

China – UK, WRDMAP Integrated Water Resources Management Document Series

Example 7.1: Simplified Multi-criterion Decision Analysis for the Shiyang River Basin IWRM Plan

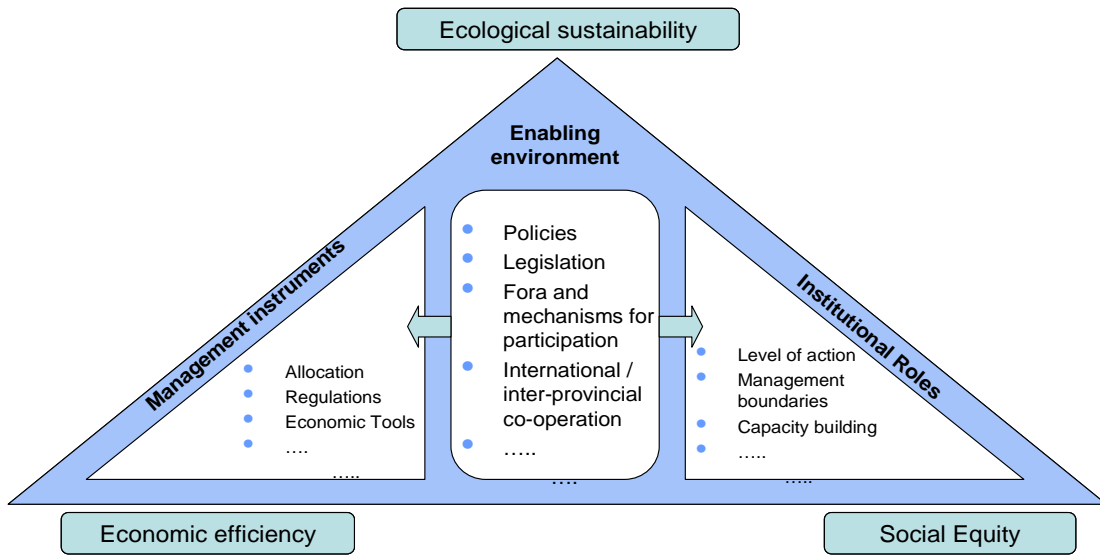
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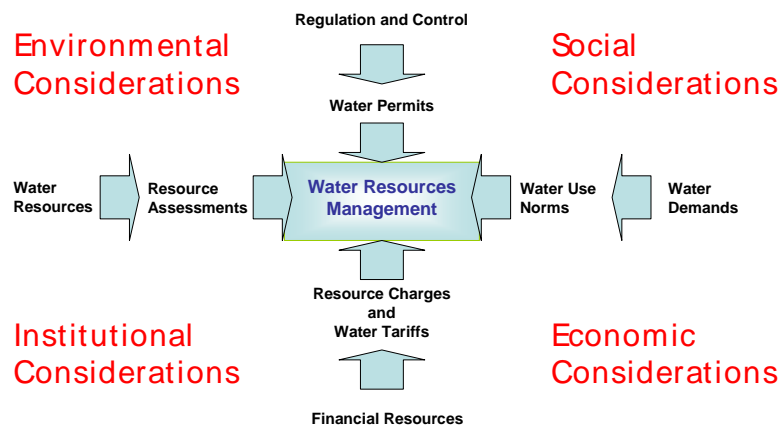


Integrated Water Resources Management (IWRM)

(Based on Global Water Partnership)



Driving Elements of Integrated Water Resources Management



(Second figure after WRDMAP)

Summary: This example shows how even a simplified Multi-criterion Decision Analysis (MCDA) can assist in dealing with complicated trade-offs between different groups of water users in a river basin.

The Shiyang River Basin Integrated Water Resources Management Plan sets out a series of interventions intended to curtail unsustainable over-abstraction and to prevent “Minqin becoming another Lop Nor”. Getting to this sustainable situation will take some painful choices.

The great advantage of MCDA is that it is easy to understand and use and does not require economics or other skills. Its main requirements are the necessary exercise of common sense and judgement and the detailed participation of all the major stakeholders in the project.

This document covers the following material:

- Introduction to the decision making process required for strategic planning
- Water use in the Shiyang River Basin
- Social setting
- Economics of planned interventions
- Simplified multi-criterion decision analysis
- Recommendations for taking the MCDA forward

Further practical guidance on the subject of MCDA is given in a Thematic Paper and Advisory Note in the same series.

The Ministry of Water Resources have supported the Water Resources Demand Management Assistance Project (WRDMAP) to develop this series to support WRD/WAB at provincial, municipal and county levels in their efforts to achieve sustainable water use.

1 Introduction

Many decisions need to be made by reference to several criteria or objectives. Planners and designers might choose a dam site on grounds of cost, size of available storage, annual inflow, location relative to water demand centres, environmental impact (including visual merit or demerit, effect on flora and fauna, etc), and social impact (number of homes, farms or factories needing to be relocated). Projects competing for limited resources might be selected on the basis of economic merit, social impact, environmental impact, ease of implementation, and regional balance.

In general, a decision-making problem or situation will usually boil down to:

- A number of alternative courses of action (variously called projects, schemes, plans, options, variants, interventions, packages);
- A number of objectives or criteria (like those listed above);
- One or more persons or groups of people to whom the criteria matter to some degree.

A decision aid must often serve as an instrument not only of analysis but also of communication and persuasion.

Among various numerical methods for MCDA, one is preferred because of its simplicity and transparency, although it can handle complex problems with large numbers of competing courses of action. It is called the weighted-average method. Because of its simplicity the principle is easy to explain to decision-makers and the wider public.

This is really just a systematic and formal way of presenting a normal decision-making process. Such decisions are normally taken on the basis of a combination of different criteria, with different degrees of importance (weightings) being given to each of the various criteria involved.

The process of discussion and exchanges of views between the various participants on the criteria and weighting is one of the most important and rewarding parts of the MCDA process.

This Example document should be read in conjunction with Thematic Paper 7.1 and Advisory Note 7.1 on the same topic of multi-criterion decision analysis (see references for details).

2 Water Use in the Shiyang River Basin

The Shiyang River used to terminate in the Qing Tu lake, which dried up in the early 1960s following construction of the Hongyashan Reservoir, and extension of irrigation in the Minqin oasis. The Minqin oasis is surrounded by desert and has been experiencing significant degradation as a result of changes in upstream water use. Good summaries of how the current situation has developed are given by Shaozhong Kang et al. (see bibliography).

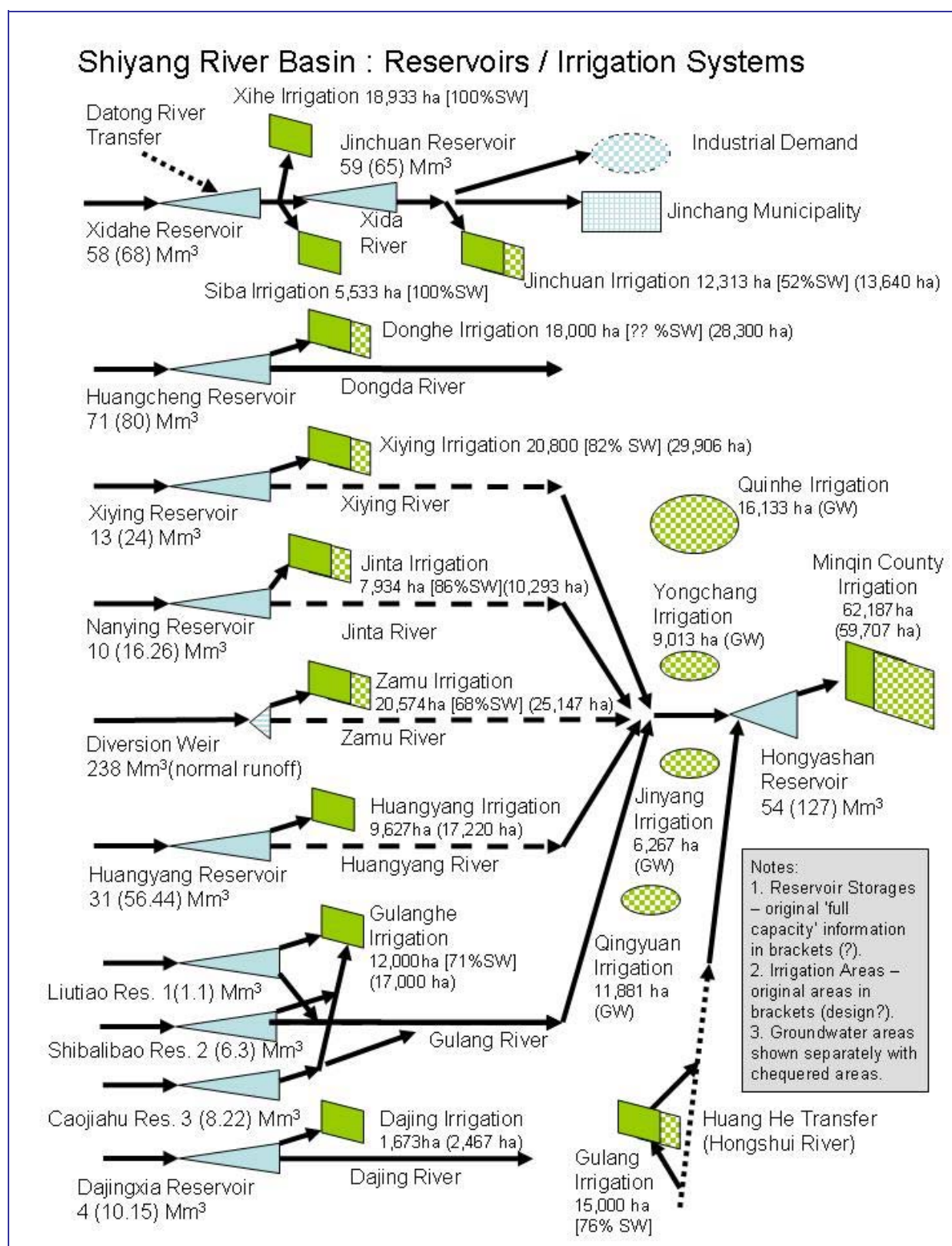
The primary water use in the Shiyang River basin (SRB) is for irrigation, which accounts for 86% of total water use. Industrial water use accounts 5.7% of water use, and urban and rural water supplies for a further 3.9%. In the Wuwei and Jinchang municipalities, which cover most of the basin area, the total cultivated area is about 415,000 ha, of which about 74% is irrigated. The irrigated area in Minqin County is about 75,000 ha.

Groundwater use has increased significantly in the SRB. In Minqin County alone there are over 9,000 wells. There are said to be 13,000 – 14,000 wells in the middle and lower basins combined.

Overall in Minqin abstraction exceeds recharge by about factor of ten. The data indicate a steady fall in groundwater levels at an average annual rate for the whole of Minqin county of 0.65m/yr with variations from 0.2 to 1.26m/yr.

The Strategic Plan for the SRB was approved by State Council in 2007. The Strategic Plan provides the framework for managing water use sustainably in the SRB through a combination of measures. Irrigation areas are being significantly reduced, irrigation efficiency improved, new transfer systems introduced, and measures introduced to increase farm income from smaller cultivated areas.

Figure 1: Water resources development in the Shiyang River Basin



3 Social Setting

The total population of the SRB was estimated at 2,268,900 people in 2003 (including the 98,300 in Gulang who benefit from the Jindian pumping project in the Yellow River Irrigation District). The area has an agricultural population of 1,745,700 people. The non-agricultural population comprised 523,200 people whilst the urban population consisted of 733,900 people (including 3,500 in the Yellow River Irrigation Area) and the rural population was about 1,535,000. The degree of urbanization is about 32%. The agricultural population is partly urban, and many farm households have members who work part or full time in urban areas (both within and outside SRB).

Implementation of the IWRM Plan will result in a number of benefits for stakeholders; specifically:

- Water Users in Rural Communities and in WUAs
 - More equitable and predictable access to water, but a smaller total volume of water, as a result of improved river basin management planning, management and development.
 - Greater access to information on water demand allocation and prices.
 - Involvement of user representatives in consultations on changes in water allocations, and on river basin planning in general.
 - Compensatory/mitigation measures to cope with reduced water availability, particularly in the lower basin areas, where existing shortages and increasing groundwater abstractions are most severe.
- Industrial water users
 - New skills and techniques required to manage changing water allocations.
 - Predictable and reliable access to water as a result of improved river basin planning, management and development.
 - Improved access to information on water allocation and demand.
 - Greater involvement in consultations on water allocations and prices.
 - Increased knowledge and resources for re-cycling, leakage detection and control
- Domestic Water Users
 - Increase in reliability of supply for upstream and downstream users.
 - Increased availability of information on water supply.
 - Enabling environment for consultation on decision making concerning water use and allocation.
- Water users on State Farms
 - More equitable and reliable access to water via involvement in decisions on basin planning and management
 - Assistance with water-saving farming.

There are several potential risks to water users from implementation of the SRB Integrated Water Resource Management (IWRM) Plan. The most crucial of these are:

- Livelihood problems faced by relatively less affluent rural water users from well closures, land reduction, and greenhouse development.
- Reductions in water supply leading to a smaller proportion of total water use being allocated to agriculture, this resulting in farmers being wary of the introduction of Water User Associations (WUAs) in some areas, equating them with the necessary implementation of enforced reductions.

These are significant benefits, but they must be translated into financial benefits to each household. Analysis of the scenarios indicates the changes in productivity of water that will result through implementation of the strategic plan. Although there is a large increase in the value of water, the volume of water is decreased in most irrigation districts. This affects the total value of production; although on average this remains essentially the same as at present, this varies considerably between irrigation districts, and in some cases is much less than the present situation.

This will need to be compensated for through more high value agriculture, or through off farm employment. Further work will be needed to achieve this.

Well closures and accompanying land reduction policies are having a significant impact on livelihoods with farmers expressing concern at reductions in their incomes. Farmers have adopted a series of coping

strategies to compensate, such as attempts to extend animal husbandry, increased cash crop cultivation, changes in cropping and irrigation, and green house development, but many – and particularly the relatively poorer farmers - are experiencing some declines in household income.

In a recent policy put forward by the Price Bureau, poor households in receipt of both rural and urban *di bao* are to receive a 20% reduction on the payment of their water fees.

4 Interventions Planned in the SRB Strategic Plan

The SRB strategic plan requires a range of structural and non-structural measures. This section describes the structural measures which use the majority of the cost, although do need to be supported by institutional and other non-structural measures to make them effective

A total area of about 75,000 ha is planned to be taken out of irrigation. Of this 29,100 ha (39%) is in Minqin, 22,400 ha (30%) in Yongchang, 12,600 ha (17%) in Jinchuan and 10,500 ha (14%) in Liangzhou. Expressed as a percentage of existing irrigation by county, the largest reduction is in Yonchang (a 54% reduction in irrigated area), followed by Minqin (40%), Jinchuan (40%) and Liangzhou (10%). No reduction is planned for Gulang.

Several inter-basin transfer canals have been proposed so that water can be diverted to the downstream part of the basin. Initially there will be a canal from Xiyang River to Caiqi to Minqin (under construction); and the two delivery channels from the Donghe to Jinchuan Xia reservoir are being rehabilitated to incorporate hydro-

electric power stations along the channels; and the Yellow River-Hongshui diversion canal will be improved

The primary and secondary canals of the surface irrigation districts will be lined and rehabilitated, with a total length of 1,658 km (108km of general main canals, 395km of main canals, 1150 km of secondary canals). This will include construction or rehabilitation of hydraulic structures, including spill weirs, sluice chambers, stilling basin construction, upstream and downstream retaining walls for Xiyang, Zamu, Jinta, Xihe, Siba, Donghe, Jinchuan, Huanyang, Gulang, Gufeng and Hongyashan, irrigation districts.

The field irrigation systems will also be improved through water savings infrastructure on 2.75 million mu (183,500ha). Of this area,

- Improved canal irrigation will cover 1.86 million mu (123,900ha);
- Pipe irrigation 272 thousand mu (18,200 ha);
- Drip irrigation for field crops 345 thousand mu (23,000 ha); and
- Drip irrigation in greenhouses 276 thousand mu (18,400ha).

Groundwater irrigation will be reformed with stricter controls on the amount of water abstracted and better management of water

5 Economics of Planned Interventions

As part of the preparation of the SRB IWRM Plan an economic analysis was carried out of the interventions in the agricultural sector proposed in the SRB Strategic Plan. These are ranked in order of benefit-cost ratio in Table 1.

It can be seen from Table 1 that there is a very wide range in the net benefit (NPV for each irrigation district. This is largely because of the high capital cost of improving the main systems of the large surface irrigation districts, (particularly Xihe, Siba and Donghe, in Yongchang County) coupled with reductions in irrigated areas which makes the cost per unit area is very high. There is a good return to the investments *within* these large irrigation districts, but these are only practicable once the main supply system has been improved. These figures highlight the need for further research into higher value cropping suited both to these areas and to the operational constraints of surface irrigation.

Lower altitude surface irrigation (such as Xiyang, Huanyang and Zamu), however, is more versatile and area reductions are not proposed and thus these schemes show a much higher benefit. Groundwater irrigation does not require any expensive distribution system, but it is already relatively efficient and thus generally shows a positive but small benefit.

Table 1: Economic ranking of irrigation improvements

Irrigation District	Area (ha)	NPV (Y x 1000)	B/C	EIRR
Xiying	21,937	157,545	2.12	23.8%
Qinghe (part)	6,113	8,308	1.90	21.7%
Huangyang/Dajing	15,099	77,451	1.88	21.5%
Zamu	20,225	104,103	1.66	19.4%
Gulang/Gulanghe	17,876	59,260	1.55	18.3%
Hongyashan	35,647	211,732	1.45	17.2%
Jinchuan	7,266	16,801	1.34	16.1%
Jinta	8,227	27,563	1.33	15.9%
Changning	1,527	982	1.18	14.2%
Yongchang	11,167	797	1.02	12.2%
Qingyuan	11,881	8	1.00	12.0%
Huanhe	2,654	-1,523	0.83	9.7%
Qinghe (part)	2,276	-1,579	0.82	9.6%
Jinyuan	8,187	-11,822	0.72	8.1%
Xihe	6,727	-44,348	0.61	6.5%
Siba	5,081	-35,709	0.58	5.9%
Donghe	7,092	-54,483	0.55	5.4%
Gufeng	1,960	-24,520	0.42	2.8%
Total		490,564	1.30	15.6%

Source: Shiyang River Basin IWRM Plan

The economic benefits in Minqin appear relatively good, but it should be noted that these are based on a large reduction in agricultural area, and the financial returns per household, rather than per unit area, also need to be considered in order to protect livelihoods. Any costs of mitigation measures to offset the impact of the area reductions should be incorporated into the analysis.

It can be seen that the surface irrigation districts in South-Western Jinchang Municipality show very poor economic returns – this is because they are at high altitude, suffer from limited irrigation supplies and have few cropping options. However they are socially important, and this must be offset against the low economic returns. It has been proposed that the

area irrigated should be reduced, thereby enabling greater transfers of water to downstream regions of Jinchuan District and Minqin County. MCDA can provide assistance in analysing and optimising these decisions.

6 Simplified Multi-criterion Analysis

The analysis in section 5 covers the economic benefits. This needs to be supported by analysis of other criteria, such as social or environmental benefits

More detailed information would be necessary to undertake a full MCDA for the strategic plan than is available at present. However, a simplified analysis has been done using two main criteria: social and economic.

The social criteria adopted here are aimed at ensuring that livelihoods should be protected by enabling farmers to continue with off-farm employment whilst benefiting from improved agriculture and that they should be protected against the impacts of irrigated area reduction.

Figure 2 shows the value tree developed for the simplified MCDA.

Scoring rules were set up for each of the Tier 2 criteria as follows:

- Economic criteria (Economic internal rate of return (EIRR))
 - EIRR > 12%: score 100
 - EIRR 7-12%: score 80
 - EIRR 0-7%: score 50
 - EIRR <0 %: score 0
- Social criteria 1: % off-farm employment/migration
 - % households with off-farm employment > 80%: score 100
 - % households with off-farm employment 50 - 80%: score 80
 - % households with off-farm employment < 50%: score 50
- Social criteria 2: % land area reduction
 - % reduction > 50%: score 100
 - % reduction 10-50%: score 75
 - % reduction < 10%: score 0

Figure 2: Value Tree for the simplified MCDA of surface water irrigation interventions

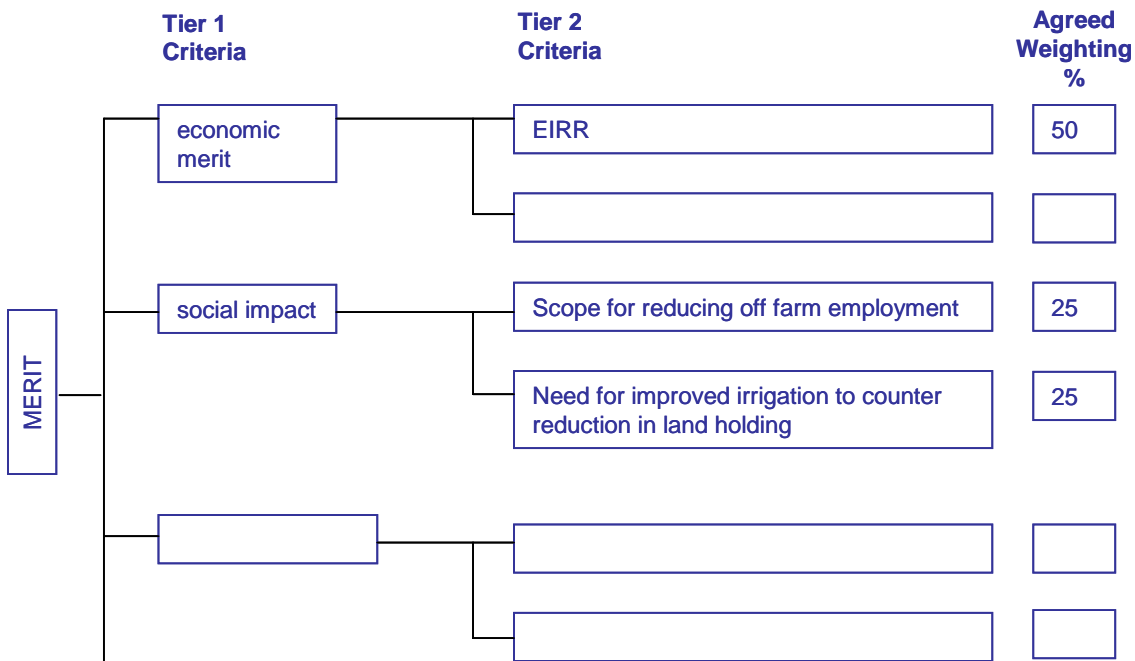


Figure 3 below (parts ‘a’ to ‘c’) shows these scoring rules graphically.

EIRR was used as the basis for the economic criterion in this case. This is a commonly used criterion, although it is preferable to use benefit / cost ratio as this reflects the relative benefits to the economy at the most appropriate discount rate. In this situation, however, the ranking is unchanged whether EIRR or BCR is used.

The rationale behind the first social criterion is that households with high levels of off-farm employment are likely to be relatively poor and yet need simplified reliable management so that they can continue with agriculture effectively.

The second social criterion was designed to take account of the fact that land areas are already small, thus

a large reduction is likely to affect poor households particularly seriously.

Figure 4 shows the record of the scoring decision for the first social criterion for the specific case of the Donghe Irrigation District. Such record sheets were prepared for each scheme and for all three criteria.

Table 2 shows the result of the scoring process and, after multiplication using the assumed weights, the **overall score** – the result of this simplified MCDA. Table 3 shows that the MCDA, applying equal weights to social and economic criteria, results in a very different order of priority. Donghe is in economic terms, one of the least favoured schemes but once social criteria are included, the importance of investment in this district becomes much higher.

Figure 3a-c: Scoring rules for the simplified MCDA of surface water irrigation interventions

Multi-criterion Decision Model

Scoring rule for:

ECONOMIC: EIRR

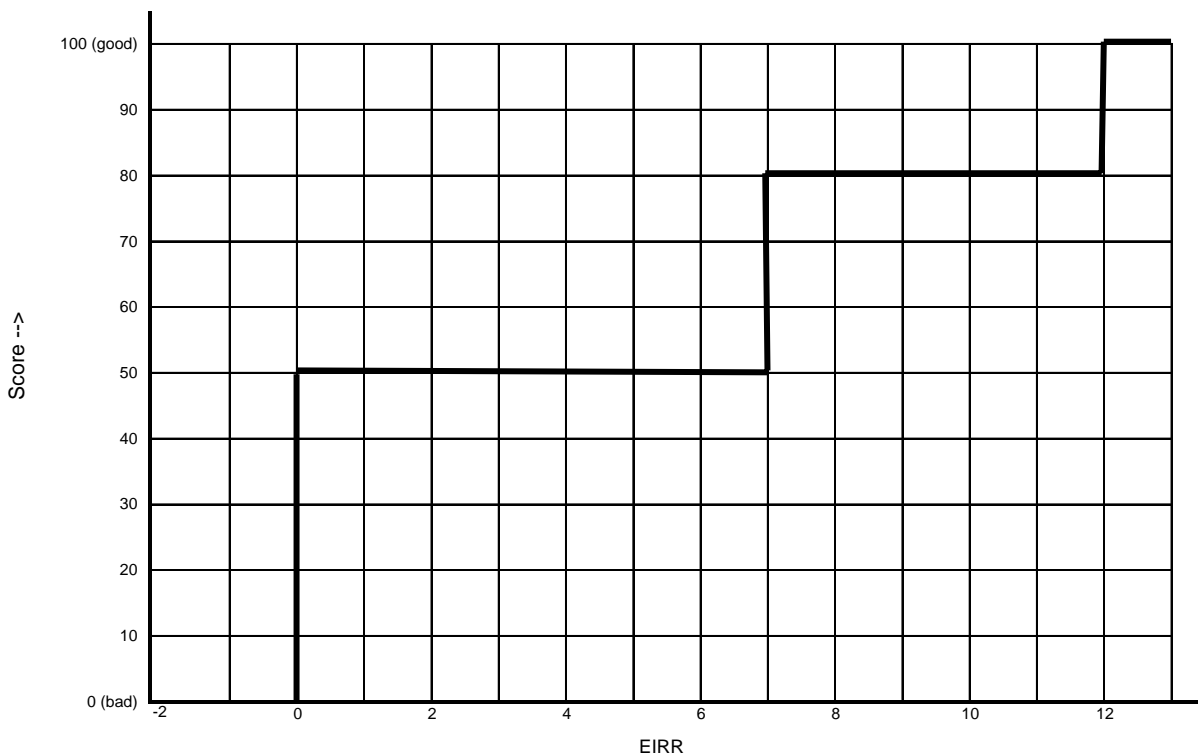
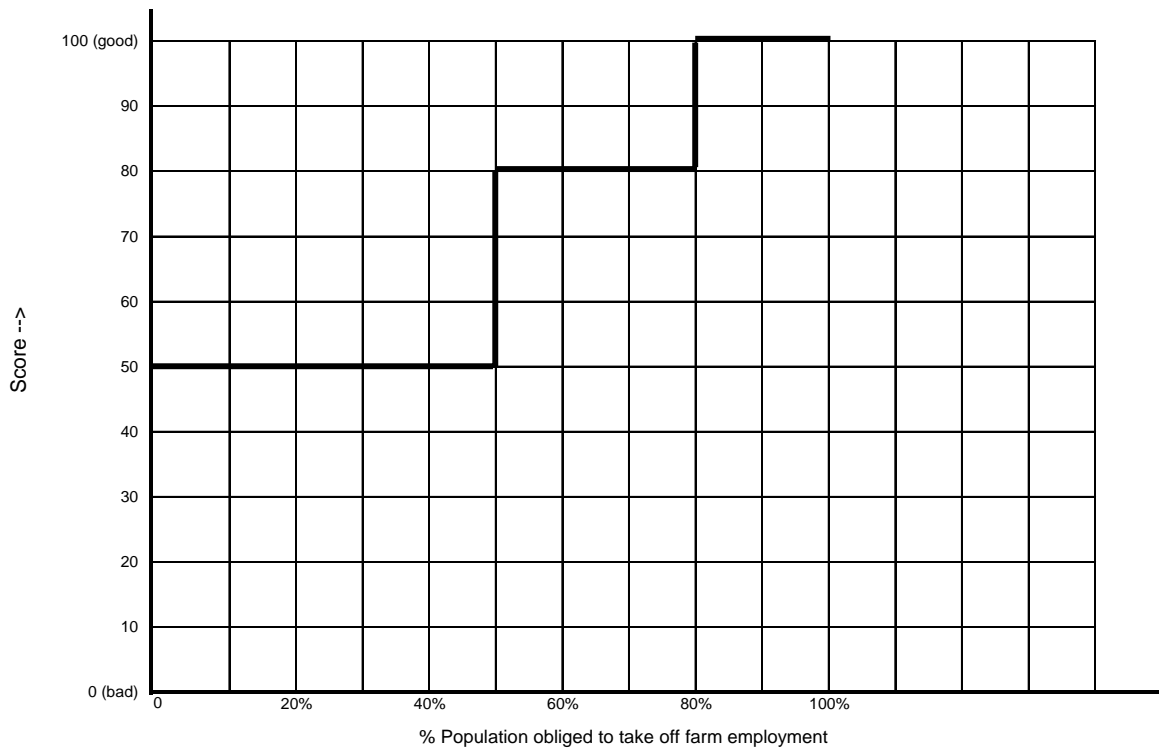


Figure 3a-c: Scoring rules for the simplified MCDA (continued)

Multi-criterion Decision Model

Scoring rule for:

SOCIAL: Scope for reducing off farm employment



Multi-criterion Decision Model

Scoring rule for:

SOCIAL: Need for improved irrigation to counter reduction in landholding

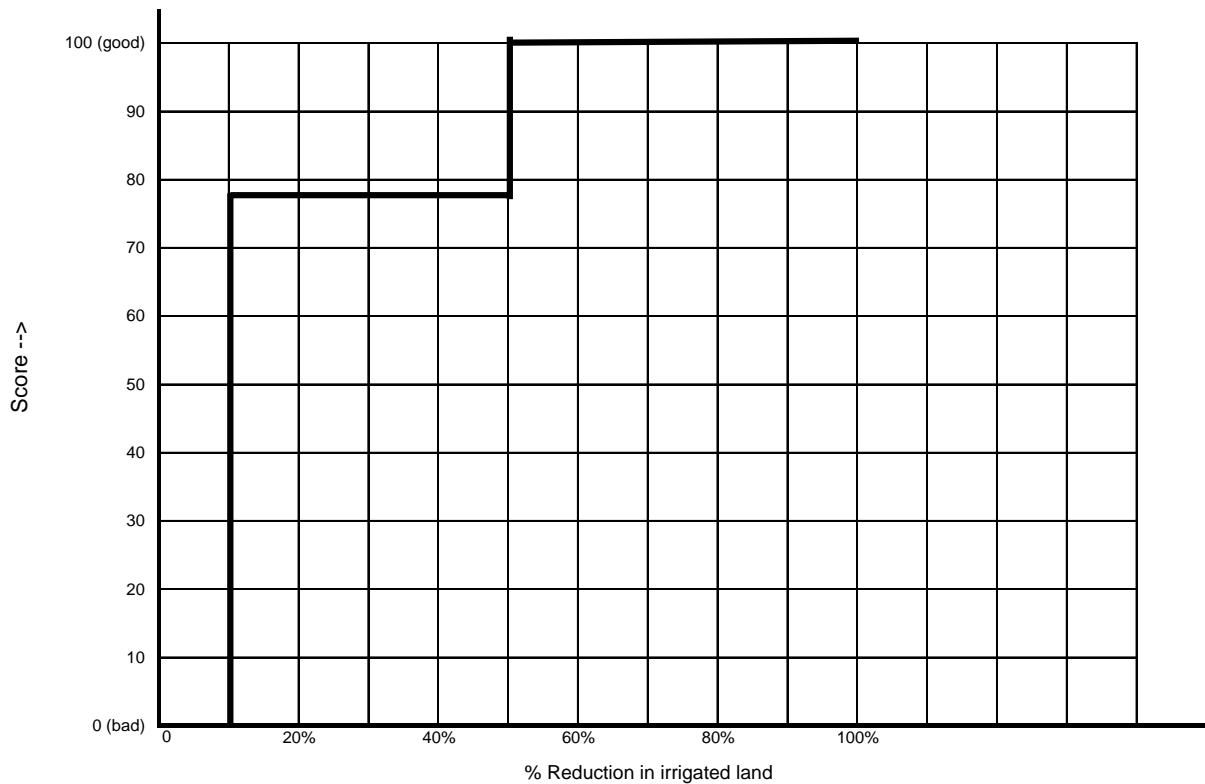


Figure 4: Record of scoring against the criterion ‘Scope for reducing off farm employment’

PROJECT: <u>Donghe Irrigation Scheme Rehabilitation</u>		
CRITERION (First Tier): <u>SOCIAL</u>		
CRITERION 1 (Second Tier): <u>Scope for reducing off farm employment</u>	SCORE: <table border="1" style="display: inline-table; vertical-align: middle;"><tr><td style="text-align: center;">100</td></tr></table> %	100
100		
COMMENTS: Donghe Scheme is at high altitude, suffers from limited irrigation supplies and has few cropping options. For this reason out migration and off farm employment are very high. If the rehabilitation goes ahead then reliability of water supplies should increase, irrigation management should be simplified and thus farm income should increase without disrupting off-farm employment opportunities. This will increase overall income.		
STUDY NEEDED? <table border="1" style="display: inline-table; vertical-align: middle;"><tr><td style="text-align: center;">N</td></tr></table> Y/N	N	DETAIL: A socio-economic baseline survey of sample villages has been carried out under WRDMAP so the benefits of the scheme can be evaluated.
N		

Table 2: Simplified MCDA Results

Irrigation District	Criterion			Overall score
	Economic	Social		
		Migration	Land reduction	
	<i>weight</i>	50%	25%	
Qinghe (part)	100	50	100	87.5
Changning	100	50	100	87.5
Qinghe (part)	80	80	100	85
Hongyashan	100	50	75	81.25
Jinchuan	100	50	75	81.25
Huanhe	80	80	75	78.75
Donghe	50	100	100	75
Xihe	50	100	100	75
Siba	50	80	100	70
Xiyiing	100	80	0	70
Qingyan	100	80	0	70
Yongchang	100	80	0	70
Jinyuan	80	100	0	65
Gulang/Gulanghe	100	50	0	62.5
Huangyang/Dajing	100	50	0	62.5
Jinta	100	50	0	62.5
Zamu	100	50	0	62.5
Gufeng	50	80	0	45

Source: Shiyang River Basin IWRM Plan

Table 3: Comparison of ranking by economic and multi-criterion methods

Ranked by BCR	Ranked by MCDA
Xiyiing	Qinghe (part)
Qinghe (part)	Changning
Huangyang/Dajing	Qinghe (part)
Zamu	Hongyashan
Gulang/Gulanghe	Jinchuan
Hongyashan	Huanhe
Jinchuan	Donghe
Jinta	Xihe
Changning	Siba
Yongchang	Xiyiing
Qingyuan	Qingyuan
Huanhe	Yongchang
Qinghe (part)	Jinyuan
Jinyuan	Gulang/Gulanghe
Xihe	Huangyang/Dajing
Siba	Jinta
Donghe	Zamu
Gufeng	Gufeng

Note Irrigation districts in bold are ranked higher by MCDA than by economic criteria alone

7 Recommendations to Take the MCDA Forward

This is just an example, and once appropriate data are collected, a more detailed and rigorous analysis can be undertaken.

Appropriate criteria and weights need to be developed and discussed with a range of stakeholders in order to reach a consensus on the conclusions.

Document Reference Sheet

Glossary:

B/C	The Benefit-Cost Ratio (B/C) is the ratio between the total discounted costs C and the total discounted benefits B (B/C) over the project lifetime
EIRR	The internal rate of return (IRR) is the discount rate at which the NPV is equal to zero and the B/C ratio is equal to one
MCDA, MCDM	Multi-criterion decision analysis, multi-criterion decision model
NPV	Net Present Value- the difference between total discounted costs C and the total discounted benefits B (C - B) over the project lifetime
WAB/WRD	Water Affairs Bureau/Water Resources Department
WUA	Water user association

Bibliography:

'Shiyang River Basin Strategic Plan', 2007, Shiyang River Basin Management Commission, MWR

Kang S et al, (2004) 'The impacts of human activities on the water-land environment of the Shiyang River Basin, an arid region in northwest China', Hydrological Sciences Journal 49(3) June 2004

'Shiyang River Basin – Comprehensive Plan, Draft Integrated Water Resources Management Plan (IWRM Plan)', October 2009, Shiyang River Basin Management Commission, MWR

SL201-97, 'Compiling Guideline on River Basin Planning', MWR

SL 72-94, 'Economic Assessment Criterion on Water Resources Infrastructure Project', MWR

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Advisory Note 2.8	Economics for IWRM Planning
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Advisory Note 7.1	Using a Multi-criterion Decision Analysis

Where to find more information on IWRM – recommended websites:

Ministry of Water Resources: www.mwr.gov.cn

Global Water Partnership: www.gwpforum.org

WRDMAP Project Website: www.wrdmap.com

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