facilities and matching engineering, steadily improving the water supply for the heavy shortage of water area, resolving the drinking water for the rural and urban habitants, etc. National tasks of the 1.33 million hectares of the "retirement of farmland to forest and to grass" and 2.33 million hectares of afforestation in the barren mountain and barren land will be mainly located in west China. Arranging 50 million hectares of "retirement of rangeland to grass". Control of water and soil erosion 11 million hectares. Other environmental programs elaborated in the national 11th Five-Year Plan are mainly implemented in West China.
The National Guideline for Medium- and Long-term Plans for Science and Technology Development (2006-2020)	by the State Council in Feb. 2006	Guiding document for China's S&T development in next 15 years. **Goals**: strengthening China's innovation capacity; achieving advanced scientific results in the world; overall capacity (strength) of agricultural science and technology entering into the advanced place in the world; placing China's technologies on energy development and energy-saving and	Energy, water resource and environmental protection are among the priority areas for research. **I. Water:** (1) Optimal allocation of water resources and integrated development and utilization of water (research on the transfer mechanism and optimal allocation tools on the interaction among surface water and underground water; utilization techniques on the polluted water, rainfall; technologies of the artificially increasing rainfall; Key technologies of integrated management of important rivers such as Yangtze and Yellow River, and Key technologies of important hydrological projects); (2) Comprehensive water saving (production water-saving technologies in industry; developing

		clean energy close to world's advanced level; providing scientific support to recycled economic models and the resource-saving and environmentally friendly society, etc. By the 2020, the share of R&D in GDP increases to more than 2.5%, the contribution rate of science and technology (S&T) to economic growth reaches more than 60%; the dependency rate on foreign S&T drop to less than 30%, etc.	matching technologies for water saving in agricultural irrigation; technologies of water saving in dryland farming and biological water saving; precision irrigation technologies; information management technology and equipment of agricultural water use; developing the technologies and tools for the living water saving). **II. Resources and Environment:** (1) Integrated resources zone classification (research on the optimal and matching technologies of water and soil for the utilization of agricultural production, ecology and environmental protection; developing analytic techniques on the spatial allocation of water and land resources; establishing the analytical forecast decision model of optimal development of water and land resources in different regions). (2) Integrated management of the Basin water resources and regional air environmental pollution; and technology assembling and demonstration of typical ecological function degraded zones. (3) Integrated management of pollution and waste recycled utilization (Restoration and rehabilitation of the ecological functions in ecologically fragile areas, such as Qinghai-Tibet Plateau, Loess Plateau, Deserted area, etc.). **III. Agriculture:** Selection of new crop varieties; Animal disease control; Agro-processing and modern storage and transportation; Integrated development and utilization of agro-forest biology; Agro-forestry ecological safety and modern forestry; Environmentally friendly fertilizers, pesticide and ecological agriculture; Multifunctional agricultural equipment; Agricultural precise operation and imformatization; Modern dairy sector.
Ministerial level			
MOST			
National Eleven Five-Year Plan on the Science and Technology Development	by MOST, Oct. 27, 2006	**Goals:** R&D in GDP reaches 2% by 2010; dependence rate on foreign S&T <40%, quotation of scientific papers among the top ten in the world, yearly patents top 15 in the world; contribution rate of science and technology to economic growth >45%, high-tech value added in manufacturing 18%, research scientists 50 million people.	13 important special research projects identified (of which Project No.7 directly on water). **Water:** control and management of water pollution (classifying the ecological functions of basin water, research on the key technologies of control of basin water pollution, ecologic recovery of water environment, etc). **Important research projects in agriculture**: Agro-forest biological engineering (developing biological materials such as biological plastics, bio-degradable plastic film, establishing 10-20 bio-energy demonstration bases); Breeding engineering of agro-forest varieties (increase of yield of new varieties by 10-15%. Establishing improved seed breeding 180-200 bases); research on the technologies of grain high yielding; technologies of pest and weed control, post-harvest storage; demonstration areas of agricultural technologies 500 million mu with average yield increasing by more than 10%; Key technologies and industrialization of food processing; Pesticide formulation programs; Key technology research and demonstration in dairy sector; Animal disease prevention and control technologies;

			Key technology research and demonstration in forest ecology construction. **The extension of agricultural technologies**: Scientific and technology extension action plan of the new countryside construction (300 model or demonstration villages, 200 model townships, 100 model counties); Spark Enriching farmers programs (establishing 50 rural regional transfer centres of agricultural science and technology; transferring 5000 advanced and practical agricultural techniques and training 50 million farmers); Transferring and application of agricultural science and technology program (demonstrating 2000 new agricultural science and technologies, forming 100 national promotion centres of agricultural science and technology); National agricultural science and technology park (demonstrating and applying 2000 agricultural new technologies, establishing 20 national agricultural science and technology transfer centres). **Resources and Environment:** Ecological system rebuilding technology and demonstration in typical fragile areas; Water cycle and its efficient utilization.
National Tenth Five-Year Plan on the Science and Technology Development --Key special research project: “New products research and Development of modern water saving agricultural technology system”	MOST identified 12 key special projects in the tenth Five-Year Plan, water-saving technology research is one of them.	**Key contents:** improving the water utilization rate/by crop/at farm level/at canal level; re-utilization of water; water saving techniques (institutes under WMR coordinating 3 projects and participating in 8 projects); emphasizing the combination of biological, agricultural, engineering and management technologies for the water saving.	**Brief introduction of this project:** Total research funds on this huge project 420 million Yuan, of which 200 million Yuan from central budget, 220 million Yuan from local governments and self-raising funds. 55 sub-projects were decomposed into three layers (key technologies, products R&D, technology assembling and demonstration). **Achievements:** since 2002, 1912 scientists from 282 research institutes, universities and enterprises involved in this big project. The project developed 110 advanced and key technologies, 146 new products, established 27 demonstration production lines, 78 pilot bases for industrialization, screen out 129 drought-resistant materials, 28 new varieties with the attributes of drought-resistant and water saving; applied 320 patents, developed 48 softwares, formulated 53 technical standards (29 already issued); published 1343 papers (of which 133 SCI/EI), books 23, trained 819 graduate students; established 18 demonstration zones of agricultural water saving (with surface of 250 thousands mu), extension to 320 million mu, saving water 8.5 billion cube meters, grain increased by 15 million tons.
MOA			
Eleventh Five-Year Plan of Rural Economic and Social Development	Issued by NDRC, June 9, 2007	**Goals:** cultivated land area maintained at 120 million hectares, grain output target 500 million tons. Food output value to agriculture 0.8:1; transfer 45 million rural labours, urbanization rate to 47%. Water irrigation efficient rate to 0.5; utilization rate of chemical fertilizers and pesticides to 35%, mechanization rate on ploughing, planting and	**Policies or measures:** developing grain production; establishing innovation system of agricultural science and technology; research on key agricultural technologies (selection of high yield varieties, breeding, resource use, etc.); fastening the extension of agricultural techniques by implementing S&T entering into farmers household and training demonstration farmers; perfecting agricultural extension system. Developing water saving agriculture. Determining the agricultural development model, scale and crop structure according to the water’s carrying capacity. In the NW China, controlling the development of high water consuming crops. Increasing investment on the continuous construction of irrigation district matching facilities and

		harvesting 45%. Afforestation 20 million hectares, forest coverage rate 20%, newly control of 25 million hectares of water and soil erosion areas, newly control of 52 million hectares of grassland, control sandy land 7.5 million hectares, ecological recovering 30 million hectares. Effective irrigation areas to 58.67 million hectares; resolving 160 million people's drinking water. 28.8% of farmers use biogas, newly building 1.2 million Km of rural road. Farmers' annual income increases by >5%.	water-saving reconstruction; taking channels lining, pipe irrigation, measurement of irrigation water to reduce water loss. The newly established irrigation district should be water saving one. Fastening the extension of the utilization of water saving equipment and techniques. In the dryland and semi-dryland areas, developing rainfall tanks. Developing dryland water saving agriculture and establishing corresponding demonstration areas. Realizing zero growth of agricultural irrigation water. **Important programs for the modern agriculture:** Large scale commercial grain production base (small scale hydrological works, improved seeds etc.); Quality grain industrialization program; Agricultural integrated development (improving the low-middle-yield farmland, integrated management of water, soil, forest and road); Modern agricultural demonstration; Basic farmland protection; Fertile land program; Improved seed program for crops and animals; Prevention system of animal disease; Plant protection program; Dryland farming water saving demonstration (according to the different physiognomy, soil, crops and farming system, improving the farm field water collection and contention and water saving irrigation by engineering, equipment, agricultural, agricultural machine, chemical and management measures); Supervision system of food safety control; Adjusting agriculture product structure; Integrated ecological management. **Important projects for the rural infrastructure**: Newly increasing water-saving irrigation area 10 million hectares; effective irrigation area 1.33-2 million hectares. Continuous construction and matching of water saving improvement (renovation) project for large scale irrigation district; Continuous construction and matching of water saving improvement (renovation) project for middle scale irrigation district; Rural safe drinking water program.
Agricultural S&T Development plan (2006-2020)	Issued by MOA, June 10, 2007	**Goals:** Agricultural R&D/Agricultural GDP 1.5%, contribution rate of agricultural S&T to economic growth 63%. Farmland degradation rate reducing by 10 percentages, soil fertility improving by 1 to 2 grades, effective irrigation rate to 0.5, use rate of straws as feed 40%.	**Programs or measures:** Water saving agriculture and soil fertility cultivation; Scientific application of fertilizers and pesticide; Grassland re-vegetation and forage use; Crops for bio-energy utilization; Agricultural non-point pollution prevention and water ecology environment recovery; Technology assembling (new materials, improved seeds, application of fertilizer according to the prescription, pest control, etc.); Agricultural S&T demonstration (S&T entering into farm household; Technician and techniques to the field).
Modern agriculture demonstration project construction plan (2007-2010)	Issued by NDRC, August 14, 2007		Central finance supports five types of demonstration project: – Special agricultural development project – Foreign oriented agricultural project – Comprehensive application of agricultural new techniques – Agricultural sustainable project – Agricultural multifunctional project (for example, agro-tourism).

MWR			
Water Law of the People's Republic of China	NPC, August 29, 2002 passed, effective from 1st October 2002.		
Management regulation on the Water taking permit and the collection of water fee	Directive of State Council, No. 460 Issued on the 24 Jan. 2006, effective 15 April, 2006		
Outline of national water saving plan (2001-2010)	By National Water Saving Office, August 20, 2002	**Situation and problem:** normal year lacks of 40 billion cube meters of water in China, of which irrigation district lacks of 30 billion cube meters, drought affected land area 300 million mu. It's projected that total demand of water in 2010 will be 698.8 billion cube meters, 800 billion cube meters in 2030, 850 billion cube meters in 2050. Over-exploitation of underground water. Serious water and soil erosion, land desertification, dust storm. Very serious water issue in NW China. Total water use control: 620 billion cube meters by 2005, 660-670 by 2010 (every river basin and province should also work out their own total water use target). Water demand of agricultural irrigation surface mainly resolved through water saving. **Goals** for agricultural water saving. By 2010, newly add water saving irrigation 100 million mu, water saving irrigation/total irrigation area >55%,	**Measures:** improving (rebuilding) irrigation district as water saving and production increase as target; developing water saving irrigation engineering; quota management of water use; levelling land (out of ground irrigation loss, field accounts for 35%); extending water saving techniques (drought resistant variety, plastic coverage, straw coverage, less or no tillage, water saving cultivation, agricultural structure adjustment); developing comprehensive water saving technologies (especially precise irrigation such as drip irrigation; combination and assembling of modern engineering technology, agricultural technology and management technology). Quota management, extending water saving irrigation system. Establish water use standard.

		irrigation efficient rate 0.5, per mu irrigation water reduced by 20-30 cube meters by 2010 compared to 2005.	
Water Conservancy Development 11th Five-Year Plan	Issued by NDRC, MWR and Ministry of Construction, May 2007	**Problems:** uneven spatial and timely distribution of water; per capita water availability world's 30%, China shorts of water (normal year) 30-40 billion cube meters; 300 million rural population use unqualified drinking water; 300 million mu of farmland affected by drought. Water and soil erosion: 3.56 million Km2 (37% of total land). **Goals:** newly increasing 30 billion cube meters of yearly water supply capacity; net increase effective irrigation areas of 20-30 million mu; by 2010 resolving 160 million rural population drinking water issue; newly increase water saving irrigation surface 150 million mu; irrigation efficient rate to 0.5; newly control 250 thousands km2 of water and soil erosion, ecological recovery 300 thousands km2. 10000 Yuan industry value added water use drops from 173 cube meters in 2005 to below 120 cube meters in 2010. Rate of quality water from 56% to 60% in water function zone; water and soil erosion/total land from 36% to 34%. Establish sound system of water law and regulations; complete the scenarios of the water distribution of the main rivers, preliminarily establish the national water right system.	**Tasks or programs:** Development and utilization of water resources (water origin place protection and water pollution prevention); construction of water saving society (agricultural water saving: determine the agricultural development distribution and scale according to the water availability; adjust cropping structure; develop modern irrigation agriculture and dryland water saving agriculture). Irrigation district water saving improvement engineering and popularize advanced water saving technologies. New irrigation district should be all built as water saving irrigation district. Ecological construction on the water conservancy. Mainly managing serious areas such as upper and middle reaches of Yellow river and Yangtze river. Reforming the conventional farming, extending conservation tillage technology. Protection of surface water and underground water. Ecological recovery of river, lake and wetland. Rural hydrological infrastructure. Strengthening the continuous construction matching and water saving improving of the large and middle size irrigation district; Water saving and benefit increasing demonstration project; Small size on-farm hydrological engineering construction (water saving facilities and rainfall collection); Management and construction of the rural rivers and canals; Construction of the hydrological engineering in pasturing areas. **NW China:** Fastening the construction of water saving society and environmentally friendly society; strengthening the management of ecologically fragile rivers; dealing well the relation between the upstream and downstream water use, increasing the water use for the ecological purpose, protect the oasis; strengthening the management of the water and soil erosion in Loess Plateau. Strictly controlling and rationally utilizing the underground water resource to maintain the rational ecologic underground water level; in the ecologically fragile areas and water heavy loading areas, restricting or banning the irrational development activities. Strengthening the environmental protection of the water origin of the rivers.
SEPA – now MEP			
Eleventh Five-Year Plan of National Environmental	State Environmental Protection Administration	**Goals:** sulphur dioxide and chemical oxygen demand (COD) discharge reduced by 10%; urban polluted water treatment rate >70%; air quality better	**Policies or measures:** protecting the drinking water source; controlling key river basin pollution; conducting national regionalization of ecologic function and initiating the protection of ecologic function zones. Rural environment: protection of soil pollution; integrated management of rural environment

Protection	of China Guofa, No.37, 2007 Released Nov. 22, 2007.	than 2 grade (292 days) in important cities: from 69.4% to 75%; 7 rivers water quality better than third grade: from 41% to more than 43%.	(10000 villages and 2000 townships); integrated management of small drainage basin; controlling the water and soil erosion and rural non-point pollution; Strengthening the water quality monitoring. I**mportant programs of environment protection**: monitoring capacity building; waste treatment; urban polluted water treatment; water pollution management of key river basins; construction of key ecological function zones and natural protection zones; rural well-off environmental protection project. **Priority of research areas in environmental S&T in 11th Five-Year Plan**: Technology of water pollution management; management technology of soil pollution and rural environment; monitoring technology of regional ecological environment protection and the construction of key ecological function zones; key technology of integrated environmental management, etc.
SFA			
Eleventh Five-Year and Middle & Long-term Plan of Forestry Development	SFA website, May 30, 2006.	**Goals:** by 2010, forest coverage rate=20% (23% in 2020, 26% in 2050), stock volume of forest 13.2 billion cube meters; breakthrough progress of ecological management in West China; alleviation of water and soil erosion in big rivers and sandification in wind dust effected areas. Key public welfare forest protection area=51 million hectares (5.37% of total land area); protected natural forest 57 million hectares; yearly afforestation 4 million hectares; all kinds of natural protection area 125 million hectares (13% of total land area); control of sandified area 7.5 million hectares.	**Projects or measures:** Natural forest protection (stopping the cutting of forest in upper reaches of Yangtze river and upper & middle reaches of Yellow river; newly planting 5.79 million hectares of natural forest); Grain-for-Green project, retiring firstly the sloping cultivated land (>25 degree) and seriously sandified land. Beijing-Tianjin dust and wind source management; Protective forest construction in “Three Norths” and Yangtze river; Wetland protection and rehabilitation project. **Important tasks for West China**: fastening ecological recovery and implementing integrated management; increasing engineering inputs and increasing the vegetation (forest and grass) effectively controlling the dust and reducing the water and soil erosion. Strictly protecting existing forest, wildlife and wetland resource; continuously implementing the “retirement of farmland to forest” in ecologically fragile places; strictly implementing the prohibition on pasturing and reclamation, woodcutting and pushing the prevention and control of sandification.
Sandification Prevention and Control Law of People’s Republic of China	Passed by NPC on the 31st August 2001, effective from Jan. 1st 2002.		
Decision of the State Council on the further	Issued by the State Council, September 8,	One figure: sandified land 1.74 million km^2, accounting for 18.1% of total land: causes: excessive pasturing,	

strengthening Sandification Prevention and Control	2005	woodcutting, reclamation and short of water and irrational utilization	
Circular of the State Council on the perfection of policy of grain-for-green	August 9, 2007, by State Council, No. 25, 2007		**Main points:** Continue to provide subvention to farmers (Yellow river basin 70 Yuan/mu; Yangtze and South China 105 Yuan/mu; plus 20 cash for living expenses. Duration 8 years for ecologic forest, 5 years for economic forest, 2 years for grass). Follow-up management of retired land; the subvention of construction of grain field for resident ration: 400 Yuan/mu in NW China; adjust retired farmland plan (original 20 million mu target, except for 4 million mu implemented in 2006, other surface temporarily stop).
Gansu Provincial level			
Outline of the 11th Five-Year Plan for Gansu economic and social development	Jan 20, 2006 by Gansu People's Congress	**Goals：**GDP annual growth 10%; 10000 industry value added water use reduced by >30%; energy consumption reduced by more than 20%; forest coverage rate to 16% (from current 12%); yearly growth rate of farmer income 6%. Urbanization rate from 30% to >35%; agricultural irrigation rate from 0.47 to 0.5. R&D in GDP from 0.98% to 1.5%.	**Gansu water resource situation:** average yearly amount 28.94 billion cube meters. Inland water availability 6.68 billion cube meters, actual utilization 7.6 billion cube meters (including repeated uses); development rate of surface water 95%, underground water 58% (Shiyang 172%); development rate of Yangtze River water 4.8%. **Projects or policies**: Integrated management of Shiyang River Basins (water saving society construction; ecological migration, artificially increasing snow in Qilian Shan Mountain) and ecological protection of Yellow River water source in South Gansu (natural forest protection, wetland protection, retirement of rangeland to grass, herdsmen habitation, etc.). **Water conservancy projects**: Sule River integrated development, completion of final stage of works of "Yin Da Ru Qin"; continue to push II term of Heihe project; implementing the agricultural water saving engineering for the irrigation district with surface >10000 mu; by 2010 irrigated area to 21 million mu. Establishing Hexi Corridor as water saving model. Quota management of water use in different sectors; establishing water pricing mechanism and compensatory/payment-based water use system. **Ecological construction**: natural forest protection; protective forest construction; grain-for-green program (retirement of farmland for forest 43 million mu, retirement of rangeland for grass 170 million mu); control of water and soil erosion 15000 Km2. Preventing the non-point pollution in the countryside; improving the environmental quality in key River Basins (Weihe, Jinghe, etc.); imposing ceiling on the pollution discharge; implementing environmental evaluation on the important construction projects. **Agriculture**: potato 10 million mu by 2010; forage surface 23 million mu, stock of sheep and cattle 35 million herds; barley surface 2 million mu (20% national total); fruits 6.5 million mu; by 2010, processing 0.55 million tons of potato, 0.38 million tons of mutton and beef, 0.7 million tons of vegetable and fruits; cultivated land area=50.4 million mu (current area=51 million mu); grain production target 8 million tons (implementing field (on-farm) drainage and irrigation works, drought resistant water source project in non-irrigation district). Resolving 3.5 million rural

			population drinking water issues. Potable water rate 45%, newly increase rural households with biogas 0.4 million. Poverty alleviation of 3000 entire villages (village as basic unit). 0.7 million more people lifted out of poverty, number of low-income people reduced by 2.4 million. **S&T**: research on: highly efficient utilization of water resource and water saving (top priority); ecological protection and recycled economy; agro-processing and industrialization, etc.
The Gansu Guideline for Medium- and Long-term Plans for Science and Technology Development (2006-2020)	Department of S&T Gansu, April 17, 2006	**Goals:** Strengthening provincial innovation capacity; achieving remarkable scientific results in some important areas; contribution rate of S&T to economic growth >50%;: establishing agricultural S&T service system; reaching advanced level in China in the areas of grass animal; developing special crops and agro-processing; important progress in Water resource utilization and water saving, sandification and water & soil erosion control.	**Priority of research areas:** **Water**: water saving, rainfall collection and utilization; optimal allocation of water resources and integrated development; comprehensive water saving technology and agricultural technology. **Ecology and environment**: technology assembling and demonstration of basin-level water environment management and typical ecologically degraded areas. **Agriculture**: technology assembling; breeding technology research; agro-processing; ecological agriculture; precise agriculture; agricultural resource saving technology. **S&T: important special research projects:** No.1: Grassland degradation prevention and management and ecological environment recovery of water source (origin) place in Upstream of Yellow River (Gansu Section): assembling the technologies on degraded grassland re-vegetation in cold area; integrated technologies of prevention and management on sandified land in highly cold areas; planting technologies of quality forage grass; recovery technologies of natural grassland; wetland ecology recovery, etc. No.2: Rational allocation of water resource and sandification control in the Inland River Basins (Shiyang River Basin as important places).Qilian Shan mountain water source self-restraint ecological recovery, highly efficient water saving agricultural technologies in oasis place; degraded ecological system recovery technology in oasis edge places; informationized management of river basin water and soil resources.
Opinions on the Implementation of Modern Agricultural S&T Innovation Action in Gansu Province	By Gansu S&T Department, May 10, 2007	**Goals:** selection of new varieties and the development of new technology; ecological protection and efficient and rational utilization of resources (especially water); effective control of sandification; innovation capacity building; technologies to control water and soil erosion, etc.	**7 S&T innovation actions in the 11th Five-Year plan:** New varieties selection of animal and plants (especially drought resistant varieties); agro-processing S&T Action; Crop high yield and high efficiency S&T Action; healthy feeding of animal and disease control Action; S&T Action plan for agricultural ecology safety (dryland farming and water saving technologies; conservation agriculture, etc.; environment protection in the ecologically fragile areas); integrated development of agro-forest biological materials; agricultural information. **Important Special Research projects:** No.1: Grassland degradation prevention and management; and water source (origin) ecological environment recovery in Upstream of Yellow River (Gansu Section). Main contents: assembling the technologies of degraded grassland re-vegetation in cold area; integrated technologies of prevention and management on sandified land in high cold areas; planting technologies of quality forage grass; recovery technologies of natural grassland; wetland ecology recovery, etc. No.2: Rational allocation of water resource and sandification control in the Inland River Basins (Shiyang River Basin as important places). Main contents: ecological recovery of Qilian Shan mountain water source place, high efficiency water saving agricultural technologies in oasis

			areas. Recovery technology of degraded ecological system in oasis edges. Informatized management of water and soil resources in river basins. **Priority Research projects:** Water optimal allocation and integrated utilization; water saving technologies; sandification control in inland river basins; control of water soil erosion in Loess Plateau; environmental protection of water source place in upper Yellow River; control of pasture degradation and pasture productivity improvement.
The 11th Five-Year Plan of Gansu water Conservancy development and reform	Issued by Gansu Department of Water Affaires, Jan. 2006	**Goals:** unit GDP water use reduced by 20%; increase of provincial water supply capacity 0.38 billion cube meters; develop water saving irrigation area 2.75 million mu; irrigation efficient rate to 0.5. Increase of irrigation area 1 million mu; construction of terraces 3 million mu; control of water and soil erosion 10000 Km2.	**Important tasks:** integrated management of Shiyang River Basin; optimal allocation of water resource; rural hydrological works; water saving society construction in Zhangye city and other 10 cities; protection of water and soil resources; informatized management of water resources. **Programs in three river basins:** Inland River Basin: Shiyang river basin (unified management of surface water and underground water, optimal allocation of water; ecological management and recovery); Qilian Shan Mountain water source protection; etc. Yellow River Basin: Lanzhou, Baiying and Dingxi (introducing water from Tao river to resolve water shortage; uplift water pumping irrigation district improvement; rainfall collection). Tianshui, Pingliang and Qingyan (Weihe River Basin integrated management, rainfall collection). South Gansu and Lingxia: pasture hydrological works with forage base construction as important content; Water source protection of Tao He River and Da Xia River. Yangtze River Basin: Flood prevention and control in the Bailong River section and middle and small size rivers. Optimal allocation of water resource. **P.S. Integrated management of Shiyang River Basin, approved by State Council in early December 2007.** Main contents: Water saving society construction; structure adjustment of industry sectors; hydrological engineering construction; water saving improvement in irrigation district, ecological building and protection of water resources. Total investment: 4.749 billion Yuan (3.104 billion Yuan invested for the period 2006-2010; 1.645 billion Yuan invested for period 2011-2020). Investment comes mainly from Central government.
Eleventh Five-Year Plan of Agricultural and Rural Economic Development in Gansu Province	Issued by Gansu Development and Reform Commission, Source: The 11th Five-Year National Program for Rural	**Goals:** cultivated land area maintained at more than 50.4 million mu (of which grain sowing area maintained at 38 million mu), grain output target more than 8 million tons. Annual growth rate of agricultural GDP is more than 5%. Contribution rate of agricultural S&T to economic growth is 52%. Farmers' annual income increases by >6%, by 2010, farmers' per capita income	**Policies or measures:** **I. Building special and advantageous agricultural product belt and adjusting agricultural production structure** With herbivorous animals and potato as leading (dominant) sectors; brewing raw material, seed breeding, fruits, vegetables, Chinese medicines as advantageous sectors; and olive, edible lily, trout, etc. as local special products. By 2010, the areas of grass for feed reach 23 million mu, rearing number of cattle and sheep 35 million herds, ratio of the output of animal husbandry/agriculture is more than 33%. Potato's planting areas up to 10 million mu by 2010, of which 2.5 million mu for processing purpose, 3.5 million mu for starch production. Planting areas

	Economic and Social Development, Edited by Du Ying, China Statistics Press, September 2007. pp. 867-877.	reaches more than 2630 Yuan. By 2010, the absolute poverty population reduced by 0.7 million, low-income population reduced by 2.4 million. Water irrigation efficient rate increases significantly. Resolving the drinking water issue of 3.5 million rural people. Increasing irrigation areas by 1 million mu, with effective irrigation areas up to 21 million mu. Developing water-saving irrigation areas 2.75 million mu. Forest coverage rate increases to around 16%, newly control of 15000 Km2 of water and soil erosion areas, management of 110000 Km2 of grassland. Retirement of farmland to forestry 43 million mu; retirement of rangeland to grass 170 million mu.	of barley for beer processing reaches 2 million mu (with output accounting for 20% of domestic market); output of grape for wine processing 80000 tonnes. Seed breeding areas 2 million mu. Fruit plating areas 6.5 million mu and plating areas of Chinese medicines 2 million mu by 2010. **II. Strengthening the construction of rural infrastructure and improving the agricultural comprehensive production capacity** Yin Tao Phase I project: Introducing 219 million cube meters of water (of which 85 million cube meters for agricultural production; developing water-saving irrigation areas 0.19 million mu). Yan Huan Ding Yang Huang Phase II project: developing irrigation area 31000 mu and resolving the drinking water for 62100 urban residents and 110300 rural populations as well as for 47000 big animals. Rural safe drinking water project: resolving the drinking water of 3.5 million rural people during 11^{th} Five-Year Plan. Rural biogas project: developing biogas for 0.4 million rural households. Improved seed project for plants and animals: establishing crop seed production base, plant/seedling breeding for fruits and vegetables and breeding base construction for potato, construction of breeding plant and station for cattle, sheep and cow. Plant and animal disease prevention project. **III. Ecological construction and agricultural sustainable development** Siyang River Basin management project: through the water resource allocation, establishment of water right system and construction of water saving society, Min Qin water inflow reaches more than 300 million cube meters by 2010 and 340 million cube meters by 2015. Grain-for-Green Project: afforestation 43 million mu during 11^{th} Five-Year period. Natural forest protection project: management and maintenance of forest of 593.56 million mu, afforestation 103 million mu. Important protective forest project: completing afforestation 12.113 million mu. Retirement of rangeland for grass. Ecological function zone environmental protection project in South Gansu. Agricultural water saving project: Continuous construction and facility matching of water saving improvement project for large and middle scale irrigation district; construction of main hydrological engineering for middle scale irrigation district; large scale pumping station improvement. **IV. Strengthening the agricultural S&T innovation and transfer capacity** Developing fully the advantages of S&T in agricultural universities, research institutes to promote the application of all kinds of advanced and practical technologies. Establishing and perfecting the S&T extension service system by reforming the extension mechanism. Taking water saving irrigation and dryland agriculture as the core of agricultural sustainable development, assembling and disseminating modern water saving technologies.

12.2 Appendix 2: Land and water resource projects in loess or related areas - recent past, current and proposed

No	Project Title or Theme	Institution and Partners	Dates, start finish	Location of Application		Technology Issues or Development	Extension Processes
				Geographic	Landscape		
1.	Institutions and policies for improving water allocation in the Yellow River Basin ADP2000/120	ACIAR, ABARE, IWMI, CCAP, USDA-ERS	Jan03 – Aug06	Yellow River Basin	River water users	Modelling of water allocation at basin level	Only to policy section in YRCC
2.	Sustainable land use change in the north-west provinces of China ADP2002/021	ACIAR, ANU, CNFEDRC	Jan03 – Dec06	NW China	Rainfed cropland	Socio-economic evaluation of Grain for Green Program	Only to policy section in SFA
3.	Improving productivity and sustainability of rainfed farming systems in western Loess Plateau of Gansu CIM1999/094	ACIAR, UA, NSWDPI, CSIRO SE, GAU, GGERI	Jan01 – Dec06	Gansu	Rainfed cropland	Conservation tillage systems, cereal legume rotations, crop simulation models	Only GAU and GGERI field demonstrations near Dingxi and Xifeng
4.	Lucerne adapted to adverse environments in China and Australia LPS1998/026	ACIAR, SARDI, WADA, UNI Tas, GAU, BFU, GGERI	Jan01 – Dec06	Gansu	Grassland	New varieties with tolerance to salinity, acidity and cold	None
5.	Sustainable development of grasslands in western China LPS2001/094	ACIAR, CSU, GGERI, GAU, NSWDPI, UQ, IMAU,	Jan05 – Jun08	Gansu and Inner Mongolia	Grasslands	Grassland management and livestock production systems	Very limited mainly policy issues. See DAFF extension project
6.	Estimate impacts on methane emission of alternative livestock systems for sustainable profitable grasslands (operates as part of Project 5)	ACIAR, AGO, CSU, GGERI, GAU, NSWDPI IESDA		Gansu and Inner Mongolia	Grasslands	Greenhouse gas emission from livestock systems	
7.	Improving rural livelihoods of herders in Inner Mongolia	DAFF, CSU, GAU, NSWDPI, IMGRI	2006/07	Inner Mongolia	Grasslands	Outcomes of project 5 on livestock production	Only in 2-3 villages
8.	Regional impacts of revegetation on water resources of the Loess Plateau LWR2002/018	ACIAR, CSIRO LW, ISWC, MWR	Jan03 – June06	Loess plateau	Coarse sandy hill catchments	Effect of vegetation on hydrology	Dissemination of a DSS to key government agencies; ~20 agency staff trained in use of DSS
9.	Promotion of conservation agriculture using permanent raised beds in irrigated cropping in the	ACIAR, UQ, CAU, GAAS, GAMB	July05 – June09	Hexi Corridor	Irrigated crop land	Raised beds for wheat maize systems	GAMB demonstrations

	Hexi Corridor LWR2002/094						
10	Improving the management of water and nitrogen fertiliser for agricultural profitability, water quality and reduced nitrous oxide emissions LWR2003/039	ACIAR, UM, CAAS, CAU	Apr04 – Mar09	Shanxi, Inner Mongolia, Yellow River	Irrigated crop land	Water and nitrogen balances. Economic model for water saving in wheat and maize crops	A DSS being prepared for use in three counties in Shanxi; working with 'lead' farmers to test 'best bets' beyond main trial sites; policy briefs to Shanxi extension depts. at provincial level
11	Water resources and salinity management in agricultural areas of inland northern China LWR1998/130	ACIAR, CSIRO LW, NBGNR	Jan01 – Sep05	Ningxia and Loess plateau	Irrigated crop land	Modelling of irrigation, drainage, ground water and salinity	
12	Australia China Environment Development Program (ACEDP)	AusAID, MOFCOM, MWR	Jul07 – Jun12	Not yet determined	Initial focus on water resources	Integration of social, economic and environmental factors to improve natural resource management	Not yet known as it will depend on individual projects funded. High level policy dialogue.
13	Water and agricultural management in Hebei	AusAID, MWR	2002/07	Northern China	Catchment	Water allocation and monitoring processes as well as landuse assessment for water	Water User Associations
14	Water entitlement and trading project	DAFF, DEW, CAS	2006/07	Inner Mongolia	Irrigation schemes	Framework for market based water management, including water user associations	Policy development at central government level
15	Sustainable Agriculture Development Project	CIDA, MOFCOM, MOA	2000-2005	Inner Mongolia	Grassland and cropland	Sustainable grazing management Forage varieties Crop tillage systems CA tillage machinery	Bureau of Agriculture and Animal Husbandry extension services
16	Sustainable Agriculture Development Project-Phase II	CIDA, MOA	July04 – Oct09	Gansu and other areas in NW China	Cropland	1. Adaptation of land resource management systems for sustainable agriculture; 2. Enhanced Sustainable Agriculture Extension Systems, and; 3. Improved enabling environment for sustainable	Bureau of Agriculture and Animal Husbandry extension services. Farmer associations

						land resource management.	
17.	EU-China River Basin Management Program	EU, MWR, SEPA	Oct06 - Sep11	Yellow River	River and watershed	Water planning and environmental management	Policy development
18.	Gansu Xinjiang Pastoral Development Project	WB, MoA in association with CIDA, ACIAR and USAID projects with similar objectives	Oct06 - Sept10	Gansu and Xinjiang	Grasslands	Integration of grassland production and conservation with livestock production	Bureau of Agriculture and Animal Husbandry extension services. Farmer associations
19.	Grain for Green Program research	SFA, FRC, NDRC	Since 2000	China	Degraded land	Social economic and biological research for rehabilitation and its impact	Through the Grain for Green Program to provinces, counties, townships
20.	Water Resources Demand Management Assistance Project	DfID, MWR	July05-Dec10	Gansu [Also in Liaoning and national aspects]	River basin Irrigation areas and cities	Case Study G-1 IWRM principles and methods for river basin planning developed, tested and documented in the Shiyang River Basin Case Study G-2 Water Saving Societies in Wu Wei and Jinchang Municipalities with Water Resource Bureaux; apply and enforce water demand management tools to balance water resources availability demand Case Study G-3 Effective community participation in shared management of surface and groundwater resources in Minqin	Development of a Shiyang River Basin Master Plan Establishment of Water User Associations
21.	A suite of projects on irrigation design efficiency, irrigation equipment, salinity, return flows, runoff pollution, environmental flows, groundwater management and hydrology modelling	MWR, NCEI, IWHR, RWRDRI, MOST	ongoing	All areas	Irrigation areas	Irrigation technology and equipment, Water supply management Drainage Pump and delivery energy savings	Ministry staff at all bureau levels and in association with operational works programs

22.	Domestic sewage disposal and sustainable irrigation technology	NCEI, ACIAR, CSIRO	1998 - 2000	Shandong	Irrigation areas	Waste water reuse	No information available
23.	Yellowatsave Project	MWR, EU, NCEI, IWRH, YRCC	1998 - 2002	Ningxia and Shandong	Yellow river	Supply and distribution systems Farm irrigation systems and management Groundwater drainage, salinity and water reuse Decision support tools for supply demand management, water allocation and savings.	Ministry staff at all bureau levels, YRCC, Universities and Institute staff
24.	Water Saving Agriculture – National Project 863 Study on farm land water productivity potential and favourable development	IEDA-CAAS, CWRCT-CAAS, MOST	finished	National	Dryland cropping	Cropping systems and efficient cultivation, biological and agronomic water saving	limited
25.	Water Saving Pilot Research project national project 973 Environmental harmony and water saving dryland farming	IEDA-CAAS, CWRCT-CAAS, MOST	ongoing	NW China	Agricultural ecosystems	Agricultural water resources and environment	
26.	Challenge Program – Conservation Agriculture for Dryland areas of the Yellow River Basin	IEDA, CIMMYT, IWMI, CCAP, CAU	2005	Yellow River Basin	cropland	Adoption of CA Poverty reduction Erosion control Improved policies CA machinery	Farmers involved in field research sites Studies of adoption by farmers and problems to be addressed
27.	Sustainable Agricultural Production with Low Inputs	IEDA. JICA, CJRDCAT	2002 - 2007	NW China	Irrigation and dryland cropping	Improved utilisation of soil, water, fertilizer inputs and minimise losses due to climate, pests and diseases Optimise fertiliser and irrigation inputs Conservation tillage for soil erosion control	Mainly to researchers and some technicians
28.	Regional Water and Soil Assessment for Managing	ISWC, ACIAR, NWSUAF, CSIRO L&W	July97 – Jun01	Shaanxi and Hebei	Crop land	Tools for optimising irrigation schedules based on increasing	Routine generation of maps of WUE throughout the

	Sustainable Agriculture LWR1995/07					WUE; hillslope hydrology measurement and modelling; increased understanding of the soil-water processes linked to elements of degradation	entire Hebei Province
29.	Development of erosion prediction and assessment – a national 973 project	ISWC, NWSUAF, MOST. MWR	ongoing	Loess	All lands	Predictive equation for soil loss at varying scales and over time. Assessment of ecological and socio-economic impacts	Research and policy
30.	Ecological systems of watersheds and management of agro-ecosystems for crop and livestock production	ISWC, NWSUAF, CAS	ongoing	Loess	All lands	Management systems for sustainable Landuse, irrigation water use efficiency, horticulture and forestry	Through field stations Also MWR, SFA and MOA staff at various bureau levels
31.	Water cycle and water resource management in Black River	CAREERI, CAS Innovation program	Jan07 – Dec09	Black River Basin	Basin	Increase water benefit of basin scale ecological water regulation and water markets	
32.	Nitrogen project	LUCPAST, MOST, DEST, UA					International staff exchanges
33.	Integrated systems approach to sustainable farming of Loess	GGERI, UNE, MOST, AusAID	1981	Loess	Crop and pasture lands	Forage legume cereal rotations Livestock cropping interactions Conservation agriculture tillage Rangeland pasture systems	Field station Training MOA staff website
34.	Research and demonstration of water-saving high yield cultivation technology in sole cropping irrigation area of Gansu Province	MOST, GAU	1999-2003	Gansu	Crop land	Technologies of change sole cropping patterns into multiple cropping system aim at improving the productivity and the water utilization efficiency of the farmland	
35.	Research on using heavy salt water in Minqin County	GAU, MOST	2000-2003	Minqin	irrigation	The difference between border irrigation, spray irrigation, drip irrigation and under film furrow irrigation etc; the difference between greenhouse plants, filed crops and fruit trees that	

						is irrigated by salt water	
36.	High efficient irrigation technology for saving water and conserving fertilizer	GAU, MOST	2001-2005	Gansu	Irrigation land	interaction of soil moisture and nutrient to improving the utilization efficiency of resources; Effect of straw mulching and reduced winter irrigation on the yield and water utilization efficiency performance of spring wheat and maize	
37.	Water requirement of main crops in Shiyang River Basin and the irrigation scheme of small border irrigation	GAAS, MOST	2000-2003	Shiyang Basin	Irrigation land	Eva-transpiration characteristics of different crops under different irrigation scheme, clarify the real water requirement of main crops for optimizing irrigation scheme of the main planted crops	
38.	Coupling mechanism of water and fertilizer in intensive sustainable intercropping system in arid irrigation areas	GAU, NNSFC	2002-2004	Gansu	Irrigation	Coupling mechanism of water and fertilizer in intensive intercropping systems for the utilization efficiency of water and nutrient	
39.	Water cycle and water resource management in the Black River	CAS Group West projects, CAREERI	Jan07 – Dec09	Black River Basin	Basin	Goal: increase water benefit at basin scale, understand water use in ecological system and integrated management of water improvement at oasis scale.	
40.	Black River Program	CAS Lanzhou, NNSFC, CAREERI	2008 - 2018	Black River Basin	Basin	Balancing ecology, economy, environment under the state goal and region development for the basin, irrigation area and farm scale	Working with Bureaux of MWR and MOA and with farmers
41.	Lanze River Basin Comprehensive Research Station program	CERN, CAREERI, MWR	ongoing	Gansu and similar areas	Basin ecosystem	Arid zone ecological restoration Irrigation system requirements, crop rotations, fertiliser usage,	Field station and training of Bureau staff

						carbon sequestration, water saving technology and ecological water requirements	
42.	Use of plastic film in crops	GBA&AH, MOA	ongoing	Gansu	Cropland	Use of plastic film for dryland moisture control, reduced irrigation and improved crop yield. Tillage systems. Fodder production and silage	Large extension service in each county and township
43.	Fertilizer Institute of GAAS field stations at Wu Wei and Zhangye	GAAS, MOA, MWR, MOST	ongoing	Loess	Cropland	Water application and efficiency, fertiliser interaction, nutrient leaching, surface mulches, tillage practices	Field station and interaction with bureau staff
44.	Integration of crop-fruit tree production in NW semi-humid region	GAAS Institute of Flowers and Fruit Trees, MOST	ongoing	NW China	Horticultural land	Irrigation methods, crop water requirements, inter cropping	

Acronyms – used in Appendices

ABARE	Australian Bureau for Agricultural and Resource Economics
ACIAR	Australian Centre for International Agricultural Research
AGO	Australian Greenhouse Office
ANU	Australian National University
AusAID	Australian Agency for International Development
BFU	Beijing Forestry University
CAAS	Chinese Academy of Agricultural Science
CAS	Chinese Academy of Science
CAREERI	Cold and Arid Regions Environmental and Engineering Research Institute
CAU	China Agricultural University
CCAP	Centre for Chinese Agricultural Policy
CIDA	Canadian International Development Agency
CIMMYT	International Maize and Wheat Improvement Centre
CJRDCAT	China-Japan Research and Development Centre for Agricultural Technology
CNFEDRC	China National Forestry Economics and Development Research Centre
CSIRO LW	CSIRO Land and Water
CSIRO SE	CSIRO Sustainable Ecosystems
CSU	Charles Sturt University
CWRCT-CAAS	Centre for Water Resources and Conservation Technologies - CAAS
DAFF	Australian Department of Agriculture, Fisheries and Forestry
DEST	Department Education Science and Training
DEW	Department of Environment and Water, Australia
EU	European Union
FRC	Forestry Research Centre, China
GAAS	Gansu Academy of Agricultural Science
GAMB Gansu	Agricultural Mechanisation Bureau
GAU	Gansu Agricultural University
GBA&AH	Gansu Bureau of Agriculture and Animal Husbandry
GGERI	Gansu Grassland Ecological Research Institute
IEDA-CAAS	Institute of Environment and Sustainable Development in Agriculture - CAAS
IMAU	Inner Mongolia Agricultural University
IMGRI	Inner Mongolia Grasslands Research Institute

ISWC	Institute of Soil and Water Conservation, CAS
IWHR	Institute for Water Resources and Hydropower Research
IWMI	International Water Management Institute, Sri Lanka
JICA	Japan International Cooperation Agency
LUCPAST	Lanzhou University, College of Pastoral and Agricultural Science and Technology
MOA	Ministry of Agriculture, China
MEP	Ministry of Environmental Protection, China
MOFCOM	Ministry of Commerce, China
MOST	Ministry of Science and Technology, China
MWR	Ministry of Water Resources, China
NBGMR	Ningxia Bureau of Geology and Mineral Resources
NCEI	National Centre of Efficient Irrigation Engineering
NDRC	National Development Reform Commission
NNSFC	National Natural Sciences Foundation, China
NSWDPI	NSW Department of Primary Industries
NWSUAF	Northwest Sic-tech University of Agriculture and Forestry
RWRDRI	Rural Water Resources Design and Research Institute
SARDI	South Australian Research and Development Institute
SEPA	State Environment Protection Agency, China
SFA	State Forestry Administration
SFA	State Forestry Administration, China
UNE	University of New England, Australia
UNI Taps	University of Tasmania
UM	University of Melbourne
UQ	University of Queensland
UA	University of Adelaide
USAID	USA Agency for International Development
WADA	Western Australian Department of Agriculture
WB	World Bank
YRCC	Yellow River Conservancy Commission

12.3 Appendix 3: Agricultural water use in China

Irrigation management reform in China

Increasing demand for China's limited water resources (across China, but mostly in northern China) from rapidly growing industry, urban populations and agriculture implies potentially dire consequences for the sustainability of water use and drastic changes in cultivation patterns. Problems in the water sector also have significant implications for China's future trade position in key crops and may affect the income of the farming sector.

Despite such grave consequences, China's government has responded relatively slowly in trying to systematically address growing water shortages. In fact, there are many laws and formal regulations specifying how communities should use and manage their water. Unfortunately, few of these measures have been implemented.

Why it is that if there is a water crisis in parts of China that farmers in these regions do not always save water? It has been shown that the adoption of water saving technology is very low in China - including in many areas in which farmers and local leaders believe water is scarce. For many types of water saving technologies, such as plastic sheeting, sprinkler systems, drought resistant varieties, drip irrigation, etc., the average adoption rates in a typical northern China rural community are only around 10 to 15 percent.

Because of the unwillingness of households to seek ways to save water, ground and surface water resources in many parts of China (especially in northern China) are being depleted and current water-use levels are not sustainable within the current water supply systems. It also is a fact that agricultural users will not be given priority for any additional sources of water that might become available. Indeed, while it is the stated goal of China's leaders to increase the area irrigated, they also explicitly acknowledge that this expansion will occur without any additional water allocation to agricultural users. Thus, using water more efficiently is the only method to increase the irrigated area and its effectiveness without increasing total agricultural water demand in northern China.

Shortly after the agricultural reforms that began in 1978, the central government encouraged the adoption of volumetric surface-water pricing. The reliance on prices to help limit water use did not begin all at once in all locations but instead was allowed to diffuse gradually as experience was gathered. Water pricing was also restricted by regional price bureaus which often did not allow water prices to rise to any where near their marginal value product. Because of the differences in the pace of implementation of surface water pricing schemes, price structures exhibit substantial variation across the country. Because of the slow pace generally, the value of the marginal product of water in most parts of China is still far above the cost that the farmer is actually paying in most regions.

With the failure and non-feasibility of several of their policy options, such as water saving technology promotion and water pricing at the household level, leaders in recent years have begun to consider community-level water management reform as a key part of their strategy to combat China's water problems, since they believe water in agriculture is being used inefficiently. Despite water shortages, users in all sectors of the economy - but especially those in agriculture - by far the nation's largest consumer of water - do not efficiently use the water that they are allocated. One study, for example, estimated that due to the poor management of the nation's canal network, only 50 percent of water from primary canals is actually delivered to the field. Local irrigation managers and farmers also do not efficiently use the water that reaches villages' fields, wasting between 20 to 30 percent of their water. Hence, overall, only about 40 percent of water in China's surface water system that is allocated to agricultural production is actually used by farmers on their crops. Others have estimated even greater inefficiencies. In response, it has been proposed that local leaders reform the institutions that manage water in China's communities.

Despite the resolve of the current leadership in China to push water management reform, there is considerable debate about its appropriateness. International evidence shows that water management and its institutional arrangements are important measures for dealing with water shortages. Since the 1980s many developing countries have begun to transfer irrigation management responsibilities from the government to farmer organizations or other private entities in order to mitigate the financial burden of water projects and to improve the efficiency of water use. Theoretically, local water management reform is supposed to rely on increased participation by farmers and provide better incentives for managers to improve access to water and increase the efficiency of the system.

Unfortunately, the records of a number of attempts to implement local water management reforms have not lived up to expectations; there are many cases internationally of efforts that have failed or generated negative influences. Collective action (getting participation right) and the failure of getting the incentives right may be among the most important reasons that the water management reforms have failed.

In fact, since the 1990s China's policy makers have actively promoted water management reform, and like similar attempts outside China, the record seems to be mixed although most evaluations are only based on anecdotes or case studies. There are reports, such as in the World Bank project areas, that water management reform has had a dramatic impact on water use efficiency and farmer income. Even in those areas in which management reform has been well-designed, however, effective implementation of the reform has been difficult. Visits to the field can easily uncover cases in which local water management changes were implemented and failed.

Although there are many similarities between international experiences and those of China, even in this early phase of reform the nation's water management reform strategy has taken on some unique characteristics - which also vary from place to place. Above all, water officials have emphasized the role of incentives in water management reform in many areas. In many of the new reform efforts, water managers are provided with monetary rewards if they can meet certain targets, such as achieving water savings. In other areas efforts have focused on encouraging participation by farmers in the management of the local irrigation system. Some have tried both incentives and participation.

While the prominence given to encouraging participation is mostly based on international experience, the attention given to incentives may be unique (especially in the case of water management reform in developing countries). The use of incentives, however, is not new in the context of China's overall economic reform effort. Reformers frequently have relied on incentives to induce agents to exert more effort, allocate resources more efficiently and enter into new economic activities. The household responsibility system primarily gave incentives to farmers for crop production. The fiscal reforms gave local leaders incentives to begin township and village enterprises. The grain reforms gave grain bureau personal the incentive to commercialize commodity trading. Clearly, high level water officials are hoping a similar set of reforms can improve the performance of China's water management. Of course, perhaps because of its relative uniqueness, when a system of incentives for managers is used for water management, it is possible that there are unforeseen consequences (i.e., it is possible that it could have effects on productivity and/or income distribution).

Trends in water management reform in northern China

According to the data from six provinces collected by the Center for Chinese Agricultural Policy (CCAP), between 1995 and 2004, China water management reforms have gradually established WUAs and contracting, in place of collective water management in northern China. However, tracking these changes is complicated by the changing nature of China's water resources. In 1995 out of the 448 surveyed villages, 235 had surface water irrigation. During the survey the enumerators found that of the 235 villages with surface irrigation in 1995, 30 of them (13 percent of villages with surface water irrigation) had stopped using surface water by 2004. However, between 1995 and 2004 17 villages (7 percent) were provided with surface water for the first time.

When examining the villages that used surface water in both 1995 and 2004 (a total of 205 villages - 235 minus 30), there is a clear tendency for villages to be reforming their water management structures. Of the 181 villages that were being managed under the traditional collective management style, only 143 were still managed in this way in 2004. In other words, in 38 villages (181 minus 143) some form of water management reform was implemented.

The reform efforts during the 1995-2004 time period were split almost exactly between shifts to WUAs and contracting. Villagers in 14 villages choose to create WUAs. Villagers in 18 villages shifted into contracting. There were also six villages that reformed only part of their village's surface water system or chose a mix of WUAs and contracting.

While the trend in northern China's villages is clearly reform-oriented, it is interesting to note that in villages that had already reformed by 1995, there is some evidence that villagers are continuing to experiment with different institutional forms and are not afraid of going back to collective management. For example, of the eight villages that had created WUAs to manage their surface water systems in 1995, three of them had either discontinued or partially discontinued the experiment by 2004. Two of the 11 villages that chose contracting systems in 1995 decided to either fully or partially go back to traditional collective management by 2004. On the one hand these shifts into and out of WUAs and contracting may mean that water management reform is not universally successful. Another interpretation for national leaders worried about whether or not surface water management reform is suitable to China's villages, however, is that even if effort is made to actively promote WUAs and contracting, villages are not locked permanently into the new management forms.

Interestingly, the emergence of water management reform is not closely tied with the creation of a new irrigation system. In the 17 villages which were the beneficiaries of new surface water irrigation systems between 1995 and 2004, 14 of them (or 82 percent) chose to be managed under the traditional collective management system. Only three - one WUA; one contracting; and one with a joint collectively managed/WUA structure - chose to implement a reform-like management system. This percentage of reformed management villages (among newly irrigated villages - 17%) is lower than the overall average (27%).

So how should one interpret the record of water management reforms between 1995 and 2004 in northern China? In the aggregate, the changes were significant. The share of collective management declined from 90 percent in 1995 to 73 percent in 2004. Across the samples, WUAs and contracting have developed at about the same pace. By 2004, 10 percent of villages managed their surface water through WUAs and 13 percent under contracting. When counting the mixed systems (which rose from two to four percent between 1995 and 2004), by 2004 27 percent of villages in northern China had been affected by water management reform. While WUAs and contracting are still far from the most common forms of water management, if we assume that half of China's 800,000 villages are in the study area, this means that more than 100,000 villages have reformed, at least nominally, the way they manage water.

While there has been a general shift from collective management to WUAs and contracting during the past five years, water management reform still varied across the six sample provinces in 1995 and 2004. For example, the use of traditional collective management between 1995 and 2004 has fallen in five sample provinces - Inner Mongolia, Ningxia, Liaoning, Shanxi and Henan. In Shaanxi and Hebei, however, the use of collective management actually rose. But even among the five provinces that experienced net positive reform, there were striking differences. In the sample villages in Inner Mongolia the use of traditional collective management fell from 89 percent in 1995 to 44 percent in 2004. In Ningxia collective management fell from 78 percent in 1995 to 31 percent in 2004. The other three provinces (Liaoning, Shanxi and Henan) reformed significantly less. The share of villages under collective management fell by only 5 to 10 percent in these three provinces.

Beyond the differences across the villages regarding their decision to reform or not, the direction of reform also varied among provinces. Most poignantly, villages in Inner Mongolia, one of the two provinces with the most actively reforming sample villages, almost all (13 of 17 reforming sample villages) decided to manage their surface water systems through WUAs instead of contracting. In contrast, villages in the other active reform province, Ningxia, generally chose contracting. There were also differences in the choice of the direction of reform in the other provinces. For example, all of the villages that had chosen to reform by 2004 in Shanxi and Hebei chose contracting. However, five of the six reforming villages in Shaanxi chose to manage their surface water through WUAs instead of contracting.

Based on the field survey, although some of the differences in water management among the Irrigation District (IDs) may be due to the characteristics of local villages and local water management initiatives (explored later in this appendix), the dramatic differences among provinces suggest that government policy may be playing an important role. For example, in 2000, in order to promote water management reform, Ningxia provincial water officials issued several documents that encouraged localities to proceed with water management reform (Wang, 2002). Regional water officials exerted considerable effort to promote water management reform in a number of experimental areas. In Hebei (a non-reforming province), when the survey approached provincial officials about water management reform in Hebei's surface water systems, no one knew anything about it. The sharp shift away from collective management (in certain provinces) is consistent with an interpretation that these policy measures were effective in pushing (or at least relaxed the constraints that were holding back) reform.

The differences among these villages and variations in the way that different regions implemented the reforms (i.e., some moved to contracting while others shifted to WUAs), however, show that the nature of the reforms are far from universal. In fact, this is what would be expected in China. These regional differences are most likely a characteristic of reform in China, a nation that often allows local governments considerable room in making their own decisions on the exact form and timing of institutional changes.

Governing WUAs

The shift in China's water management institutions demonstrates that the nation's communities at least in part are following policy directives that are being developed and issued from upper-level governments. This section examines how local leaders govern traditional and reformed water management institutions, especially WUAs. It also examines the difference between governance in WUAs and contracting (the two competing types of reform).

When villages report that their water systems are being run under a certain institutional form, field data show that there appears to be fairly major shifts in responsibilities. When a village claims its surface water system is being managed under the traditional collective management system, nearly all water management activities are carried out by the village leadership. Canal maintenance, coordination of water delivery and water fee collection is fully (100%) the responsibility of the village. In a small share of villages (22 percent) farmers themselves operate the sluice gates according to the schedule set by village leaders. Respondents reported during the survey that 33 percent of villages with collectively managed irrigation systems also depended on township or ID officials if there was a dispute that required resolution.

Likewise, when a WUA is set up most of the responsibilities for managing the village's canal system is carried out by the WUA. In villages with WUAs the respondents said that the WUA board is fully (100%) responsible for the operation of sluice gates, water fee collection and conflict resolution. Interestingly in half of the villages with WUAs, the WUA had responsibilities for canal maintenance, but in the other half the village leadership - apart from the WUA - held responsibility. This was done, at least in several villages, because canal maintenance was carried out by small group leaders and the small group members, while the WUA is a village-wide organization. WUAs also split responsibility with village leaders and farmers for coordination of water delivery.

In contrast, the organization of water management activities is more complicated when contracting is used. In contracting villages, the village council fully (and jointly with the contractor) helps the contractor carry out the activities. Certainly in part this is because contractors may lack the ability to carry out certain activities (e.g., canal maintenance). It also may be that they are unable to act as a disinterested party in the execution of other activities (e.g., dispute resolution).

Incentives

Another major difference in governance among water management institutions concerns the incentives paid to managers if the irrigation system in the village performs well and earns a profit. In the analysis it was assumed that village leaders are the managers of traditional collectively managed irrigation systems. The chair of the association (or board members) is the manager of the WUAs. The contractor is the manager in contracting villages.

Under these assumptions the differences in the incentives paid to managers clearly vary across institutional form and over time. For example, in none of the villages (in either 1995 or 2004) that were run as collectively managed systems were village leaders paid a bonus or given any part of the residual revenues once all expenses were paid.

Leaders of WUAs were provided with more incentives which increased over time. Specifically, leaders in 14 percent of villages with WUAs in 1995 and in 32 percent of villages in 2004 financially benefited if the irrigation system made money at the end of the cropping year. Even by 2004, however, WUA managers in less than one-third of the villages earned incentives of any kind.

In contrast, the incentives paid to contractors rose quickly and reached a high proportion of villages by 2004. Although only 27 percent of the contracting villages offered managers financial incentives in 1995, the percentage reached 76 percent by 2004. Clearly, the nature of incentives distinguishes contracting significantly from collective management and WUAs.[19]

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[19] It should be noted, however, that the existence of financial incentives for managers is considered a controversial feature of contracting among some officials and academics. The problem is that it is possible that in pursuit of his/her own profits, the manager of an irrigation system will cut back on services that are

Practice and theory: participation in WUAs

According to field data, practice and theory vary sharply. Definition of participation includes three parts: how farmers participated in the process of establishing the reform process (e.g., the setting up of the WUA); the selection of the managers; and whether or not farmers were invited to attend regular business meetings. These three aspects of decision making almost cover all the major activities of water management institutions (their creation; the selection of the leader; and input into day to day business procedures).

Despite the important roles that farmers play in water management in some parts of the world, according to this data, participation is not part of either China's traditional, collectively-run, or contracted water management. Traditionally, the implementation of many government services in China is carried out from the top down with little consultation with or participation of farmers. Although collectively-managed services, such as those provided by collectively-run water organizations, in theory are supposed to be determined by the entire collective, in fact, village leaders have managed their villages in a large part based on the authority that they have derived from higher-level officials. In these sample villages it was found that farmers participated little (and mostly not at all) in collectively-run water management organizations. Similarly, by definition (and according to the survey results), contracting involves transferring control and income rights to an individual and involves almost no participation of farm households.

In contrast, the reforms that led to the creation of WUAs explicitly attempt to encourage farmer participation. However, practice often varies from theory. In the CWIM survey areas farmers have little voice in deciding on the establishment of WUAs or appointing the management team for their community's irrigation system. For example, at least in the early stages of the development of WUAs (the only organization stage that can be observed since this type of management is so new in the sample villages) the data show that, on average, only 12.5 percent of WUAs involve farmers in the decision on their establishment. In fact, most farmers (70 percent) who are in villages in which the local irrigation system is nominally managed by WUAs did not even know that they were part of a WUA.

Farmers also are seldom encouraged to participate in other aspects of water management. Based on a random sample, none of the WUA governing board members are actually elected by farmers. Only 25 percent of WUAs allow farmers to participate in the process of selecting managers. As a result, in most cases (70 percent of the WUAs), the governing board of the WUA is the village leadership itself. In a minority of cases (30 percent of the WUAs), village leaders appointed a chair or manager to carry out the day-to-day duties of the WUAs. In many of these WUAs, however, the managers actually have close ties to the village leadership (for example, the manager frequently is a former village leader or a close relative of a current one). Moreover, although 80 percent of WUAs hold regular meetings, farmers are invited to participate in only about 25 percent of these meetings.

Compared with collective management and contracting, however, WUAs are more accountable to farmers. As discussed above, it is reasonable to assume that a relatively

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demanded by farmers (and which may be a routine part of the services provided in villagers with collectively managed irrigation systems or WUAs). Because of these potential conflicts, in the agreements between villages and contractors, there are many stipulations about what is required and what can and can not be done. Perhaps because villages are so small, monitoring is fairly good and effective and there have not been many troubles reported in the sample villages. Anecdotes and stories told by officials, however, suggest that in some villages there have been conflicts been contractors and villagers which have been caused by the differences in objectives between a profit-oriented manager and a set of farmers that want inexpensive, reliable and timely service.

high degree of transparency at least in part reflects a relatively high degree of accountability. The field survey found that the degree of transparency for WUAs is higher than other management forms. In fact, all WUAs have some degree of transparency. Nearly 40 percent of WUAs shared all three types of information about the irrigation system with farmers (in other words, the WUA told farmers about the way water fees are generated; the volume of water that was actually delivered by the ID to the village; and the actual area that was irrigated). About 50 percent of WUAs shared two of these three types of information.

Incentives for farmers

Somewhat ironically, since one of the main goals of water management reform is to provide farmers with better irrigation services, the design of the water management reforms placed little emphasis on incentives for farmers. In many villages the water management reforms mandated that water fees paid by farmers should be reduced. However, the reduction in the water fees in most villages was quite modest. On average, water fees were reduced by only about nine percent.

12.4 Appendix 4: Public agricultural extension systems in China

Evolution of public agricultural extension system in China

The public agricultural extension structure in China is built upon the central planning economy. Institutional administrative organization of this system starts from the top national level via provincial, municipal and county level down to the township and village level. This top down approach is closely related to the actual circumstances at the time that the system was set up, such as the shortage of supply of raw agricultural materials, a collective-owned land system and a less developed commodity economy.

The development of the Chinese agricultural extension system can be described in four stages since the communist party came into power 50 years ago. The first stage started in the early 1950s soon after the People's Republic of China was established. The Ministry of Agriculture designed a top-down national agricultural extension network. In the early periods, county breeding farms were the centre of the public agricultural extension system. From 1955, regional agricultural technology stations became the major body of this system. By the end of the 1950s, more than half of the counties in China had agricultural extension stations. However, during the second stage (the 1960s), the newly developed agricultural extension system was destroyed by the Cultural Revolution and severe natural disasters. Agricultural extension officers were reallocated and assigned to other tasks.

In the 1970s, the third stage, agricultural extension recovered and was further expanded. Besides thousands of agricultural extension institutes at the county level, extension stations were set up in about 26,000 communes and 300,000 production brigades (the lowest production unit at that time). At the top level, the Ministry of Agriculture was mainly responsible for the national agricultural extension activities. To a certain extent the National Committee of Science & Technology and the National Committee of Planning were also involved.

The fourth stage refers to the last two decades of economic reform. During this period, the agricultural extension system went through dramatic changes and this process is still going on. The first impact came from the introduction of the "Household Responsibility System", which focused on individual farmers as the basic production unit, instead of the production brigades in the previous collective system. With the dismantlement of the extension structures at commune and brigade level, the whole extension system came under a process of restructuring and readjusting. Several approaches have been experimented with, such as converting the governmental extension organizations into independent companies, and encouraging other organizations (such as universities and research institutes) to extend their research results. Intensive discussions are currently focusing on how the old extension structure could be reorganized in order to meet the new requirements and what methodological approaches are most suitable and useful in the current Chinese circumstances.

Presently, agricultural extension in China operates at five different levels of management in the whole country. They are National Agricultural Technological Extension and Service Centre (NATESC), Provincial Agricultural Technological Extension Centre (PATEC), Municipal Agricultural Technological Extension Centre (MATEC), County Agricultural Technological Extension Centre (CATEC), and Township Agricultural Technological Extension Stations (TATECs). By the end of the 1980s, the system employed an extension staff of more than one million people. By the mid-1980s, China had established stations in every rural county and township, even in remote regions, and this large system provided high-quality agricultural extension services.

The NATESC was set up in 1982 at the national level, and was reorganized in 1996 by combining separated extension services into one comprehensive unit with 148 staff. PATEC's Provincial Plant Protection (PPPS), Provincial Soil Fertilizer Station (PSFS), and Provincial Seed Station (PSS) are now set up at the provincial level. There are 162 provincial extension services with 4,656 technical staff. MATEC's Municipal Plant Protection Station (MPPS), Municipal Soil Fertilizer Station (MSFS), and Municipal Seed Station (MSS) are now set up at the municipal (prefecture) level. There are 403 extension units with 20,121 technical PATEC staff in the entire country. CATEC includes County Plant Protection Station (CPPS), County Soil fertilizer Station (CSFS), and County Seed Station (CSS) and these are set up at county level. There are 7,373 extension units with 130,452 technical CATEC staff in the country. The Chinese government has also been trying to reform county extension services since 1979 by combining isolated extension units into CATECs. They have been very successful. More than 1,800 CATECs have been set up in the whole country. County extension services are mainly responsible for management of extension services in the county, extension programs dealing with plant protection, seed, soil, fertilizer, crop cultivation, etc. TATECs are set up at the township level. There are about 71,060 extension units with 235,341 technical staff in the TATECs. TATECs are mainly responsible for the management of extension services in the township, extension programs dealing with plant protection, seed, soil, fertilizer, crop cultivation, etc. TATECs are the key service providers, which directly connect with farmers and serve the farmers. By the end of 1997, there were about 49,000 extension units and about 384,000 staff working in the cropping sector in China. In addition, there are about 400,000 farmer service organizations that cover 20 percent of the villages in China, with 1.03 million farmer technicians and 6.6 million demonstration households.

Extension services at the national, provincial, and municipal levels try to keep close contact with agricultural research departments and agricultural universities and colleges. The mechanisms for such contact are fixed expert meetings, professional meetings, project coordination groups, evaluation meetings, etc. The local extension services also liaise with agricultural schools and applied research institutes. CATEC provides coherence among agricultural schools, institutes, broadcasting schools, and extension services. Township extension services maintain strong functional relationship with local government and other line departments.

Public agricultural extension system stations are organized by the agricultural sub-sector. Most agents are based in crop or livestock stations, but most counties and townships also have agricultural machinery, aquatic products, and agricultural economics stations. Most counties have established specialized stations in addition to the five types listed above, including crop management, plant protection, horticulture, and soil and fertilizer technology, as well as stations corresponding to locally important agricultural products. For example, cotton-growing areas have stations specializing in cotton.

The public agricultural extension systems have became overstaffed, in part because of the proliferation of specialized stations. This overstaffing has created a financial burden for local governments. To improve efficiency, most counties restructured their public agricultural extension system by merging different stations and establishing new agricultural extension service centres. For example, most counties have merged their crop management technology stations, plant-protection stations, and soil and fertilizer technology stations to establish single crop-technology extension service centres.

Characteristics of the public agricultural extension system in China

1. **Directly led by government.** In addition to establishing development policies for agricultural extension, government is also directly in charge of preparing plans for agricultural extension projects; and organizing implementation and managing staff, funds and facilities of national extension agencies. National finance is the major funding source for agricultural extension.

2. **Belonging to narrative agricultural technology extension**. Generally, agricultural extension in China means that through experiment, demonstration, training and consultant services, extension agencies extend agricultural technology to various stages of agricultural production. Such an extension system emphasizes the extension and application of agricultural technologies, while capacity building for farmers and livelihood improvements have been overlooked.
3. **Dualism of organization and management.** Agricultural extension agencies are not only directly led by the upper level of agricultural administrative agencies, but are also technically guided by upper level extension agencies. Since the agricultural administrative agencies have stronger administrative power, the agricultural extension system is mainly controlled by administrative agencies.
4. **Centred by national agricultural extension agencies and coordinated by many institutes.** In China, agricultural extension agencies above the township level belong to national extension agencies, and such agencies are the major bodies for agricultural technology extension. In addition, some research institutes, universities, science and technology commissions and other organizations which provide services for agricultural production, also work on extension programs.

Existing problems in the public agricultural extension system

The traditional extension approach in China is based on the central planning system. As a result the current extension system has several problems, particularly when facing the development of a market economy:

1. ***Gap between research and needs.*** The present agricultural extension system is directly led by government and has a strong administrative nature. Therefore, it cannot adapt to a market economy - there are large gaps between research results and market demand, and no close relationships between research, education, extension and production. If there is no potential market demand, it is hard to convert research results into production. However, the existing agricultural extension system does not allow research activities to be closely linked with market demand. On one hand, there is not enough effective demand from farmers; on the other hand, there is also an ineffective supply of research results.
2. ***Not enough funding inputs.*** Since the 1980s, the share of research and extension funding of agricultural GDP has steadily declined. In 1980, it was 0.27 percent, but this number declined to 0.17 percent in 1985 and 0.12 percent in 1990. The World Bank suggested that the share of research and extension fund of agricultural GDP should be 1 to 2 percent. Even so, during township government agency reform, extension funding has been further reduced by a large amount. Due to the reduction in extension funding, many technicians have left the extension stations, the time input of technicians has been reduced, and the extension system has generally been destroyed. Insufficient extension funding is one of the major reasons for inefficient extension activities in China. Presently, most of the extension funds are used for technicians' salaries and only 10 percent of the funds are available for extension activities. Some limited extension funding is provided by local governments. In addition, most extension stations have no extension projects. Based on one survey, less than 30 percent of county extension stations had extension projects and only 14 percent of township stations had extension projects.
3. ***Scarcity of high quality extension staff.*** High quality technicians are the key to effective agricultural technology extension. Presently, many of the extension stations are short of high quality technicians and therefore the extension system does not work well. Based on one survey in the late 1990s, in about 30 percent of the extension stations, there were no formal extension technicians, and most of the staff were on short term contract. In addition, the age distribution of technicians was not even. For example, in the township level extension stations, 82 percent of staff were either more

than 50 years old, or younger than 35 years old. Only 18 percent of the staff were aged between 35 to 50 years old. Of these extension staff, most of them were only familiar with selected specified knowledge - few staff were familiar with the comprehensive approach to agricultural production and were considered to have modern knowledge.

4. ***Poor incentives for extension staff.*** In the present extension system, efforts and performance of extension staff in extending agricultural technologies are not closely linked with salaries, and these staff have limited incentives to extend technologies. Such a system also influences the efficiency of agricultural technology extension.
5. ***Changing role of farmers in the knowledge system.*** During the central planning period, the central government designed the extension program and selected certain new agricultural technologies for nationwide extension. From the top to the bottom, all extension institutes were promoting these new technologies until they reached the farmers. At this time, farmers were collective farm members and had no decision power over what they wanted. Nowadays, however, farmers are independent decision-makers and their activities are profit driven. They only adopt new technologies if they can benefit from them. The top-down approach is no longer appropriate for agricultural extension. Instead, farmers' wishes and demands should be carefully considered. Strong involvement and participation of farmers are becoming more and more important to ensure the success of agricultural extension.
6. ***Low capability of farmers to adopt new technologies.*** In China, since most farmers do not have a good education and training, their capability to adopt new technologies is low and this influences extension work. In addition, since farmers do not understand the potential profit from adopting new technologies, they are afraid to adopt new technologies due to their potential high risks. Therefore, farmers are not very responsive to new technologies and there are few incentives to adopt new technologies.
7. ***Unsuitable technology and project selection mechanisms.*** Project and technology selection mechanisms used by the traditional agricultural extension systems cannot adapt to production demands by farmers. The purpose of agricultural research and extension in China is to increase production output. However, modern agriculture must react to buyers' markets, and the demand by consumers for more diversified and higher quality products. Agriculture in China is in the process of adjusting its production structure, which results in a behavioural change in terms of technology demand by farmers. For example, farmers' demand for production technology for grain crops tends to decline and their demand for production technology for cash crops tends to increase. Farmers' demand has transferred from high output technologies to high quality technologies. In addition, farmers need more technologies that can save funds instead of saving labour.
8. ***Limited scope of extension.*** Traditional agricultural extension was not only focused on "transferring technology" to farmers, but this technology was also limited to "strategically important" crops such as rice, wheat and maize. With agricultural structure adjustment, more farmers have changed to the production of cash crops, and this technology is not yet available. Furthermore, the contents of the agricultural extension messages should include broad concepts, such as farmer communication amongst each other, informal agricultural education, etc. Chinese farmers strongly require new knowledge to improve their decision skills when they face a series of challenges in the market economy.
9. ***Poor organization of farmers.*** In China, agricultural extension agencies have to directly interact with millions of small farmers since farmers are not organized by themselves. This lack of farmer organizations has not only increased the transaction cost of technology extension, but also constrained the extension channels for agricultural technologies. How to establish farmer organizations (or associations) has been emphasized by many researchers and policy makers.

Reform of public agricultural extension system

Rural reform started in the early 1980s and was mainly due to the implementation of the Rural Household Contract Responsibility System (RHCRS). This reform was not only essential for agricultural production and rural development, but it also had great impact on agricultural extension. First of all, with the RHCRS, the old "People's Commune System" was abolished and farmers now have the right to make independent decisions on using their small pieces of contracted land, so they no longer have to listen to the directives of the cadres and government. The clientele for extension becomes millions of rural households instead of the smaller number of communes, brigades, and production teams. This means that previous extension methods are no longer relevant. Meanwhile, the extension system is seriously affected by financial shortages and other factors. In order to sustain and strengthen the extension system so it can play an important role in agricultural development, significant reforms have been carried out, as outlined below.

First Reform

The first reform was to establish a new type of extension system that combines (i) technology experimentation, (ii) demonstration, (iii) extension, (iv) training, and (v) commercial services (mainly supplying inputs). Over-scattered extension agencies were merged to build technical strength by using all available resources. The priority of reorganization was to set up CATECs by merging different stations of crop cultivation, plant protection and soil/fertilizer, and research institutes for county agricultural sciences and other disciplines. Another goal was to improve and set up TATESs and at the village level create Agricultural Technology Demonstration Households (ATDHs). Some villages, especially in developed areas, also established service organizations. By about 1992, 1,469 CATECs and about 45,000 TATESs were set up. They have played an important role in China's agricultural development.

This new system has four basic features. First, it is under the leadership of government agricultural departments/bureaus. Second, the system has two key functions - to provide technology extension and social services to the farming community. Third, it has CATECs as its focal point and works through supporting extension and farmer organizations at the townships and village levels. Fourth, the system is implemented by state extension personnel and by technicians paid by farmers and collectives (townships and villages).

Second Reform

A second reform to China's extension system was to implement payment for extension services such as "diagnosis and prescription" (clinical services) and "technology contracts." Once a contract is signed between extension agencies and farmers (or sometimes between townships and villages), the extension agencies are responsible for technical guidance, input supply, and yields (and sometimes for marketing), and pay any losses due to technical failures. Farmers complete the work required by extension agents and pay the service fee to extension agencies according to the contract after harvest. This extension approach to technology contracts is unique to China, and is popularly applied nationwide.

This extension system tightly combines responsibility and economic interests for both extension agencies and farmers. The advantage is that farmers are assured of applying the techniques, and extension agents gain an incentive to serve farmers. Extension agencies at the grassroots level also organize paid services such as unified plant protection and tillage through which technology is applied to farmers' land. Through these essential reforms in methodology and management, China's extension services have gradually shifted from being administrative or instruction-oriented, to motivation- or service-oriented and from directing to influencing or advising farmers to adopt technologies to obtain higher production and profits. However, as some studies have shown, agricultural extension system agents may have conflicts of interest. Because they earn some income from selling fertilizer, pesticides, and seed to farmers, some studies have shown that some agents recommend more pesticides, fertilizers, or expensive seed than farmers really need.

To further vitalize extension organizations and overcome severe funding shortages, extension agencies, especially under the county level, have found a way to "self-finance" or "self-develop" by running enterprises themselves. Most of these are agriculture-related businesses, but some have nothing to do with agriculture especially in developed areas such as the Yangtse Delta. Rather than just relying on government financial allocations, extension organizations are able to accumulate economic strength to support or subsidize extension services delivered to farmers, as well as to motivate extension agents.

Even when the government can't afford to completely finance all extension organizations, when there is limited supervision or monitoring, and when farmers have little to say in what is extended, both farmers and extension agents can cooperate successfully because of the material incentives. Practice shows that in China, free extension services are not only too expensive to be funded by the government, and this process creates more bureaucracy in the extension system, but also, even with very strict discipline, such services can't guarantee success.

Third Reform

The third reform to China's extension system was a shift from government monopolized extension to cooperative extension. This means that, in terms of financing and organizing, government-financed extension agencies are still the mainstay of the system. Collectively financed (paid by townships, villages, and farmers), extension staff and organizations at a grassroots level also play an important role. Some related government agencies such as the Department of Education, the Commission of Science and Technology, and the Department of Commerce; various associations, farmers' technology clubs, and some agriculture-related enterprises, such as pesticide and plastic film manufacturers, also participate in agricultural extension. However, "cooperative extension" in China is different from that in the United States.

Fourth Reform

In 1993, the central government issued the “Regulation of Chinese Agricultural Technical Extension”, which focused mainly on reforming the organizations and strengthening service functions at county and township levels, through integrating separate extension stations, such as seed stations, agro-management stations, agro-tech extension stations, etc., into one extension center. By 1996, Agricultural Technical Extension Centers (ATECs) had been established and were operating in over 65 percent of all counties. Since then the service functions have been extended and completed.

In the early 1990s, through the same regulation, the Chinese government formalized commercial reforms by classifying stations by their source of funding: fully funded stations, partially funded stations, and self-funded stations. Counties had flexibility in how to implement these reforms, and in some counties that were less able to finance agricultural extension, all the CATECs have became self-funded stations or partially funded stations. Cuts in funding for CATECs affected the day-to-day operations of the system. Several studies have found that agricultural extension services have been greatly reduced since the early 1990’s.

At the end of the 1990s, the Chinese government carried out another type of public agricultural extension system reform. This reform shifted the administrative rights (including personnel, finance, and materials, or “three rights”) from county agricultural bureaus to township governments. The reform was intended to enhance the capacity of township governments to manage their agents in township agricultural extension stations; to strengthen extension service to farmers (the service had been weakened by commercial reform); and to reduce the budgetary burden on the county agricultural administration departments, which were responsible for the stations' budgets. However, several studies have shown that the reform cut the links between the county agricultural extension stations and the township agricultural extension stations, thus interfering with technical services to farmers. The Ministry of Agriculture criticized the reforms, in part because they increased the time agents spent on administration and reduced the time available for the provision of agricultural extension services.

Fifth Reform

In 2006, the central government issued the "Suggestions on the Deepening Reform of Agricultural Extension System" which promoted the latest round of reform. The purpose of this reform was to establish one efficient agricultural extension system that can provide high quality services for the establishment of a new rural society. According to the suggestion, through reform one energetic agricultural extension system will be established. In the new system, national agricultural extension agents are the major body and will coordinate the work of many agencies.

There are seven aspects of the reform: (i) establish a highly efficient feedback mechanism of farmers' demand; (ii) establish position responsibilities for institutional extension staff; (iii) innovate extension approaches for new agricultural technologies; (iv) perfect an assessment mechanism for national extension staff; (v) establish dynamic management of institutional personnel; (vi) perfect a coordination mechanism for county extension agencies; and (vii) establish multiple extension mechanisms for government dominated extension agencies.

According to the suggestions, this new reform should be finished by the end of 2007. However, reform has been difficult and the expectations of the policy designers have not been realized. Until now, except for some demonstration counties, most counties have no clear reform scenarios that can be implemented. There is also an ongoing argument about the reform – should investment be increased first, or should the management system be reformed first? Some people think that if government does not reform the management system, increasing funding will not be effective. Under the present management system, extension staff cannot allocate much time to public extension work. Officials from finance agencies, science and technology agencies, personnel agencies and development and reform agencies hold such opinions. Some other agencies (especially agriculture and technology extension agencies) are of the opinion that if investment is not increased, it will be difficult to promote successful reform.