Exploration and Investigation of WUR System and WUR Trading
Case study in Zhangye city, Middle Reaches of Heihe River Basin, Northwest of China

Ke Qian
March, 2009
Exploration and Investigation of WUR System and WUR Trading
Case study in Zhangye city, Middle Reaches of Heihe River Basin, Northwest of China

By

Ke Qian

Thesis submitted to the International Institute for Geo-information Science and Earth Observation in partial fulfilment of the requirements for the degree of Master of Science in Geo-information Science and Earth Observation, Specialisation: (fill in the name of the specialisation)

Thesis Assessment Board

Thesis Chair: Prof. Dr. Ir. J. A. Zevenbergen
Thesis examiner: Ir. M. C. Kees Bronsveld
                        Prof. Ma Zhiming
                        Prof. Qian Hui
Supervisor: Dr. Ir. L. G. J. (Luc) Boerboom
Second Supervisor: Dr. M. A. (Ali) Sharifi
Disclaimer

This document describes work undertaken as part of a programme of study at the International Institute for Geo-information Science and Earth Observation. All views and opinions expressed therein remain the sole responsibility of the author, and do not necessarily represent those of the institute.
Abstract

The main problem in Heihe River Basin is water shortage caused by the drastic population growth and the development of the irrigation area in the middle basin over the past decades. In 2001, the state of council promulgates the Master Plan of Heihe river Basin, which formulated the water right for the middle reaches and lower reaches of Heihe River quantitatively. Chinese government takes Zhangye City, which is located in the middle reaches of Heihe River Basin, as experimental site to implement the new water right system with tradable water quotas. The objective of this study is to explore and investigate the water use right (WUR) system and WUR trading, and their impacts in Zhangye city to make recommendations to improve the current situation. The survey fieldwork of doing interviews and distributing questionnaires in the study area got the first-hand information and data to help understand WUR system and WUR trading; moreover, the software of WEAP modelling quantified the water right, observed the impacts of WUR system to help make alternatives for the future implementation of WUR system and WUR trading in Zhangye city. In Zhangye city, the farmers, citizens, livestock, industrial bodies and other organizations are the subjects of water right; water use right can be defined as the subjects of WUR who possess the WUR to use, to trade, to transfer and to develop the water resource, which is split to the land right (some attached) and proprietary right of water resource. WUR was allocated through the amount of water resource level by level; water quotas provide the technical standard for the water utilization. The good combination of “water use right allocation” and “water quota management” in Zhangye city stimulates the water-saving and water-using adjusting in all sectors. Water right certification and water tickets make the water trading carry through smoothly, although the current water trading just happened between the farmers. Finally, it is advisable to raise water price to 0.084 Yuan/m³ currently and take the consideration to further raise water price to 0.12 Yuan/m³ step by step and year by year. Apart from this alternative, paying more attention to the ecosystem part is crucial and essential for Zhangye city which is not only contributing to the recovery of eco-environment but also maintain the social-economic stable in the study area.

Key words
water right, WUR system, WUR trading, WEAP, water ticket, Zhangye city
# Table of contents

Abstract

List of Figures

List of Tables

Acknowledgements

## 1. Introduction

1.1 Background

1.2 Research Problem

1.3 Research Objective and Research Questions

1.4 Research Methodology

1.5 The structure of the thesis

## 2. Literature Review

2.1 Water rights

2.1.1 What is “Water Right”?

2.1.2 Relationship between water right and land right

2.1.3 Water Rights System

2.2 Water Rights Allocation System

2.2.1 The principle of water right allocation

2.2.2 Priority of Water Rights in China

2.2.3 How to allocate water right?

2.3 Water Rights Trading System

2.3.1 Tradable Water Right

2.3.2 Tradable water right system

2.4 WEAP modeling Method

## 3. WUR system and WUR trading in Zhangye city

3.1 Study Area Description

3.1.1 Location

3.1.2 Geology, geography and soils

3.1.3 Climate

3.1.4 Social-economic situation

3.1.5 Hydrology construction situation

3.2 Fieldwork

3.2.1 Selection of the Organizations

3.2.2 Preparation of the Fieldwork

3.2.3 Data collection

3.2.4 Analysis and Summary
3.3 Current Situation of WUR System and WUR Trading in Zhangye city ..........36
3.3.1 Water Utilization......................................................................................36
3.3.2 Existing Water Utilization Problems ..........................................................37
3.3.3 Water Use Right System.............................................................................38
3.3.3.1 Who Owns Water Use Right?.................................................................38
3.3.3.2 Definition of Water Use Right in Zhangye city.................................40
3.3.3.3 Water Use Right Allocation.................................................................41
3.3.4 WUR Trading.............................................................................................46
3.3.4.1 Water Tickets.......................................................................................48
3.3.4.2 Rules of WUR Trading..................................................................49
3.3.5 Water Market ...........................................................................................51
3.3.6 Irrigation District (ID) and Water User Association (WUA)..................51
3.4 Experiences and Deficiencies.......................................................................52

4. Scenario analysis based on WEAP modeling ............................................57
4.1 Introduction of WEAP Modeling................................................................57
4.1.1 Features..................................................................................................58
4.1.2 Scenario Analysis..................................................................................59
4.2 WEAP Modeling in Study Area.................................................................59
4.2.1 Modelling Demand and Supply in WEAP..............................................60
4.2.2 Scenario Building..................................................................................68
4.2.3 Scenario analysis and Results ...............................................................72
4.3 Summary .....................................................................................................82

5. Discussion, Conclusions & Recommendations ...........................................85
5.1 Discussion ....................................................................................................85
5.2 Conclusion ...................................................................................................86
5.3 Limitation of the Research and Recommendations ................................87

Appendix A ......................................................................................................89
A.1 Interview for Director of Water Affair Department.....................................89
A.2 Interview for Irrigation District Leader......................................................90
A.3 Interview for Farmers ..............................................................................91
A.4 Interview for Academic Expert ...............................................................92
A.5 Questionnaire for Farmers .....................................................................93

Appendix B ....................................................................................................97
Appendix C ....................................................................................................101
Reference .......................................................................................................103
**List of figures**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1-1</td>
<td>Reason for the water-saving of Zhangye city</td>
<td>2</td>
</tr>
<tr>
<td>Figure 1-2</td>
<td>Research Framework</td>
<td>5</td>
</tr>
<tr>
<td>Figure 2-1</td>
<td>Definition of water right in different understanding levels (WET 2008)</td>
<td>10</td>
</tr>
<tr>
<td>Figure 2-2</td>
<td>Choosing a computer model (Droogers, 2006)</td>
<td>22</td>
</tr>
<tr>
<td>Figure 3-1</td>
<td>The map of Heihe River Basin and study area</td>
<td>28</td>
</tr>
<tr>
<td>Figure 3-2</td>
<td>Framework of Fieldwork</td>
<td>30</td>
</tr>
<tr>
<td>Figure 3-3</td>
<td>Fieldwork Methodology</td>
<td>31</td>
</tr>
<tr>
<td>Figure 3-4</td>
<td>Living standard influential degree by the WUR system and Trading</td>
<td>35</td>
</tr>
<tr>
<td>Figure 3-5</td>
<td>The ability of farmers to save water from the water resource distributed</td>
<td>35</td>
</tr>
<tr>
<td>Figure 3-6</td>
<td>The satisfied degree for the current WUR system</td>
<td>35</td>
</tr>
<tr>
<td>Figure 3-7</td>
<td>The adequate degree of the distributed water</td>
<td>36</td>
</tr>
<tr>
<td>Figure 3-8</td>
<td>The satisfied degree for the water measuring system</td>
<td>36</td>
</tr>
<tr>
<td>Figure 3-9</td>
<td>Water demands for all sectors in 2007 Source:(SYWR 2007)</td>
<td>37</td>
</tr>
<tr>
<td>Figure 3-10</td>
<td>The Subjects of the Water Use Right in Zhangye City</td>
<td>39</td>
</tr>
<tr>
<td>Figure 3-11</td>
<td>Understanding of Water Use Right in Zhangye City</td>
<td>40</td>
</tr>
<tr>
<td>Figure 3-12</td>
<td>Total water amount distributed level by level in Heihe River Basin</td>
<td>43</td>
</tr>
<tr>
<td>Figure 3-13</td>
<td>Activity Diagram for the WUR Allocation and WUR Certificate Issuing</td>
<td>46</td>
</tr>
<tr>
<td>Figure 3-14</td>
<td>Crop pattern adjustment from 2000 to 2002</td>
<td>47</td>
</tr>
<tr>
<td>Figure 3-15</td>
<td>One case of WUR trading with water tickets</td>
<td>48</td>
</tr>
<tr>
<td>Figure 3-16</td>
<td>Water Ticket Sample Source: (Chen, Zhang et al. 2005)</td>
<td>49</td>
</tr>
<tr>
<td>Figure 3-17</td>
<td>WUA Framework and Duties</td>
<td>52</td>
</tr>
<tr>
<td>Figure 4-1</td>
<td>Conceptual framework of WEAP</td>
<td>58</td>
</tr>
<tr>
<td>Figure 4-2</td>
<td>WEAP Schematic of the Liyuanhe ID</td>
<td>60</td>
</tr>
<tr>
<td>Figure 4-3</td>
<td>Annual activity level for the five demand sites</td>
<td>61</td>
</tr>
<tr>
<td>Figure 4-4</td>
<td>Annual activity level for Agriculture</td>
<td>62</td>
</tr>
<tr>
<td>Figure 4-5</td>
<td>Annual activity level for Domestic</td>
<td>62</td>
</tr>
<tr>
<td>Figure 4-6</td>
<td>Annual activity level for Livestock</td>
<td>62</td>
</tr>
<tr>
<td>Figure 4-7</td>
<td>Demand priority for Flow Requirement</td>
<td>63</td>
</tr>
<tr>
<td>Figure 4-8</td>
<td>Demand priority for demand sites</td>
<td>63</td>
</tr>
<tr>
<td>Figure 4-9</td>
<td>Water demand for the five demand sites during 2000-2015 in WEAP</td>
<td>64</td>
</tr>
<tr>
<td>Figure 4-10</td>
<td>Supply requirement in the five demand sites during 2000-2015 in WEAP</td>
<td>65</td>
</tr>
<tr>
<td>Figure 4-11</td>
<td>The Annual Available Groundwater Supply to all demand nodes</td>
<td>66</td>
</tr>
<tr>
<td>Figure 4-12</td>
<td>The various level of reservoir construction</td>
<td>67</td>
</tr>
<tr>
<td>Figure 4-13</td>
<td>The demand-side management savings in Water price raising scenario</td>
<td>69</td>
</tr>
<tr>
<td>Figure 4-14</td>
<td>Unmet demand in the demand sites during 2000-2015 in WEAP</td>
<td>69</td>
</tr>
<tr>
<td>Figure 4-15</td>
<td>The map of unmet demand of demand sites in 2001 in WEAP</td>
<td>70</td>
</tr>
<tr>
<td>Figure 4-16</td>
<td>Unmet demand of domestic compares reference with high population growth scenario</td>
<td>73</td>
</tr>
<tr>
<td>Figure 4-17</td>
<td>Supply requirement of the demand sites in the water price raising scenario</td>
<td>73</td>
</tr>
<tr>
<td>Figure 4-18</td>
<td>Unmet demand of demand sites in Water price raising scenario</td>
<td>74</td>
</tr>
</tbody>
</table>
Figure 4-19  Unmet demand of “Domestic” and “livestock” compare reference with priority changing 1 .................................................................................................................................................................................. 74

Figure 4-20  Unmet demand of Agriculture compare reference with priority changing 1 ................. 75

Figure 4-21  Unmet demand of Forest & Graze and Industry compare reference with priority changing 1 ........................................................................................................................................................................... 75

Figure 4-22  Unmet demand of “Forest & Graze” compares reference with priority changing 2......... 76

Figure 4-23  Unmet demand of other demand sites compares reference with priority changing 2....... 76

Figure 4-24  Coverage of the requirement met of Forest & Graze in WEAP........................................ 77

Figure 4-25  Unmet demand of Industry compares reference with priority changing 3 ................. 77

Figure 4-26  Unmet demand of “Forest & Graze” compares reference with priority changing 3 ......... 78

Figure 4-27  Unmet demand of other three demand sites compares reference with priority changing 3. 78

Figure 4-28  Unmet demand of “Agriculture” compares reference with priority changing 4 ............ 79

Figure 4-29  Unmet demand of “Domestic” and “Livestock” compares reference with priority changing 4 .................................................................................................................................................................... 79

Figure 4-30  Unmet demand of “Industry” compares reference with priority changing 5 ................. 80

Figure 4-31  Unmet demand of “Forest & Graze” compares reference with priority changing 5 ........ 80

Figure 4-32  Unmet demand of other three demand sites compares reference with priority changing 5. 81

Figure 4-33  Groundwater capacity of supply preference changing 1 in WEAP............................. 81

Figure 4-34  Groundwater capacity of supply preference changing 2 in WEAP............................. 82
List of tables

Table 1-1 Research Sub-objectives and Research Questions................................................................3
Table 2-1 The definition of water right from different angle........................................................................9
Table 2-2 Three Category of Definition of Water Right..................................................................................11
Table 2-3 The history of the water right system ..............................................................................................14
Table 2-4 The strengths and weaknesses of the WEAP model (Mathijssen 2007) ..........................................24
Table 3-1 Metrological Feature Indices in Zhangye city Source: (Liu, Zhang et al. 2008) .....................29
Table 3-2 Social-economic Development of Each County in Zhangye City in 2007 .................................29
Table 3-3 Chosen Organizations ..................................................................................................................31
Table 3-4 Interviews in Organizations ........................................................................................................33
Table 3-5 Response Rate of Questionnaire for the Farmers ........................................................................33
Table 3-6 Water Quotas in Each Sector in Zhangye City Source: WAZC (2003) ........................................42
Table 3-7 Format of Water Right Certificate (WAZC 2003) ........................................................................44
Table 4-1 Water use rate for each demand site .............................................................................................63
Table 4-2 Loss rate for each sector in demand water ....................................................................................64
Table 4-3 Supply preference of the river and groundwater for demand sites ..........................................65
Table 4-4 The supply data for Yinggezui reservoir .........................................................................................67
Table 4-5 Comparing actual observation and WEAP modelling for validity in supply requirement ........68
Table 4-6 Demand priorities assigned in Demand Priority changing 1 .......................................................70
Table 4-7 Demand priorities assigned in Demand Priority changing 2 .......................................................70
Table 4-8 Demand priorities assigned in Demand Priority changing 3 .......................................................71
Table 4-9 Demand priorities assigned in Demand Priority changing 4 .......................................................71
Table 4-10 Demand priorities assigned in Demand Priority changing 5 ....................................................71
Table 4-11 Supply preference assigned in Supply preference Changing 1 ...............................................72
Table 4-12 Supply preference assigned in Supply preference Changing 2 ...............................................72
Table 4-13 The results of the scenarios and the corresponding recommendations .....................................83
Acknowledgements

There is a kind of sweet that is pleasure after pain: there is a kind of love that you know but you can not stop; there is a kind of thanks that you can not express in words---

Although my thesis was completed in China, I will never forget my study life in the Netherlands and the people ever helped me without requiring return. The list of persons I need to thank seems endless and increasingly international that ever supported and encouraged me sincerely. Firstly, I would like to thank my supervisor Luc Boerboom for instructing me patiently and untiringly. I am very grateful for his invaluable comments for the structure and content of my thesis. Besides, I really appreciate him for the patience to give me bright directions to enlighten me. I would also like to thank my second supervisor Ali Sharifi for giving me effective guidance and heartfelt encouragement.

I have to show my great thanks to the people who truly helped me a lot during my fieldwork in China. They are my Chinese supervisor Lipeicheng who arranged everything well for me, which makes the fieldwork smooth and successful; Chen Jijun, section chief of water conservancy in Gansu Province; Geigui, Tianjunshen, Luan limin who are working in water authority of Zhangye city; Zhaojing and Zou hongyuan, researchers in water conservancy in Shaanxi Province; officers in Administration Department of Liyuanhe Irrigation District. And my special thanks to my schoolmate, Han caibo, who accompanied and assisted me from beginning to end during my fieldwork.

In addition, here are thanks to Doctor Tulahdar, Ir.M.C Kees Bronsveld, Javier Morales, Prof. Ma Zhiming and Prof. Qian Hui for giving me warm-hearted help.

I also want to express my sincere appreciation to my dear teacher Li Xia who taught me both scientific and life knowledge and skills that quite useful in my life. My dear ITC friends are so nice that enrich my life. They are Pei lingling, Qin changbo, Fei teng, Hao pu, Chen fangfang, Huang zhiling, Chen dandan, Guo zhidong, He nannan, Zhou liang, Zheng Miaomiao, Jing jing ,He qian, Yao xiaojun, Qiao liang, Hong jie, Wang xiaofen, Liu qi.

I would also like to give my thanks to my friend to Zhang tingting, Zhong weizheng, Zhang yiming, who gave sincere support to me.

I duly acknowledge my indebtedness to my dear sisters who share happiness and woe with me during the one and half year time. They are Zhu tianduowa, Lv yue, Wang fan.

Lastly, the most honest thanks will give to my beloved mother, father and my boyfriend for all the visible and invisible support and selfless dedication.

Ke Qian
Chapter 1

Introduction

1.1 Background
The main problem in Heihe River Basin is water shortage caused by the drastic population growth and the development of the irrigation area in the middle basin over the past decades. In 2005, the water shortage is 410 M m$^3$/a (Chen, Zhang et al. 2005). In 2010, according to the Master Plan of the Heihe River Basin (MWR 2004), the water shortage is expected to be 774 M m$^3$/a for the whole river basin. The middle river basin, which encompasses more than 90% of the total irrigated farmland and over 85% of the total population, consumes 78% of the total water demand. The main water user is agricultural irrigation, which accounts for above 80% of the total water consumption. Moreover, another problem is ecosystem degradation in the lower Basin. The intensive exploitation of the water resources in the middle reaches of the basin has lead to the severe deterioration of the water environment in the lower reaches, such as secondary salinization and desertification. In addition, the discharge in the lower basin of the river has decreased significantly and more than 30 tributaries as well as the terminal lakes have dried up until 2002.

In order to resolve these problems effectively, in 2001, the state council promulgates the Master Plan of the Heihe River Basin (MWR 2001). “When the water from the upstream discharge at Yinluoxia station reaches 1.58 billion m$^3$/a, Zhangye city located in the middle reaches of Heihe River Basin has to increase discharge of 0.225 billion m$^3$/a to the lower basin, which means 0.95 billion m$^3$/a, at Zhengyixia station, should be released to downstream.” The 0.63 (1.58 minus 0.95) billion m$^3$/a of residue water resource is the gross water right of Zhangye city. This leads to decrease abstraction of 0.48-0.58 billion m$^3$ within 3 years for Zhangye city in Heihe River (Ma and Han 2008). Hence, the government enforces Zhangye city to reduce the utilization of water resource, which leads to the subsequent water-saving measures: the implement of water right system with tradable water quotas. Figure 1-1 shows the reason for the necessary water-saving in Zhangye city.
In early 2002, the Ministry of Water Resource (MWR) of China initiates an experimental project of establishing water-saving society in middle reaches of Heihe River Basin—the first project of its kind in China. The experimental period is from 2002 to 2004. It aimed to establish a new water use right (WUR) system with tradable water quotas and to reallocate water resources reasonably and efficiently through market-based instruments. However, due to the legal, management, social and administrative barriers, WUR system was hard to implement effectively in Zhangye city and WUR trading was not popular, either (MWR, 2004).

1.2 Research Problem

On one hand, the Chinese government takes Zhangye City as experimental site to implement WUR system and WUR trading, which is supposed to resolve the water resource problems. At the same time, the government hopes Zhangye city explore a new road of social-economic harmonious development and hydro-construction applicable to the water resource bear capacity for the arid and semi-arid areas in the northwest of China (Li and Tian 2003). On the other hand, as the first experimental site, Zhangye city is just under the exploration phrase. There still have some problems during the implementation of WUR system and WUR trading, although there were some achievements of environmental restoration in the lower basin.
Until now, the construction of water-saving society (exploratory road) in Zhangye city has been experienced for six years. It is worthwhile to learn some experiences for the other water-shortage areas in northwest of China. Moreover, it is necessary to make recommendations for Zhangye City to improve the implementation of WUR system and WUR trading.

1.3 Research Objective and Research Questions

The overall objective is to explore and investigate the water use right (WUR) system and WUR trading, and their impacts in Zhangye city to make recommendations to improve the current situation. In order to reach the overall objective, the sub-objectives need to be pursued and the research questions connected to the objectives are shown in the below table: (Table 1-1)

Table 1-1 Research Sub-objectives and Research Questions

<table>
<thead>
<tr>
<th>Research sub-objectives</th>
<th>Research Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>• To describe water right and situation of water resource utilization in the middle reaches of Heihe River Basin</td>
<td>• Who are the subjects of the water right?</td>
</tr>
<tr>
<td></td>
<td>• What is water right in the middle reaches of Heihe River Basin?</td>
</tr>
<tr>
<td></td>
<td>• What is the situation of water resource utilization in Zhangye City?</td>
</tr>
<tr>
<td>• To analyze the current WUR system and current WUR trading in the middle of Heihe River Basin</td>
<td>• How the water use rights are allocated?</td>
</tr>
<tr>
<td></td>
<td>• How the water use right trading is doing?</td>
</tr>
<tr>
<td>• To make recommendations (alternatives) for the WUR system and WUR trading in the middle reaches of Heihe River Basin</td>
<td>• What kind of water right allocation is recommendatory for the study area in the near future?</td>
</tr>
<tr>
<td></td>
<td>• What will be the positive and negative consequences of the alternatives?</td>
</tr>
</tbody>
</table>

1.4 Research Methodology

The research methods can be categorized into four main sections:
- Literature review
- Reports and policy documents
- Interview and questionnaire
- WEAP modelling

(1) Literature Review

A review of the existing literature focus on the following topics:
- Water right
- Water trading
- Water market
- Water price
- Heihe River

(2) Reports and Policy Documents

Water right and water trading reports and policy documents about Heihe River Basin need to be collected and critically reviewed. Because the data from the documents and reports is reliable, it can be used directly. So, it is a wise way to extract the data from them for the purpose of my research.

(3) Interview and Questionnaire

The interview and questionnaires are aimed to elicit the perception of the stakeholders on how the current WUR system and WUR trading works and identify what changes are needed in order to improve the situation. The subjects interviewed will be institutional agencies, scientific experts, village leaders and farmers, etc. The Questionnaires will be designed for the farmers in Zhangye city, the middle reaches of Heihe River Basin, to get the information about WUR system and WUR trading.

(4) WEAP Modelling

In order to quantify the water right, observe the impacts of the WUR system and WUR trading and make recommendations for the future implementation of WUR system and WUR trading in the middle reaches of Heihe River Basin, the computer model of WEAP conforms to the application of these requirements. Water right in WEAP is represented by the form of supply preference, demand priority and the amount of water resource distributed. Through the changing of demand priority, supply preference, and other parameters, such as demand-side management savings (related to water price), there are some scenarios formulated accordingly. The WEAP model allows the simulation and analysis of various water right scenarios and scenarios of water users’ behaviour and reaction.

Scenarios are developed as analysis instrument to understand the impacts of WUR system and WUR trading in Heihe River Basin. The demand priority scenarios are based on how urgent the water users need the water resource. As Heihe River, reservoirs and groundwater are the main supply sources for the irrigation of farmland, environmental areas and other sectors, the scenarios will be built based on the changing of different supply preferences. Water users’ behaviour and reaction are based on the supply preference, the amount of water resource distributed and other factors, such as water price. The scenarios of the water user’s behaviour and reaction will be built based on the varied irrigation methods, varied water-demanding crops planting and varied water-saving technical innovation applied etc. After the discussion of the scenario results, it can be understand what impacts need to be taken more consideration, how the WUR system and WUR trading affect the water user’s behaviour, and how to improve the implementation of WUR system and WUR trading, which attempt can be taken as recommendation.
1.5 The structure of the thesis

The research is divided and presented as five chapters:

- **Chapter 1: Introduction**
  In this chapter, the background of the research, the problem definition, the research problem, the objectives, the research questions and the methodology used are addressed.

- **Chapter 2: Literature Review**
  This chapter presents an overview of the literature on the problems related to this research. There are five main aspects discussed here: water rights, water rights system, water rights allocation system, water rights trading and WEAP modelling method.

- **Chapter 3: Current Situation of WUR system and WUR Trading in Zhangye city, the Middle Reaches of Heihe River Basin**
  The analysis of this chapter is based on the investigation made in the fieldwork. The content includes two aspects, which are fieldwork methodology and analysis of WUR system and WUR trading in Zhangye city, the middle reaches of Heihe River Basin.
• **Chapter 4: Scenario analysis based on WEAP modelling**

This chapter is the different scenario analysis based on the WEAP modelling, to explore the impacts of the WUR system and WUR trading in the middle reaches of Heihe River Basin, and make alternatives for Heihe River Basin to improve current situation.

• **Chapter 5: Discussion, conclusion and recommendation**

The discussion and conclusion are made, and the limitation of this research is stated meanwhile the recommendations for the further research work are addressed in succession.
Chapter 2

Literature Review

“Water right” is a controversial concept in China, due to emphasis set on different respects by different subjects, which as a result, lead to different definitions of water rights. The clear definition of water right is the premise of the water right allocation and water right trading. In Zhangye city, it is necessary to make clear the definition of water right to understand deeply water right system and water right trading. The central government has already allocated water right for Zhangye city through the political regulation; hence, water right allocation system was employed to specify the water right for each sub-levels and water right trading was adopted to make water right transferable and also provide pre-condition for water market.

Water rights allocation is the allocation activities conducted by the State applied with administrative mechanism or marketable mechanism among the different regions or different water subjects that have water use right and abstract right. Water right trading is the transferable paying activity conducted by the equitable subjects in the water market, who own water use right and water abstraction right.

In this chapter, the literature review will give background knowledge of water right, water right system, water rights allocation system, water rights trading and WEAP modelling. Firstly, it will introduce the different definitions of water right in China and other countries. Secondly, the history of water right system will be elaborated. Thirdly, the principles of water right allocation, the methods of water right allocation and the priority of water right in China will be described. Fourthly, how the water right trading is doing is addressed. Last, the review of WEAP modelling is proposed to introduce the characteristics and the relationship with water right.

2.1 Water rights

As with any resource, when water is abundant, there is relatively little attention to rights. However, with increasing scarcity and competition for this vital resource in many places, there has been growing attention to water rights in the water resource management literature in recent years. However, just as water is a fluid and dynamic resource, flowing and seeping in many channels, so also water rights are fluid and dynamic, rarely a single, consistent system (Ruth Meinzen-Dick and Bakker 2001). Stronger water rights will apply even during periods of scarcity – dry seasons and drought years – while weaker rights may be denied when water is scarce (Ruth Meinzen-Dick and Bakker 2001). To understand water rights requires going beyond formal statutory law (which may or may not be followed), to look at the many bases for claiming water (Benda-Beckmann, Benda-Beckmann et al. 1996; Kolavalli 2001).
2.1.1 What is “Water Right”? 

Through long-term formation and development, water rights are defined in a different way by different countries. According to the definition made by Scott and Coustalin (1995), the so-called water right is defined as the right to enjoy or use water resources. Bryan Bruns (2004) points out water rights are socially recognized claims to water, which may be composed of a bundle of rights to access, consume, exclude, manage and transfer. A broad definition includes many institutions involved in allocating access and resolving conflicts. The government of Washington department of Ecology considers water right is a legal authorization to use a predefined quantity of public water for a designated purpose (Washington Department of Ecology 2005). In western part of U.S, water right is the legal right to capture and use water. It is based upon ① quantity; ② source; ③ priority date; ④ nature of use; ⑤ point of diversion, and ⑥ beneficial use (Water Bank 2005).

In China, water right is the property right of water resources. Water right means that organizations and individuals have the right to use surface water and groundwater resource owned by the nation or the collective in accordance with law, namely water resource usufruct (Wang, Dong et al. 2008).

In the theoretical domains, there are different viewing angles (jurisprudential circle, economic circle and water conservancy circle) to the definition of water right. In the actual practical domains, there is not consensus about water right. The table 2-1 shows the different angles to the definition of water right.

In the jurisprudential circle, Cao Mingde (2004) thinks water rights is the bundle of rights based on the proprietorship of water right, which including right of possession, the right of use, the right of earnings and the right of disposing. Water right is the real right for usufruct which is separated from the proprietary right. According to Pei Liping (2001), water right is the right of use or right of earnings followed by the stipulation of law or the regulation of contract for the non-owner of water resource, is not the proprietary right of surface or ground water resource. Huang Xisheng (2004) points out water right is just proprietary right. The right of possession, the right of use, the right of earnings and the right of disposing derive from proprietary right; they can not be considered as paratactic right to proprietary right.

In economic circles, Wang Yahua (2005) thinks there are two viewpoints on water right in China in the broad sense and in the limited sense, respectively. It refers to the generic term of water resources ownership and other related rights in a broad sense. Whereas in the limited sense, it is a complete set of water resources right system that is purposed to satisfy the needs of society, economy and environment, established on the basis of water resources natural conditions and ensured through legislation, and achieved through administrative mechanism and market mechanism.

In the circle of water conservancy, Wang Shucheng (2001), Minister of Ministry of Water Resources, pointed out that according to Water Law of P.R.C., the proprietary right of water resource belongs to state; therefore, water rights are right of possession and right of use. The natural person, legal person and other organizations can utilize and develop water resources.
Table 2-1 The definition of water right from different angle

<table>
<thead>
<tr>
<th>Angle of Viewpoint</th>
<th>Definition of water right</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Jurisprudential circle</strong></td>
<td>Water right is the bundle of rights based on the proprietors' right of water right, which includes the right of possession, the right of use, the right of earnings and the right of disposing. Water right is the real right for usufruct which is separated from the proprietors' right. (Cao)</td>
</tr>
<tr>
<td></td>
<td>Water right is the right of use or right of earnings followed by the stipulation of law or the regulation of contract for the non-owner of water resources, is not the proprietors' right of surface or ground water resources. (Pei 2001)</td>
</tr>
<tr>
<td></td>
<td>Water right is just proprietors' right. The right of possession, the right of use, the right of earnings and the right of disposing derive from proprietors' right, they can not be considered as patent rights to proprietors' right. (Huang 2004)</td>
</tr>
<tr>
<td></td>
<td>Water rights are right of proprietors, right of use and right of operation. (Jiang 2000)</td>
</tr>
<tr>
<td><strong>Economic circle</strong></td>
<td>In a broad sense, water rights are water resources ownership and other related rights. In the limited sense, it is a complete set of water resources right system that is purposed to satisfy the needs of society, economy and environment, established on the basis of water resources natural conditions and ensured through legislation, and achieved through administrative mechanism and market mechanism. (Wang 2005)</td>
</tr>
<tr>
<td><strong>Water conservancy</strong></td>
<td>Water rights are right of proprietors and right of use. The natural person, legal person and other organizations can utilize and develop water resources. (Wang 2001)</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td>Water right covers ownership, right of use and other related rights of water resources. It has classified as right to use water (right to use certain amount of water), right to discharge wastewater (right to use self-cleaning capacity of water), right to use water energy, right to occupy navigational water channel. (WET 2008)</td>
</tr>
<tr>
<td></td>
<td>Water right is a kind of right to monopolize water resources right of use for a long term, a result of division of water resources ownership and water resources right of use, right over the property of another established on the basis of state-owned or public belongings, and usufructuary right formed under restriction of laws and limited by some conditions. (WET 2008)</td>
</tr>
</tbody>
</table>
There are also some other statements about definition of water right. According to the report of Chinese WET (water entitlement and trading) project (2008), in the broadest sense, water right covers ownership, right of use and other related rights of water resource. According to different purposes, contents and targets of right of use, it is classified into many rights like right to use water (right to use certain amount of water), right to discharge wastewater (right to use self-cleaning capacity of water), right to use water energy, right to occupy navigational water channel. In the broad sense, water right means the aggregation of people’s rights related to water resource in case of scarcity of water resource (including one’s own or other people’s right of benefit or right of infringement). In the most fundamental sense, water right refers to right of possession, right of use, right of earnings and right of disposing of water resource. In the limited sense, water right just means right of use water resources. Defined in the most limited sense, water right refers to a kind of right to monopolize water resources (right of use) for a long term, a result of division of water resources ownership and water resources right of use, right over the property of another established on the basis of state-owned or public belongings, and usufructuary right (right to use and benefit from others’ property according to laws or legal contract) formed under restriction of laws and limited by some conditions (WET 2008).

![Definition of water right in different understanding levels (WET 2008)](image)

Moreover, there are three different viewpoints about definition of water right in China currently. The first one only refers to water resources right of use. The second one refers to right of proprietorship and right of use of water resource. The third one means set of rights consisting of ownership, right of possession, right of disposing, right of use of water resource and right of earnings. The table 2-2 shows the three category of definition of water right.

---

**Figure 2-1** Definition of water right in different understanding levels (WET 2008)
Table 2-2 Three Category of Definition of Water Right

<table>
<thead>
<tr>
<th>Viewpoint</th>
<th>Name of authors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>“One Right” theory</td>
<td>Zhouxia, Bochun, Zhangyue and Rengguang</td>
<td>Right of use</td>
</tr>
<tr>
<td>“Two rights” theory</td>
<td>Wang Shucheng, Guan Tao</td>
<td>Proprietary right, Right of use</td>
</tr>
<tr>
<td>“Multiple rights” theory</td>
<td>Jiang Wenlai, Ma Xiaqiang</td>
<td>Rights bundle: right of possession, right of use, right of earnings, right of disposing</td>
</tr>
</tbody>
</table>

(1) “One Right” theory

Zhouxia thinks “water rights” is water resource use right (Sheng and Cheng 2002). Bochun (2001) thinks “water rights” is the legal water use right which includes different rights and interests of water environmental protection and governance. Zhangyue and Rengguang points out water rights problem is the allocation problem of water use right (Liu 2003). All of these statements reflect the content of “One Right” theory.

(2) “Two rights” theory

These statements refer to ownership of water resource and usufruct. The Minister of Ministry of water resource, Wang Shucheng, considers water rights are ownership of water resource and usufruct; Guan Tao (2002) thinks water rights have two parts: ownership and usufruct real right.

(3) “Multiple rights” theory

Most of the scholars hold the statements of “multiple rights” theory. Multiple rights mean water rights are the rights bundle that is constituted of multiple rights. The statement of “multiple rights” theory is complicated and the range of rights definition is different. All in all, they think water rights include ownership of water resource, right of disposing and right of use. Jiang Wenlai (2000) thinks water rights are the aggregation of water resource rights under the water shortage conditions, they are ownership of water resource, water management right and water use right. Ma Xiaqiang (2002) thinks water rights are not just one right, they are the rights bundle; water rights are a series of rights which consist of ownerships, use right, amount allocation right, tradable right, transferable right. A starting point in dealing with this complexity of water rights is to go beyond simple concepts of “ownership”, to look at the bundle of rights various users and management entities might have. A single user rarely has full rights to control, use, and dispose of water. Rather, different stakeholders have the right to use water for a certain purpose, or subject to certain conditions.

Schlager & Ostrom (1992) propose a useful classification of these bundles of rights in a hierarchy ranging from limited, short-term rights to extensive, long-term rights to the benefit stream, as follows:
• **Access**: The rights to enter a defined physical property. This might apply to recreational water use (like swimming), where the main ‘use’ is simply to be in the water, but would generally apply only to non-consumptive, in-stream uses.

• **Withdrawal**: The rights to obtain the benefits from that property by taking out some of the flow. In water resources, in-stream uses versus withdrawal rights represent an important distinction.

• **Exclusion**: the rights to determine who will (and will not) have access to the resource.

• **Management**: the rights to regulate use patterns, thus transforming the resource and potentially altering the stream of benefits from that resource. Management rights also provide the ability to define access or withdrawal rights.

• **Alienation**: the rights to sell, lease, or bequest rights to the resource.

Access and withdrawal are considered use rights, while exclusion, management, and alienation are rights of control over the resource. “Ownership” is often conceived of as holding the full bundle of rights. With this hierarchy as a guide, it is possible to ask which types of water users are able to claim which types of rights, and what type of legal framework those rights (or claims) are based upon.

### 2.1.2 Relationship between water right and land right

The objects of water right are the surface water and groundwater within in the specific range, and the land is the carrier of the water resource; therefore, it is inevitable that there (do has) is connective relationship between water right and land right. There are two patterns of identification of rights of water resource. The first one is water resource privately owned which is connected to land ownership. The subject of proprietary right of water resource is private person. The second one is water resource publicly and independently owned. The subject of proprietary right of water resource is the state or the collective.

The first one is the traditional pattern of water resource allocation. In the European continental legal system (civil law system), in the German civil code, French civil code and English civil code, the independent proprietary right of water resource does not be stipulated clearly, while the proprietary right of water resource or unsfructory right is attached to the land right or the land utilization institution.

In the 552nd article of French corpus of civil law, “the land ownership includes the overground and underground ownership”. In the 704th article of Swiss corpus of civil law, “the fountain is the constituent part of the land…….. and groundwater has the same status as fountain.” (Pei 2001) These common laws do not stipulate the independent proprietary right of water resource, but emphasis on that the water use right can not be partitioned or be independent from land ownership or the right of possession to be transferred. At that time, during the agricultural economic period, the land is the source of wealth and repute. Even in the industrial period, the land ownership is still under the emphasis by the people. At that time, the value of water resource is just reflecting in the farmland irrigation, while the public benefit value of environment and ecosystem of water resource is far from being emphasized by the people. Another reason is that if the resource is sufficient for the people to share and access, there is no need to require the agreement of the government or other people. It will not become the property of
any body; while if the supply of the resource is limited, it will become the private or public property. (Pei 2001)

In the middle of 20 century, with the development of society, the multi-values of water resource emerge obviously. People became to realize that the water resource also has the huge eco-environment value and the functions between economic and eco-environment of water resource are dependent and affected each other. With the rapid development of economic and society, the conflict between supply and demand of water resource became serious; there is an urgent need for the legislation to be rectified and modified to resolve the water resource disputes. Besides the corpus of civil law, the “Water Law” is issued to make the water resource become the independent object. For example, in the “English water resource law” in 1963, it stipulates that the water resource belongs to the state; “water law” in Japan stipulates that the river is the public property; and the second article of “water resource law” in Taiwan province, China, stipulates that “the water resource is the natural resource, it will not affected by the accessing of land ownership. The private ownership system of the proprietary right of water resource changed to public ownership system in which the proprietary right of water resource is partitioned to land ownership. (Cui 2002)

Therefore, in the modern water resource system, water right and land right are the two independent rights. The possession of water right is not based on the firstly possession of land right; Owning the land right does not mean owning the water right, the water right can be just applied for it followed by the regulations and rules of legislation. Cui (2002) points out that the split of water right and land right does not reflect that impossibility of the disposing of them together. For example, “Water Possession Law” of Kansas state of America stipulates, “the immoveable property of water right is attached to or partitioned from land; the attached water right can be sold, leased, mortgaged, bequeathed and use other voluntary way to be transferred; the partitioned water right has no relationship with land right, land owners have to apply for the water right in addition; moreover, if water owners want to the occupy the adjacent land, they also need to apply for the land right followed by the law.”

2.1.3 Water Rights System

Before 1900s, there is no legal system stipulating water right. The regulations about water right belong to land right stipulations. There are two reasons: firstly, land right is more emphasis than water right in agricultural economic times, people thinks who owns the land equals owns water resource; secondly, there was enough water resource before 1900s; there was no need to establish exclusive water right institution. Everyone could get the water as what he/she want. Water resource was considered as “inexhaustible in supply and always available for use”. So, water right system is not necessary when it is abundant and freely available. However, after the 1900s, with the social and economic development, there are drastically increasing in using water resource, water shortage emerges and water crisis intensified continuously. Therefore, there are many water rights systems established by the legal and judicatory system in different countries in the world. The “riparian right system”, “prior appropriation right system”, “tradable water right system” and “public water right system” are be introduced as follows: ( see table 2-3)
## Table 2-3: The history of water right system

<table>
<thead>
<tr>
<th>Year-Points</th>
<th>Definition</th>
<th>Origin</th>
<th>China and China</th>
<th>Benefit to whole society</th>
<th>The market economy of water allocation and water right reform and efficiency improvement</th>
<th>A system of administrative water right</th>
<th>Tradable Water</th>
<th>Right System</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950+</td>
<td>Water usage</td>
<td>prefers to allocate water rights to the land use connected to the major grain areas.</td>
<td>More people have access to water.</td>
<td>Reverse the idea of land for water.</td>
<td>Government intervention, which is compatible with the market economy.</td>
<td>Public water right</td>
<td>Tradable Water</td>
<td>Right System</td>
</tr>
<tr>
<td>1960+</td>
<td>Water usage</td>
<td>Reverse the idea of land for water.</td>
<td>Water is a public right available</td>
<td>More people have access to water.</td>
<td>Government intervention, which is compatible with the market economy.</td>
<td>Public water right</td>
<td>Tradable Water</td>
<td>Right System</td>
</tr>
<tr>
<td>1978</td>
<td>Water usage</td>
<td>Rural蘇農民 (farmers)</td>
<td>The idea of land for water.</td>
<td>More people have access to water.</td>
<td>Government intervention, which is compatible with the market economy.</td>
<td>Public water right</td>
<td>Tradable Water</td>
<td>Right System</td>
</tr>
<tr>
<td>1980-1990</td>
<td>Water usage</td>
<td>Rural蘇農民 (farmers)</td>
<td>The idea of land for water.</td>
<td>More people have access to water.</td>
<td>Government intervention, which is compatible with the market economy.</td>
<td>Public water right</td>
<td>Tradable Water</td>
<td>Right System</td>
</tr>
<tr>
<td>1995</td>
<td>Water usage</td>
<td>Rural蘇農民 (farmers)</td>
<td>The idea of land for water.</td>
<td>More people have access to water.</td>
<td>Government intervention, which is compatible with the market economy.</td>
<td>Public water right</td>
<td>Tradable Water</td>
<td>Right System</td>
</tr>
</tbody>
</table>

*The table describes the evolution of water right systems in China, highlighting key points from 1950 onwards.*
(1) Origin of Water Right System: Riparian Right system

The origin of the water right system is “riparian right” system. “Riparian rights system” is a system of utilizing the water resource connected to the riparian land reasonably, while not affecting the water rights of other owners of the riparian land (Singh 1991). It is originated from the English “common law” and “code napoleon” in 1804 (Mather 1984), and then it developed in the eastern United States, which becomes one of the influential basic theory of water right in the world. So far, “riparian right” is still the basic theory of water affair law and water management policy in the Canada, Australia, England and states in the eastern United States (Huang 2005).

Under the riparian principle, all landowners whose property is adjacent to a body of water have the right to make reasonable use of it. These rights cannot be sold or transferred other than with the adjoining land, and water cannot be transferred out of the watershed. In the “riparian right” system, the exclusion of water rights is related to the land right. When the people owns the land right, that means he/she owns the water right; when he/she sold the land right, the water right is sold at the same time.

However, the exclusion of the water right leads to the waste of water. Because there is a large amount of land not connecting to the riparian river, the owners of the land cannot enjoy the water right. Especially, in the water stress areas, the riparian right hinders the social and economical development. The “riparian right” is just suitable for the area with the abundance water; in the semi-arid and arid water shortage areas, there are many problems of adopting this system (Chang 2001). Therefore, there is a need for a new system to substitute for “riparian right” system.

(2) Prior Appropriation Right System

“Prior appropriation right system” is a system of prior occupation of water resource. The core of the “prior appropriation right” is priority. There are three aspects in “prior appropriation right” system: ① first in time, first in right; ② beneficial use; the using of water should not impair other people’s benefits; ③ use it or lose it (RCWR 2001). In times of water shortage, the oldest water right is satisfied in full before junior water rights are satisfied. “Prior appropriation right” is originated from the western United States (Singh 1991); it is suitable for the water shortage areas.

At the beginning of the development, there was few people hold land adjacent to the water resource; most of the land adjacent to the body of water belongs to the States. In order to guarantee the productivity, the mining owners and farmers had to channel through the land that is belonged to the States. The court cannot follow the theory of riparian rights. As time passed, the courts began to adopt the principle of “first in time, first in right” to resolve the water conflicts, then it developed into “prior appropriation right” system. The validation of the “prior appropriation right” is the starting date of the channelling project. The people started channelling first; he/she owns the water right first. Although the finishing date of the channelling project is before the starting date, the water right of the first starting project is prior to water right of the first finishing one. In the water shortage period, the oldest water right is satisfied first; and whether the junior water object can be satisfied, which depends on whether there is still the residual water left from the fore one.
Compared to the “riparian rights”, the “prior appropriation right” is more flexible; it does not need to connect to the land adjacent to the body of water. However, the prior appropriation right is limited to the beneficial use; if the owners of the water right do not utilize the water within the legal limited time, the water right will be forfeited. Although the prior appropriation right system conquered the limitations of riparian right system and it can make best use of the water resource, there are still two drawbacks: 
①water right trading and transfer are limited; ②failing in effective use of water. (Huang 2005)

With the water resource unbalanced problem becoming more and more serious, people realize that the key point of the addressing water shortage is improving the using efficiency and allocation efficiency. It is necessary to construct a new water right system with incentives to improving efficiency, the tradable water rights system occurred.

(3)Tradable Water Right system: The Innovation of “Prior Appropriation Right” System

“Tradable water right system” is a system of transferring water right with paying to improve efficiency of water allocation and water utilization, which is compatible with the market economy (Huang 2005). Water resources can be transferred and allocated to the high-efficiency sectors. And the tradable water right is based on the right of amount of water allocation, not related to the land nor water resource priority. Tradable water rights emerge in the western America water shortage area first.

In the recent years, the tradable water rights system is becoming acceptable in general; more and more countries and regions have already adopted or been ready to adopt tradable water rights system. For instance, Chile and Mexico have implemented this system in 1973 and in 1992, respectively; the Middle East areas (water stress countries) are discussing and wanting to adopt this system (Shatanawi 1995).


“Public water right system” is a system of all the water resource in the public belongs to the whole society, which is originated from the Soviet water management theory and practice. China is carrying out the public water right system currently (Chang 2001). Article 3 of Chinese Water Law stipulates, “Water resources are owned by the State, that is, also owned by the whole people. The waters in ponds and reservoirs possessed by agricultural collective economic organizations are collectively owned.” That means all the water resource, including river, lake, reservoir, channel, groundwater and seawater in the national territory belong to the whole people.

In 1976, the second international conference about “Water law and water administrative” was hold in Venezuela, it promoted: “all the water resource is public, belongs to the whole society or in the charge of States, which should be clarified in the Water Law.” (Huang 2005) Under the international background, many countries including developed countries had modified and rectified into the new Water Law. In these laws, the rights of water resource represent the public ownership trends; water rights progress into the direction of modernization, that is, water resources develop into the object of the independent ownership, which is separated from the land resource; the water resource belongs to the States or the Royal (Pei 2003).
2.2 Water Rights Allocation System

Water rights allocation is the allocation activities conducted by the State applied with administrative mechanism or marketable mechanism among the different regions or different water subjects that have water use right and abstract right. Water rights allocation is a significant method to utilize water resource efficiently and realize optimal resource combination (Huang 2005). Huang (2005) also points out there are three characteristics of water rights allocation: the object of water rights allocation is natural water resource; one of the subject of water rights allocation must be the government administrative organization; the content of the water rights allocation are extracted rights and use rights of natural water resource.

2.2.1 The principle of water right allocation

Water right allocation is based on the principle of sustainability, promoting harmonious development of population, water resource, and environment, economic, which can provide reasonable water right allocation. According to Huang (2005), there are nine principles of water rights allocation:

- Satisfied domestic water use first, give attention to both productivity water use and eco-environment water use
- Promote social sustainable development
- Unify planning and macro-regulated allocation
- Total water amount control and water quota management, fix supply for demand
- Consider valley as a unit to work out water amount allocation plan
- Respect customary water rights
- First in apply for the congeneric water rights
- Combine gratuitous and compensatory transferring
- Limited time with granted water rights

2.2.2 Priority of Water Rights in China

The seventh article of Chinese “Water Law” stipulates, “For water resource, the State applies, in accordance with law, the system of licensing for water-taking and the of compensation for use of water, except for water of the ponds and reservoirs belonging to rural collectives that is used by such collectives and their members.” The 48th article stipulates, “Any unit or individual that extracts water and utilizes water resources directly from a river or lake or underground shall, should follow the regulations of the extracted permit system and compensation system for use of water resources and apply to the water resource administrative department or river basin authority for a water-taking license to acquire the right to take water, and pay water resource fees, except where only a small amount of water is extracted for domestic use or for drinking by poultry and livestock reared outdoors or in pens.” According to the above two articles, China has adopted the principle of “prior appropriation right” as the rules of water extraction and water right acquirement (Liu, Gao et al. 2002).

Moreover, the 21st article of Chinese “Water Law” stipulates, “Exploiting and utilizing water resource should satisfy domestic water use first, and then meet agricultural, industrial, eco-environmental and navigating water needs; in the arid and semi-arid regions, eco-environmental water resource should be considered.” Therefore, in China, the priority of water extraction is as follows: domestic water, agricultural water, industrial water, eco-environmental water, and navigating water, and in arid and
semi-arid areas, the eco-environmental water needs to be taken into account. According to Zhong (2003), the priority of eco-environmental water resource should be put in front of industrial water resource, in order to represent the eco-value and sustainable development. In China, the priority of new water right is follow by the application date, i.e. “first apply, first in right” (Liu, Gao et al. 2002).

The regulation of “water resource extracted permit operation measures” in China stipulates, “extracted water resource should guarantee the urban and rural domestic water using, taking agricultural, industrial, navigating and environment protection water resource into consideration. The provincial government can make the sequences of water extraction in accordance with the present situation in the designated areas.” So, the basic sequence of water rights allocation is: domestic water---production water---eco-environment water. Different regions have different situations; the sequence of water rights allocation should be work out by the local conditions in order to achieve the optimal water-using efficiency.

2.2.3 How to allocate water right?

According to Prof. Huang Xisheng, who is working in the Law department of Chongqin University China, there are three statements about how to set up water right allocation system: First, the “freely extracted” system. In this system, water resource is regard as the natural resource inexhaustible in supply and always available for use. The owners of the water resource extract the water as much as he/she want; Second, the “prior appropriation allocation system”. This system follows the principle of “first come, first serve”, it is also called as “waiting system”; the third one is the competitive system. During the water shortage period, the present water resource is allocated by the competitive means. There are two forms of competitive allocation system: administrative allocation and marketable allocation (Huang 2005).

Administrative allocation is the central or local governments allocate the water use right and extracted right according to the legal system among the different valleys or administrative areas, which is an important intervention means of water rights. Marketable allocation is the process of the water rights allocation using marketable value and competitive mechanism. For instance, the transfer of water rights among the subjects of water resource is one pattern of water rights marketable allocation.

There are two categories of water rights allocation in China: water rights administrative internal allocation and water rights administrative external allocation. Water rights administrative internal allocation is administrative organizations at all levels allocate the water resources among the different valleys and jurisdictional areas. It is a kind of macro-allocation. According to Chinese “Water Law”, the responsibilities and duties for administrative organizations are: ① the developing and planning departments of State council and the water resource departments of State council are in charge of macro-allocation for the whole country; ② Provinces, autonomous regions and municipalities directly under the central government are in charge of the valley water rights allocation in their own jurisdiction areas; ③ the local governments are in charge of the local water rights allocation in their own jurisdiction areas.
Water rights administrative external allocation is water resource departments at all levels transfer water extracted rights and water use right to water users. The concept of water rights allocation sequence is local water resource departments make the sequences for the different water rights in accordance with extent of urgency of the water using when the water shortage occur (Huang 2005).

Referring to the local water rights allocation, there are some water rights allocation methods according to the population, agricultural areas, GDP and mixed-criteria. Population criteria is an equal allocation for the people, it is the main criteria of domestic water allocation. In agricultural areas, the farmland areas become the main criteria of agricultural water allocation. Since GDP represents the economic level of local people, water-using amount is corresponding to economic level in general, it is more reasonable to adopt GDP criteria to allocate water rights. This is the main criteria of production areas. Because different regions, different sectors and different social group have different preferences in water rights allocation criteria, one method of giving weights to the three criteria to fit for the present condition is called mixed-criteria allocation. Huang (2005) indicates mixed-criteria allocation considers different water demand, maintains the water uses’ interests, it is a scientific and reasonable allocation method. Zhangning (2007) adds two more model for the water rights allocation: the status quo distribution model and the market distribution model. Status of water distribution model is to distribute water in recognition of the existing households water usage (one or the weighted average of recent years), and followed by the principle of "dating back ". The market based distribution model is allocating water rights through an open auction. Generally speaking, the auction price of this part of the allocation of water is higher than the price of water rights above. Water is generally purchased in industries with high marginal output, for a higher efficiency is expected. They usually pay higher property prices for this water.

2.3 Water Rights Trading System

Before the middle time of 20 century, the water rights trading had been emerged in America and Australia; however, the concept of tradable water right was really brought forward as the instrument of water resource allocation until the 1980’s under the requirement of sustainable utilization of water resource background. Until nowadays, Chile and Australia have already implemented the legislated tradable water right system (Pei 2007); other countries are under the exploration of tradable water right theoretically and practically. In 2000, the first practical case of water right trading happened in China: the drought-ridden city of Yiwu, in Zhejiang province, paid 200 million yuan (US$29 million) to its neighbouring city of Dongyang in exchange for 50 million m³ of drinking water every year in perpetuity. In 2006, the water authority in Beijing announced the city would pay 20 million yuan in “environmental compensation” to the neighbouring province of Hebei and purchase water from both Hebei and Shanxi province (Zhou Jigang, Peng Guangcan et al. 2008). In 2005, the document of “Comments of water right transferring of Chinese water authority” states that “water right transferring is the transferring of use right of water resource”; while there lacks systematic research of tradable water right in China (Pei 2007). Therefore, it is essential to make clear of the definition of tradable water right first.

2.3.1 Tradable Water Right

There are three representative statements about tradable water rights in the domain of “water right” (Pei 2007):
“Theory of allocation quantity”
According to Chang Yunkun (2001), the water right of marketable allocation should have the quality of exclusion and partition, the right of allocation quantity based on use right of water resource has both qualities. “Right of allocation quantity is the right of utilizing water resource of the subject of water resource within the limited quantity and limited period.” This is the main theory in economic circle of China (Huang 2005).

“Theory of use right of water resource and use extracted right”
According to Huang xisheng (2005), water right is the property right of water resource, and also the private right, so it can be transferred; the use right of water resource and the extracted right of water resource has the quality of transfer, they are tradable water right.

“Theory of quotas of tradable water right”
According to the Paul Holden (1996), “water right is the right of water quotas or extracted and accepted right. The current water right is right of water quotas; this right should be owned by the subject of water and then be transferred to other people.

According to Pei Liping (2007), “tradable water right is the legislated right of property to the water quotas for the non-owner of water resources which is including quota water right, allocation quantity right and operation right.” She points out the tradable water right is the property right which is possessed by the non-owners; it comes from proprietary right of water resource and separated from it also; it has the exclusion quality and transferable quality, has transferable value beside the actual utilizable value so it can be seen as the object of trading. Quota water right is the right to the specific water resource; allocation quantity right is the proportional water right consumed in the specific year; Operation right is the actual right of extracting water, utilizing water, discharging water, storage water and operating water.

2.3.2 Tradable water right system
According to Environment Agency of Washington, water rights trading is the transfer of licensable water rights from one party to another, for benefit (Environment Agency 2003). Water right trading is a policy instrument that can be used for both water quality and water quantity management. For water quality, the instrument is interesting primarily for eutrophication (discharge of nutrients) and temperature (discharge of cooling water). The instrument is less suitable for toxic and bio-accumulating substances. As for water quantity, possible applications are trading of water storage duties (a land owner is obliged to provide a specific water storage capacity, but he may also pay another land owner to do this instead), and trading of water use rights in the case of water shortages (Eco-consult Environmental Economics 2007).

According to the Environment Agency of England (Environment Agency 2003), Water rights trading is expected to:

- Provide an incentive for abstractors to invest in water efficiency measures to make surplus water available to trade;
- Allow potential abstractors in areas where water would not otherwise be available due to environmental objectives to access water resources currently licensed to other abstractors;
Enable licence holders to manage their water needs more flexibly in response to temporary changes, for example in relation to irrigation needs for different crops;

Allow licence holders to adjust the level of water rights they hold in response to any change in the reliability of their abstraction;

Enable licence holders seeking to retire, restructure or diversify to realize the value of their water rights whilst retaining their land or selling it separately.

According to MMA Sustainable Land Investments (2008), Water Rights Trading provides income through the sale of water rights. Water rights can be used to allow water withdrawals for agricultural or urban use, or to allow water to remain “in stream” for the benefit of aquatic species and ecosystems. Water Trading is a framework for managing transfers of water rights. Some water transactions are simply water commodity sales, while others produce management of water resources for the benefit of aquatic species and ecosystems. According to the Environment Agency of England (2003), the practical benefits that trading may bring include:

- Providing the opportunities for those wishing to compete with existing water suppliers to acquire potential sources of water.
- Enabling the allocation of water rights to be adapted to land use patterns and farming methods within an area. More flexible allocation should increase agricultural profitability where this depends on the availability of water; losses from crops should be reduced and trading will create the scope for farmers to switch crops where water availability or reliability was previously a constraint.
- A relatively regular potential supply of water rights for sale may develop in areas where changes to the economic characteristics of an area are taking place, for example, where industrial activities that need large volumes of water for cooling are declining. The opportunity to trade will provide greater incentives for rights to be made available rather than remaining allocated to land that is now used for a different purpose. This may accelerate the rate of change in the economic characteristics and structures of these areas and provide an incentive for particular users or industries to develop locally.
- Giving clear signals indicating the value of water through trading should encourage abstractors to improve levels of water efficiency. It may be possible to reduce the need for water efficiency conditions to be included in abstraction licences if trading assists the Agency in achieving more efficient use of water resources. However, this will require the trading market to give strong, clear signals on water efficiency.

However, there is not a legitimated regulation about water rights trading in China. The third article of the Chinese “Water Law” stipulates, “Water resources are owned by the State, i.e. water resource is owned by the whole people. The water in ponds and reservoirs possessed by agricultural collective economic organizations is collectively owned.” The proprietary right of water resource is forbidden to be transferred, while there are no regulations about the water use rights or the beneficial rights. Furthermore, the States has clarified the water-extracted rights, but according to the regulation of
“Water Resource Extracted Permit Operation Measures”, it forbids the trading of the water-extracted rights certificates. In China, there are the huge legal hurdles for water rights trading.

The proprietary right of water resource is the mother right of tradable water right; the tradable water right is partitioned to the proprietary right, which is the independent and exclusive property right. So, there exists the separation of proprietary right of the state and possession of water right. The water right trading refers to the transfer of the possession of water right. In China, there are two kinds of water rights trading markets: primary trading market and secondary trading market. Primary trading market is the granting market conducted by the State to natural water resource use-rights and extracted rights. It is also called “initial allocation market”. In the primary trading market, the State applies administrative permit, auction and bidding methods to ascertain the number, price and grantee for the water rights. In the primary trading market, the status of the two parties are not equal; the State monopolies the water resource and is the absolute owner of the water resource. The granter is in the dominant position; the grantee is in the subordinating position. The secondary trading market is the priced regulatory market, in which the status of two parties are equal; the water resource of use-rights and extracted rights allocated by the initial process are under the compensating transfer based on the agreements between the two traders (Cao 2004). It is also called secondary allocation market.

2.4 WEAP Modeling Method

According to Hetty Mathijssen (2007), in the report of “Evaluating the usefulness of the WEAP model”, computer simulation is an attempt to model a real-life situation so that it can be studied to see how the system works, while, in many cases, building a computer model is expensive and time-consuming, so the best alternative is finding a suitable existing computer model. When choosing a computer model it is important to take into account the scale of the problem and the computer model. Figure 2-2 shows the scale of the problem can be divided into two dimensions: the spatial scale and the physical detail.
From the figure 2-2, there are various computer models distributes over the graphic area. As the yellow ellipses distribute bias to the right-hand corner, it illustrates that the model with the high spatial scale can not has the high physical detail. WEAP model is useful for the water problems on the system scale with low physical detail, which is suitable to be chosen as the computer model to analyze the current river system with low physical detail.

2.4.1 Why WEAP?
WEAP model is developed by the Stockholm Environment Institute (SEI). It operates at a monthly step on the basic principle of water balance accounting. The user represents the system in terms of its various sources of supply (e.g. rivers, groundwater, and reservoirs), withdrawals, water demands, and ecosystem requirements. The Water Evaluation And Planning System (WEAP) is an object-oriented computer-modelling package designed for simulation of water resources systems and trade-off analysis. WEAP stores information characterizing a water system in a transparent and easy-to-use database.

The characterizations, simulation and usefulness of WEAP are summarized as follows:

- **Characterization**
Characterization includes water use patterns, equipment efficiency, losses, environmental flows, return flows, reuse rates, pollution loadings, and priorities for the demand side, and supply sources, hydrologic flow patterns, surface and groundwater storage, costs, and operation and allocation rules for the supply side. Rivers, canals, demand sites, water and wastewater treatment plants, conveyance and pumping facilities, local water sources, and surface and groundwater reservoirs comprising the water system are quickly drawn and linked in a graphical interface and can be organized to match real geographic locations with the help of imported GIS map layers. (Marion W. Jenkins, Guilherme F. Marques et al. 2005)

- **Simulation**
WEAP operates on the basic principle of a water balance and can be applied to municipal and agricultural systems, a single watershed or complex transboundary river basin systems. Moreover, WEAP can simulate a broad range of natural and engineered components of these systems. Simulation allows the prediction and evaluation of “what if” scenarios and water policies such as water conservation programs, demand projections, hydrologic changes, new infrastructure and changes in allocations and operations. (Marion W. Jenkins, Guilherme F. Marques et al. 2005)

- **Usefulness**
WEAP is a useful mode because it is easy to understand for decision makers and the clear interface makes the model easy to handle. WEAP has many options to create a scenario as long as the scale fits. The possibility to evaluate scenarios on high scale (temporal and spatial) is wide ranging and dependent on the users’ own creativity (Mathijssen 2007). The table 2-4 summarized by Hetty Mathijssen shows the strengths and weaknesses of the WEAP model.
Table 2-3 The strengths and weaknesses of the WEAP model (Mathijssen 2007)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial and temporal scale</td>
<td>Large scale overviews is what basin managers need. Large scale contributes to fast calculations.</td>
<td>User created variables gives limited possibility for smaller scale.</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Updating the data input is easy by ReadFromFile function. General knowledge can be incorporated, no need for measured data.</td>
<td>Accuracy of the model can be affected by incorporating general knowledge.</td>
</tr>
<tr>
<td>Relevance</td>
<td>Water Year Method is insufficient to model climate change. Management option should fit the scale of the model</td>
<td></td>
</tr>
<tr>
<td>Comprehensive scenarios</td>
<td>ReadFromFile function can model climate change. Many possibilities to add scenarios.</td>
<td></td>
</tr>
<tr>
<td>Validity</td>
<td>Adding streamflow gauges.</td>
<td>Numerical validation options are limited. Rainfall runoff from catchment areas cannot be modeled very detailed.</td>
</tr>
<tr>
<td>Understandability of the model</td>
<td>WEAP is working on the simple principle of a water balance.</td>
<td>The model suggests a simplicity that underestimates the expertise that you need to build a valid model.</td>
</tr>
<tr>
<td>Transparency Clearness of interface</td>
<td>Schematic view clearly shows the structure of the model. Many options to import and export data from/to other programs (MS excel, text file, vector, raster)</td>
<td>Many options to graphically show results make it difficult to find the correct view.</td>
</tr>
</tbody>
</table>

WEAP is promoting itself as a flexible model (SEI 2005) which is usually appreciated by decision makers. It is easy to change input data and it is easy to make different result graphs. This is important when showing results to decision makers. It can generate many scenarios in a short time. However, this does not mean that these scenarios are relevant. The flexibility of the model can therefore also be a pitfall, which always produces the relevant outputs together. WEAP being a high level planning and strategic analysis tool brings along a risk. The input data does not need to be measured which makes rough estimates sufficient for running the model. This also means that it is easy to play with the input and it is possible to get any result you like. Furthermore, the results in WEAP should be interpreted correctly. (Mathijssen 2007) WEAP is a tool to help in understanding the water allocation in the study area and shows what will happen if certain measures are taken.

However, there are two important limitations of WEAP: the Water Year Method and the Rainfall Runoff from catchments. Although WEAP is not aiming at modelling climate change and rainfall runoff processes these applications are incorporated in the model. When using these methods one should realize the calculations are very global and it is better to use other data (from other models) as an input to incorporate these processes (Mathijssen 2007).

2.4.2 Relationship between WEAP and Water Rights

Water rights in WEAP are represented by the form of demand priority; supply preference and the amount of water resource distributed. The demand priority is the urgency of the demand sites need the water resource for utilization and development, which is also endowed with the principles of equity, fairness and efficiency. The demand priority is represented by the digit (The lower digit indicates the higher priority). The supply preference is to be assigned the digit (The lower digit, the higher degree of
preference) to indicate the preference of the supply source of meeting the demand sites. The amount of the water resource distributed represented in WEAP is by the form of “annual activity level”, “annual water use rate”, “loss rate”, “reuse rate” and “demand-side management savings” to be calculated to “annual demand water” and “supply requirement”, which is can be analyzed to observe the impacts of different scenarios. These “water rights” in WEAP are integrated to be functioned and analyzed to generate the scenarios and explore the impacts, finally make the recommendations to improve the current situation.
Chapter 3

WUR system and WUR trading in Zhangye city, the middle reaches of Heihe River Basin

As mentioned in the chapter 1, the main objective is to explore and investigate the WUR system, WUR trading and their impacts in the middle reaches of Heihe River Basin. This chapter will introduce the current physical situation of study area, and through the fieldwork to get the first-hand information about the WUR system and WUR trading, which can be analyzed and summarized as good experiences and deficiencies for the other parts of semi-arid and arid areas in northwest of China. The impacts of WUR system and WUR trading will be discussed in the chapter 4. In addition, there are seven research questions have been addressed.

- Who owns water use right in Zhangye City?
- What is the definition of water use right in Zhangye City?
- What is the situation of water resource utilization in Zhangye City?
- How the water use rights are allocated?
- How the water use right trading is doing?
- What are the experiences can be learned for other areas in northwest of China?
- What are the problems of WUR system and WUR trading?

3.1 Study Area Description

This section will describe the physical situation regarding to the location, geography, climate, social-economic situation and hydrology construction situation of Zhangye city.

3.1.1 Location

The Heihe River, the second longest inland river in China, originates from the Qilian Mountains that lies mainly in the Qinhai province, which are steep mountains whose attitude is among 3000m-5000m. Due to the cold climate and the sufficient precipitation, the runoff generated from this part is the source of the surface water and groundwater. The river does not flow to the sea but ends in two terminal lakes of the Ejina oases in the desert, namely, West Juyan Lake and East Juyan Lake, which are located in the western part of the Inner Mongolia Plateau. The study area is Zhangye City in Gansu province, which is located somewhere midstream of the Heihe River and is also the middle part of Hexi corridor. The middle stream of Heihe River is between the Yingluoxia station and Zhengyixia station, which is 185 km long, and the area is 25,600 km².
3.1.2 Geology, geography and soils
Since Zhangye city is located in the flat plain; the topography is fairly smooth, with loamy soil, abundance of sunshine. The altitude of the city is high (among 1300 to 1700 meters). Under the plain, there is rich deposit of groundwater.

3.1.3 Climate
The climate of the Zhangye City is relative dry, which belongs to continental climate. In winter, the climate is dry, cold and there is rare snow weather; in spring, there is strong wind and heavy sand, the rainfall is little; during summer period, the weather is cool and rainfall is concentrated. The average annual temperature is 7.3°C, the lowest temperature is -28.7°C, the highest temperature is 39.8°C. The average annual precipitation (1971-2000) is 140 mm, the biggest annual precipitation is 214.3 mm (1983), the smallest annual precipitation is 69.5 mm (1962), the changing range is between 47%-64%. The annual open water evaporation in the Zhangye city is 2002.5 mm (1971-2000). The drought index is 15; it is one of the driest zones in the world. The main climate features are shown in table 3-1.
3.1.4 Social-economic situation

According to the Statistics Department of Ministry of Water Resource in Gansu Province (WRSY 2007), the Zhangye city is 42,000 km$^2$ in size and governs six counties, Ganzhou, Shandan, Minle, Gaotai, Linze, and Sunan.. The city currently has a population of 1.28 million (90% of population in the Heihe River basin), including a rural population of 988,600 and an urban population of 291,400. In 2007, the population density is 30 person/km$^2$ (Liu, Zhang et al. 2008); the GDP is 14.66 billion Yuan. Since Zhangye City is a grain-producing base established by the Central Government of China in the 1950s, it is a traditional irrigation agricultural economic area, which is dependent on irrigation, and the farmland area is 233,040 ha; the effective irrigation area and forestland-grassland irrigation area are 199730 ha and 333100 ha, respectively. According to Statistic Yearbook of Gansu Agriculture(2004), the ratio of agriculture, forestry, stockbreeding and fishery is 78.72:2.24:18.79:0.26. The farmland area, population and GDP account for 95%, 91% and 89% respectively, in the whole Heihe River Basin.

During the near 10 years, it provides the 35% of the commercial food just occupying 5% of farmland in Gansu Province. Cereal crops, such as wheat and corn, are dominant. Cereals, accounted for 76.5% of all cropland in 1995. In recent years, with changes in agricultural policy in China, farmers can choose crops. Some cash crops, such as alfalfa and vegetables have been planted in increasing areas. In 2003, cereal crops accounted for 51% of planted area (SBZC 2003). Hence, water-intensive crops (such as wheat and corn) are still popular and the water supply is not sufficient.

### Table 3-2 Social-economic Development of Each County in Zhangye City in 2007

<table>
<thead>
<tr>
<th>Region</th>
<th>Population (10000)</th>
<th>Farmland Area (10000 Mu)</th>
<th>GDP (M Yuan)</th>
<th>Grain Crop Production (ton)</th>
<th>Cotton Production (ton)</th>
<th>Oil plants Production (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ganzhou</td>
<td>50.03</td>
<td>70.37</td>
<td>6663.26</td>
<td>323153</td>
<td>13</td>
<td>6022</td>
</tr>
<tr>
<td>Sunan</td>
<td>3.62</td>
<td>6.21</td>
<td>713.54</td>
<td>8317</td>
<td>123</td>
<td>124</td>
</tr>
<tr>
<td>Minle</td>
<td>23.69</td>
<td>92.81</td>
<td>1658.42</td>
<td>226076</td>
<td>--</td>
<td>26723</td>
</tr>
<tr>
<td>Linze</td>
<td>14.76</td>
<td>28.36</td>
<td>1836.3</td>
<td>135930</td>
<td>937</td>
<td>57</td>
</tr>
<tr>
<td>Gaotai</td>
<td>15.91</td>
<td>33.05</td>
<td>1827.59</td>
<td>79092</td>
<td>7280</td>
<td>894</td>
</tr>
<tr>
<td>Shandan</td>
<td>19.54</td>
<td>59.71</td>
<td>2004.58</td>
<td>157337</td>
<td>--</td>
<td>7352</td>
</tr>
<tr>
<td>Zhangye</td>
<td>127.55</td>
<td>331.51</td>
<td>14663.71</td>
<td>968805</td>
<td>8353</td>
<td>55931</td>
</tr>
</tbody>
</table>

Note: 1 ha =15 Mu

### 3.1.5 Hydrology construction situation

Until 2007, there are 23 irrigation districts with the farmland area of above 667 ha, including eight large-scale irrigation districts. There are 43 middle-sized and small-sized reservoirs and 35 pool
embankments with the total water capacity of 0.2 billion m$^3$; It has constructed 893 main and branch canals with the total length of 4415 km. Moreover, there are 19 small-scale hydro-stations and 5007 wells.

### 3.2 Fieldwork

According to the research objective and methodologies in Chapter 1, a fieldwork is conducted in China. The motive of the fieldwork refers to collect information to analyze the current situation of WUR system and WUR trading in Zhangye city, the middle reaches of Heihe River Basin and get the raw data for the WEAP needed to evaluate and make recommendations (describe in the Chapter 4). The framework of fieldwork is shown in figure 3-2 as below.

**Figure 3-2 Framework of Fieldwork**

The methodology of fieldwork is show in figure 3-3, which includes the four steps: the selection of organization, preparation for the fieldwork, data collection and data analysis.
### 3.2.1 Selection of the Organizations

In order to enhance the understanding of WUR system and WUR trading in Zhangye city and also get the raw data of WEAP needed, the organizations that are in charge of this field were searched on the internet, and three organizations were chosen as the further study of fieldwork.

- **The Chosen Organizations**

After serious considering the duties, functions and locations of these relevant organizations, the Gansu Province Water Conservancy Department, Water Affair Bureau of Zhangye City, and Administrative Bureau of Liyuanhe Irrigation District were chosen as the destination of fieldwork. Table 3-3 shows the chosen organizations of the fieldwork.

#### Table 3-3 Chosen Organizations

<table>
<thead>
<tr>
<th>Name of the Organizations</th>
<th>Location</th>
<th>website</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gansu Province Water Conservancy Department</td>
<td>Lanzhou city, Gansu Province</td>
<td><a href="http://www.gssl.gov.cn/">www.gssl.gov.cn/</a></td>
</tr>
<tr>
<td>Water Affair Bureau of Zhangye City</td>
<td>Zhangye city, Gansu Province</td>
<td><a href="http://swj.zhangye.gov.cn/">http://swj.zhangye.gov.cn/</a></td>
</tr>
<tr>
<td>Administrative Bureau of Liyuanhe Irrigation District</td>
<td>Zhangye city, Gansu Province</td>
<td>---</td>
</tr>
</tbody>
</table>
3.2.2 Preparation of the Fieldwork

- Define the methodology of fieldwork
  A lot of information and data about WUR system and WUR trading in middle reaches of Heihe River Basin can be collected through literature review, however, the mostly materials we got just described the “be-used—to” situation, not the “current” situation. Hence, it is quite necessary to adopt directed observation, interview and questionnaire as research methods to understand the current situation. And the reliable secondary data, such as water resource yearbooks, government reports and files, is needed to obtain as well. The designed interview questions and questionnaire were attached in the Appendix A.

- Define participants
  As mentioned previously, the raw data WEAP needed and current information about WUR system and WUR trading must be collected to support the research. In Gansu Province Water Conservancy Department, a director of water resource department was interviewed. In Gansu Research Institute of Water Conservancy, an expert of water resource management was interviewed. In the Water Affair Bureau of Zhangye City, the director of the water-saving office and one WUR researcher were interviewed. In the Administrative Bureau of Liyuanhe Irrigation District, the director was interviewed. Moreover, there were 60 questionnaires designed for the farmers lived in Liyuanhe Irrigation District, Linze County.

3.2.3 Data collection

As discussed in the methodology of fieldwork, there are four methods employed for the data collection. They are directed observation, interview, questionnaire and documents. In the following paragraphs, the details of how these methods work and what data has been collected through each of them are described.

By Interview

The interviews in China were carried out for one week in two cities (Lanzhou and Zhangye). Most of the interviews were arranged in advance by telephone, while a few additional interviews were arranged during the fieldwork. As the semi-structured interview is flexible, allowing new questions to be brought up during the interview as a result of what the interviewee says, this kind of interview was adopted for the most of the interviews. In order to keep friendly and easy conversation, the unstructured interviews were employed for the farmers, although a few questions had been formulated in advance. All the interviews were lasting within sixty minutes with around 10-15 questions. For the questions of status of WUR system and WUR trading, some questions were enhanced by another two or three question to get more specific answers. The information and data collected from the interviews were recorded in paper format and digitized subsequently. Table 3-4 shows the interviews that were done during the fieldwork in China.
EXPLORATION AND INVESTIGATION OF WUR SYSTEM AND WUR TRADING: CASE STUDY IN ZHANGYE CITY, THE MIDDLE REACHES OF HEIHE RIVER BASIN, NORTHWEST OF CHINA

Table 3-4 Interviews in Organizations

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Organization</th>
<th>Date</th>
<th>Acquired Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr. Yuanhong Li</td>
<td>GRIWC¹</td>
<td>18, Nov</td>
<td>The good experiences and problems of WUR system and WUR trading in Zhangye city</td>
</tr>
<tr>
<td>Mr. Liming Luan</td>
<td>WABZC²</td>
<td>19, Nov</td>
<td>The background of WUR system and WUR trading in Zhangye city</td>
</tr>
<tr>
<td>Mr. Gui Ge</td>
<td>WABZC²</td>
<td>20, Nov</td>
<td>Current situation of WUR system and WUR trading in Zhangye city</td>
</tr>
<tr>
<td>Mr. Zhu</td>
<td>ABLID³</td>
<td>21, Nov</td>
<td>Current situation of WUR system and WUR trading in Liyuanhe ID</td>
</tr>
</tbody>
</table>

1. Gansu Research Institute for Water Conservancy  
2. Water Affair Bureau of Zhangye City  
3. Administrative Bureau of Liyuanhe Irrigation District

By Questionnaire

As farmers are the main water users in Zhangye city, the questionnaire is designed for them. The aim of questionnaire is to elicit the perceptions and impacts of the current WUR system and WUR trading and to identify what changes are needed in order to improve the situation. To be specific, the social-economic situations such as annual income, water utilization situation such as water fees, and attitudes to the WUR system and WUR trading were the main content in the questionnaire. The questionnaire was designed in open-ended questions and close-ended questions. With the help of the Administrative Bureau of Liyuanhe Irrigation District, 60 pieces of questionnaire were sent to the farmers in three different small towns. In each small town, the leader of the village gathered 20 farmers together to complete the questionnaire. The overall response rate attained 95%. (See Table 3-5)

Table 3-5 Response Rate of Questionnaire for the Farmers

<table>
<thead>
<tr>
<th>Name of Small Town</th>
<th>Number of Questionnaire Distributed</th>
<th>Number of Questionnaire Collected</th>
<th>Rate of the Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xinhua</td>
<td>20</td>
<td>18</td>
<td>90%</td>
</tr>
<tr>
<td>Nijiaying</td>
<td>20</td>
<td>20</td>
<td>100%</td>
</tr>
<tr>
<td>Xiaotun</td>
<td>20</td>
<td>19</td>
<td>95%</td>
</tr>
<tr>
<td>In total</td>
<td>60</td>
<td>57</td>
<td>95%</td>
</tr>
</tbody>
</table>

The farmers’ perceptions of current situation are direct and reliable, which can be taken as the first data source to understand the WUR system and WUR trading in Zhangye city.
By Directed Observation

As for this study, it is fortunate to see how the measuring system and monitoring system of water resource are working, what the water tickets and WUR certificate look like, how the current physical situation of the study area.

By Documents

During the fieldwork, the documents in digital and paper format were collected. They are “Yearbooks (2000-2007) of Gansu province water resource and hydropower”, “Yearbooks (2005-2007) of water resource (water supply and water demand) in Zhangye City”, “Copy files related to the WUR system and WUR trading in Liyuanhe ID”, “Digitized files about construction of water-saving society in Zhangye city” and “Digitized data of water utilization in Zhangye city and Liyuanhe ID”.

3.2.4 Analysis and Summary

After getting the data and information from the fieldwork, it is necessary to analyze and summarize the collected data to understand more about the research work for the prediction for the future. The analysis and summary of the current situation of WUR system and WUR trading is addressed in the following.

Interview Findings:

• The farmers, citizens, livestock and industrial bodies are the subject of water use right. The farmers are the dominating subjects of water resources in Zhangye city.

• Water Use Right in Zhangye city is the subjects of WUR who possess the water use right to use, to develop, to transfer and to trade certain amount of water.

• There are two indicator systems for WUR allocation: total amount control system and water quota system. Total amount control system: to distribute the water resources level by level; Water quota system: to establish water quota for unit of a product in each sector in Zhangye city.

• WUR Certificate and Water Tickets are the two symbols of WUR in Zhangye city.

• There are Regulations and Rule of WUR trading in Zhangye city, although WUR trading in Zhangye city is not popular.

• Water User Association (WUA) is the non-governmental organization that is constituted of the farmers themselves.

Questionnaire Findings: (57 respondents)

• 9% of farmers think their living standard is influenced by the WUR system; 94% thinks not influenced

• 22.6% of farmers think they can save water; while 77.4% think they can not

• 74% of farmers are satisfied with the current WUR system; 13% are basically satisfied; 13% are not satisfied.

• 91% of farmers think the WUR (amount of water resource) distributed to them is adequate; 6% think the water distributed to them is not enough; 3% think the water distributed to them is much more.

• 33% of farmers are not satisfied with the water measuring system currently; 67% are satisfied.

These findings are shown in the following figures graphically:
Influenced (54 in 57)  Not-Influenced (3 in 57)

Figure 3-4  Living standard influential degree by the WUR system and Trading

Can Save (44 in 57)  Can not save (13 in 57)

Figure 3-5  The ability of farmers to save water from the water resource distributed

not-satisfied (8 in 57)  basically satisfied (7 in 57)  satisfied (42 in 57)

Figure 3-6  The satisfied degree for the current WUR system
3.3 Current Situation of WUR System and WUR Trading in Zhangye city

This section will describe the WUR system and WUR trading in the following aspects: the current situation of water utilization, the subjects of water right and the specific definition of water right in Zhangye city, WUR allocation system including “total amount control system” and “water quota system”, WUR trading and water market in Zhangye city.

3.3.1 Water Utilization

As Zhangye city is the one of the biggest grain base in China, and above 2/3 of the population is living by the farming, agriculture irrigation is the biggest consumer of water resource in Zhangye city, which accounts for above 80% of water utilization. How to transfer the water resource from the agriculture to
other sectors to utilize water more efficiently and create more value for the society is the focal point of the water reallocation of the new WUR system. The figure 3-9 illustrates the percentage of water demand for each sector in 2007.

![Figure 3-9 Water demands for all sectors in 2007](image)

**Figure 3-9 Water demands for all sectors in 2007  Source:(SYWR 2007)**

The water utilization in agricultural, industrial and domestic sectors in 2007 is described as follows:

- **Agricultural Water Use**

  The available irrigation area is 242,100 ha, including 207,250 ha of farmland and 31,640 ha of forestland and grassland. The agriculture water utilization is 2.10 billion m$^3$. (SYWR 2007)

- **Industrial Water Use**

  In Zhangye City, the industrial part mainly constitutes the machinery, chemical, hydrological, architectural and paper-producing sectors. In 2007, the industrial water use is 69 million m$^3$; the water consumption is 460 m$^3$ per ten thousands Yuan. The reuse rate is 45%; the annual wastewater amount is 14 million m$^3$. (SYWR 2007)

- **Domestic Water Use**

  In 2007, the urban domestic water use quota is 113 L/ (person·d), which has increased 33 L/ (person·d) compared to 2003. The municipality water consumption accounts for 42% of the urban water consumption, which is 18 million m$^3$. The rural domestics water consumption index, large livestock water consumption quota and little livestock water consumption quota are 60 L/(person · d), 45 L/(piece · d) and 32 L/(piece · d), respectively (WSO 2004). The livestock water consumption in 2007 is 25 million m$^3$. The urban domestic water consumption and rural domestic water consumption is 20 million m$^3$ and 15 million m$^3$, respectively (SYWR 2007).

### 3.3.2 Existing Water Utilization Problems

The “Heihe River Allocation Bill” stipulates that “until 2003, the water resources coming from the upper stream of the Heihe River Basin reaches 1.58 billion m$^3$, Zhangye City, which is located in the middle stream, should guarantees the water amount of 0.95 billion m$^3$ flow to the down stream of Heihe
river. That means Zhangye City has to decrease the drawing water amount of 0.58 billion m$^3$, which is the 23% of local water utilization for the whole city. For the current irrigated farmland, the average volume of water available is 9985 m$^3$/ha. That volume might be sufficient to produce most crops in other regions but not in Zhangye City. The water use efficiency is low; the water pollution problem is serious; and there lacks incentives for water conservation.

- **Low Water Use Efficiency**

  Compared to advanced level of 70%-90%, water use efficiency in agriculture is fairly low, which is between 50%-55%. Most of the water projects and irrigation systems were built in the 50s and the 60s by local government. The traditional earthed canals suffer serious seepage loss, which is 48 – 62% of the total water transferred (Chen, Zhang et al. 2005). Some water must be delivered through a long open canal in the desert, leading to a loss of the water due to evaporation and seepage (Xu.P 2002). Farmers continue to plant water-intensive crops and use inefficient irrigation methods, such as flood and furrow irrigation. According to MWR (2004), only 50% of farmland in the middle reaches that used up almost all the water of Heihe River is well irrigated and much arable land has been abandoned due to water shortage.

- **Lack Incentive for Water Conservation**

  The water authorities and farmers do not have incentive to conserve water. Since the larger the irrigated areas are, the more revenue the water authorities can collect, water authorities are not motivated to reduce water supply. On the other hand, the farmers worried about the government would reduce the water quotas to invest to other sectors if they saved water, which made farmers maintain the doctrine of “use it or lose it”.

- **Water Pollution**

  Increasing water pollution has been observed in the region due to agricultural and industrial activities, increasing population and urbanization. Large amounts of domestic and industrial waste are directly discharged into the river. This pollution causes the river quality of the middle basin to exceed the national standards for the Class III surface water. (Class I, II and III: human being can have direct contact with it and it can serve as raw water for drinking water; Class IV: limited for industrial use and amusement use except swimming; Class V: only for irrigation).

### 3.3.3 Water Use Right System

This sub-section summarized three aspects involved in the subjects of water use right in Zhangye city, the specific definition of water right in Zhangye city and the new allocation system for water use right in Zhangye city as follows:

#### 3.3.3.1 Who Owns Water Use Right?

Article 3 of Chinese Water Law stipulates, “Water resources are owned by the State, that is, owned by the whole people. The waters in ponds and reservoirs possessed by agricultural collective economic organizations are collectively owned.” Therefore, this research about water right will not involve with proprietary right of water resource, the focus will be on the right of use and other related rights, such as right of possession, right of earnings and right of disposing.
Water use right is utilizing water resources to do fishery and vegetation breeding, navigation, hydropower producing and water entertainment, etc (Huang 2005). Water resource has the split property as land resource; the ownership and utilization right of water resource are split. Water resource ownership is exercised by the State Council on behalf of the state, while the State Council is not the true water user. Article 4 of Chinese Water Law stipulates, “The State shall encourage and support various undertakings to develop and utilize water resources.” Therefore, the citizens, legal bodies or the other organizations can be granted with paying to obtain use right of water resource, then become the subject of the water resource.

In Zhangye city, the water demand bodies are agriculture, industry, urban and rural households, livestock and ecosystem. The farmers, citizens, livestock, industrial bodies and other organizations are the subjects of water use right. The farmers not only use water resource to maintain the everyday life, but also to irrigate the farmland, forest and graze (Administrative bureau of Irrigation District arrange the irrigations for the forest and graze every year for the farmers). As the previous section mentioned the irrigation sectors accounts for above 80% of the total water demand. The farmers are the dominating subjects of water resources in Zhangye city. The urban citizens are also the subject of water resource in Zhangye city. The industrial bodies and other organizations that are developing and utilizing water resources are the subjects of water use right as well in Zhangye city. The figure 3-10 illustrates the subjects of water use right in Zhangye city.

Note: The bigger the circle, the more the WUR the subject holds

Figure 3-10  The Subjects of the Water Use Right in Zhangye City
3.3.3.2 Definition of Water Use Right in Zhangye city

Water use right is right to use water, that is, the right to use certain amount of water (MMA 2008). In Zhangye city, the water users use water resource according to the amount of water resource distributed. The amount of water distributed is the initial water right, which has been quantified and weakened juristically. Here, the initial water right is the water use right. The subject of the water use right can utilize water to irrigate farmland, to irrigate forest and graze, to manufacture the products, to develop the water resources, to feed to livestock, to drink, etc. According to vice minister of Water Resource “Jing zhengshu” (2001), Water-use rights, which used to be solely owned by the State, are allowed to be sold and purchased. In Zhangye city, for the farmers, Water Use Right can be sold or purchased by other farmers, which are constrained in the agricultural and ecosystem field. They cannot utilize the water to do profitable business in order to ensure the food security. For the urban citizens, they just can use and drink water. The industrial bodies and other organizations (the volume of abstraction water above 2000 m$^3$), such as waterworks and hydroelectricity plant, should apply for the “water abstraction permit” first before utilizing water. They just can develop or use the water resource within the application water amount.

All in all, Water Use Right in Zhangye city can be defined as the subjects of WUR who possess WUR to use, to trade, to transfer and to develop the water resource, which is split to the land right (some attached) and proprietary right of water resource; water use right is subordinate to proprietary right of water resource, which is granted by the state to the subject of water resource so as to get the secondary ownership of water resource, then can exert the attributes of water right (possession right, use right, disposing right and earning right). The real ownership of the water use right still belongs to the state and agricultural collective economic organizations. The figure 3-11 shows the understanding of the Water Use Right in Zhangye city.

![Figure 3-11 Understanding of Water Use Right in Zhangye City](image)

The water right in Zhangye city has the double properties with land right. Basically, the water right is connecting to the land right, representing in that if the owner of the farmland rent or sell the farmland to other people, the renter or buyer has the right to require the water right distributed on the farmland. That means, the water right could be transferred with the land right together. They have certain connective relationship. On the other hand, except for the irrigation land, the water right is independent from the land right. Owning the land right doesn’t mean owning water right; there is a need to apply for the water right and land right respectively when the water is utilized in industrial and domestic sectors.
If the water users want to develop or utilize water, they have to apply for the “water abstraction permit” then become the secondary owner of water resource. Referring to the Graze & Forest land, the proprietary right belongs to the State; it is not allowed to be rent or sold, there are no secondary owners of water right for Graze & Forest land.

### 3.3.3.3 Water Use Right Allocation

In the Heihe River, when the water discharge to Yinluoxia station reaches 1580 Mm$^3$/a, 950 Mm$^3$/a should be released to downstream according to the Master Plan of the Heihe River Basin (MWR, 2001), which has determined the water rights of the middle reaches and the lower reaches, respectively. The Zhangye city in the middle reaches may issue a secondary water use right detailing allocation to each department, each unit irrigation district, each Water User Association (WUA) or each village and finally each farmer. As such, each farmer and water user group, as well as WUAs, has proportional water right to access a certain amount of water for any given season.

There are two indicator systems for WUR allocation: “total amount control system” and “water quota system”. Total amount control system is to distribute the water resources level by level; the water quota system is to establish water quota for unit of a product in each sector in Zhangye city.

Since agriculture irrigation is the biggest water consumer in Zhangye city, water use right (WUR) allocation for the agriculture is the key factor in Heihe River Basin. The checking and ratifying WUR areas is an important step during the WUR allocation.

- **Check and Ratify WUR Areas for Water Users**

Checking and ratifying the WUR area is the premise of making clear water use right. In the rural area, the household contract responsibility system has been implemented for nearly 30 years, that is, the farmland area has been ratified for nearly 30 years. Until now, there has been experienced a series of changing of farmland area, such as the land development, agricultural regulation of division into district, etc. They have affected the confirmation of irrigation area. Considering the developing right and land use right for the farmers, they should declare the initial WUR area themselves to the water resource authority. The declaring items are including the contract land area, private plot area, wasteland area, crop patterns, population and the number of livestock. Then, the water resource authority arranges to check and ratify through field investigation, and build tables and book of the initial WUR area for the water users. At last, the results will be publicized. The land use certificate is the basis of the initial WUR area confirmation, which makes the initial WUR area confirmation accurately and reliably.

The irrigation area after the process of declaring, checking and ratifying is called initial WUR area. According to Li and Tian (2003), the WUR area is the initial WUR area not the effective irrigation area, which reflects the rights and responsibilities of the holder of WUR. Followed by the history surveying custom, the unit of WUR area is still Mu (1 Mu=0.067 ha).

- **Distribute Water Resource Level by Level**

“Total amount control system” is under the macroscopical sense. It distributes the water resource level by level From the river basin, province level to prefecture level and county level, from the town level,
village level to water user association level and ends to water user level, the water use right has been quantized levelly. Figure 3-10 shows the total water amount distributed level by level in Heihe River Basin. Each level has been distributed by the limited amount of water resources. Each water user should use water resource according to the amount of water resource distributed. According to Lixi and Tian (2003), all the farmers in the irrigation districts had been involved in the discussion of the plan of water allocation. The water allocation plan of lower level has been examined and verified by the higher level of water authority. There still is some water saving for the uncertain factors, such as annual variation of water resource, the changing demand of the water users.

The water resource distribution obeys the following principles: maintain the stabilization of society, ascertain the food security and leave space for the development. That means it would meet the domestic water use and eco-system water use first, which can secure the stabilization of society and food production, and make the water be allocated to the high-efficiency using field, which can ensure the economic development.

- **Analyze and Confirm Water Quota**

After ratifying the initial WUR area, water quota for unit of a product is an important factor. The confirmation of water quota is a complicated process, considering not only the history water-use situation but also the current water-use situation, and the difference between the different sectors should be taken into account as well. Furthermore, there are issued “agricultural water quota in Zhangye city (2003-2010)”, “industrial water quota in Zhangye city (2003-2010)”, “domestic water quota in Zhangye city (2003-2010)”, which provide the technological standards for water quotas in each sectors. Table 3-6 is showing some water quotas in each sector in Zhangye city.

<table>
<thead>
<tr>
<th>Agriculture Irrigation (m³/Mu)</th>
<th>Industry (m³/t)</th>
<th>Ecosystem (m³/Mu)</th>
<th>Domestic water use (L/perso • d) (L/piece • d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat 350</td>
<td>Metallurgy 90</td>
<td>Farmland shelter forest 160-260</td>
<td>Urban citizen 80</td>
</tr>
<tr>
<td>Maize 410</td>
<td>Chemical engineering 350</td>
<td>Windbreak&amp; sand-fixation forest 160-260</td>
<td>Rural citizen 60</td>
</tr>
<tr>
<td>Vegetable 540</td>
<td>Paper making 420</td>
<td>Urban grass 1300</td>
<td>Big livestock 45</td>
</tr>
<tr>
<td>Graze 260</td>
<td>Textile 140</td>
<td></td>
<td>Small livestock: Pig 30 Sheep 10</td>
</tr>
<tr>
<td>Oil Plants 240</td>
<td>Building material 250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fruit Tree 290</td>
<td>Food 250</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forestry 350</td>
<td>Machinery 180</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: 1 Mu=0.0667 ha
Figure 3-12  Total water amount distributed level by level in Heihe River Basin
**Water Right Certificate Issuing**

Water right certificate is an effective certificate of enjoying water use right for the water users. The water right certificates are issued according to the “Chinese Water Law” and “Plan of water resource amount distributed in each ID”. The water resource authority of county level distributes the water right certificates to the water users. Until 2006, there are 286,600 WUR certificates issued and distributed to the farmers, which account for 82% of the total farmer families (ZYWAB 2006). On the Water right certificate, the effective irrigated area is specified and classified into several categories. According to the measured irrigated areas and quotas, the total water requirement for the individual farmer can also be specified on the WUR certificate, which are including population, number of livestock, the amount of water supply (surface water resource, groundwater resource, fountain water resource), and the amount of water demand (agriculture, ecosystem, domestic water and industry). The period of validity of WUR certificate is 5 years temporarily (Li and Tian 2003). Table 3-7 is the format of water right certificate.

**Table 3-7  Format of Water Right Certificate (WAZC 2003)**

<table>
<thead>
<tr>
<th>Name of Holder</th>
<th>Name of WUA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of Water Supply Engineering</td>
<td>Surface Water Engineering</td>
</tr>
<tr>
<td></td>
<td>Fountain water Engineering</td>
</tr>
<tr>
<td></td>
<td>Groundwater Engineering</td>
</tr>
<tr>
<td>Household Population</td>
<td></td>
</tr>
<tr>
<td>Number of Livestock</td>
<td></td>
</tr>
<tr>
<td>Type of Water Supply</td>
<td>Surface Water m³/year</td>
</tr>
<tr>
<td></td>
<td>Fountain water m³/year</td>
</tr>
<tr>
<td></td>
<td>Groundwater m³/year</td>
</tr>
<tr>
<td></td>
<td>Total Amount m³/year</td>
</tr>
<tr>
<td>Agricultural Water Demand</td>
<td>WUR Area Mu</td>
</tr>
<tr>
<td></td>
<td>Water Amount m³/year</td>
</tr>
<tr>
<td>Ecosystem Water Demand</td>
<td>WUR Area Mu</td>
</tr>
<tr>
<td></td>
<td>Water Amount m³/year</td>
</tr>
<tr>
<td>Domestic Water Demand</td>
<td>Drinking m³/year</td>
</tr>
<tr>
<td></td>
<td>Livestock m³/year</td>
</tr>
<tr>
<td>Industrial Water Demand</td>
<td>Others m³/year</td>
</tr>
</tbody>
</table>

The amount of surface water resource and fountain water resource is the amount of water resource coming from the mouth of tertiary canal; the amount of groundwater is the amount of water resource coming from the mouth of the well. The agricultural and ecosystem water quotas are the net water demand in the farmland. The total water amount is fixed by the normal year; the actual water amount will be regulated according to the actual water resource situation and followed by the principle of adding in the water-sufficient year, decreasing in the water-shorting year.
When the ID confirmed the amount of water resource distributed, there is a need to establish annual water amount for the water users. The process of issuing water right certificate is as follows:

- **Declare WUR Area**
  Water users declare the self-situation, such as contract land area, private plot area, wasteland area, crop patterns, population and the number of livestock to the water authority of Irrigation District.

- **Field Investigation and Check**
  The water authority of Irrigation District does the field investigation and checks the WUR area and other declaring items.

- **Publication**
  The water authority of Irrigation District puts up the results of investigation publicly.

- **Reconsidering**
  The water users reconsider the results of publication. If they do not agree with the results, they can tell the water authority of Irrigation District. The water authority of Irrigation District will do the field investigation again, and refer to the information on the Land Use Right certificate also. In the end, the water users have to accept the results.

- **Signature**
  The water users agree on the amount of water resources distributed and put their fingerprint as signature on the paper.

- **Registration**
  The water authority of Irrigation District registers the information about the WUR area and other information (crop patterns, population and the number of livestock), then builds the tables and book for each household.

- **Report**
  At last, the water authority of Irrigation District reports on these books to the higher level (water authority of county level).

- **WUR Certificate Issuing**
  The water authority of county level issues the WUR certificate.

- **Distribution**
  The WUR certificates are distributed from the county level, ID level to the Water User Association. At last, the Water User Association distributes to the water users.
In Zhangye city, each water user is distributed by the annual amount of water resource, which should be utilized restrictedly. According to the Mr. Luan, the director of water-saving office in water affair bureau of Zhangye city, the water-saving awareness of farmer was improved; 80% of farmers were considering adjusting crop patterns or adopting high-technical irrigation methods to save water. Therefore, the saved water can be sold to other people. Theoretically, water markets can be formed. In
Zhangye city, the WUR trading just occurred between farmers. There are also some WUR trading between the IDs and villages, even different sectors. According to the Mr. Ge, the director of water resource department in water affair bureau of Zhangye city, “there has been transfer case of water resource between different sectors in Zhangye city. In 2003, the Xijun Irrigation District transferred 11 million m$^3$ of water resource to the heat-engine plant of Zhangye by the regulation of government without paying, because the heat-engine plant is a major project in Zhangye city. The water trading between Irrigation Districts rarely happened these years. And it is also regulated by the government.” Therefore, this research about WUR trading in Zhangye city just focuses on the farmers.

There is one example of WUR trading happened in Zhangye city. During the field-survey, according to Mr. Luan, the director of water-saving office in water affair bureau of Zhangye city, the WUR trading was implemented most actively in Hongshuihe ID. The farmer, “Zhuhong”, lives in the Pengzhuang village. His family has four people. They have 14 Mu farmland and 4,000 L amount of WUR. Before 2002, he mainly planted grain crops. The water using amount is more than 800L/Mu·a. If he followed the precious planting practice, he just can irrigate five Mu of farmland. In order to irrigate all the farmland, he considered adjusting the crop patterns. In 2004, he planted three Mu of wheat, four Mu of beer barley, three Mu of Chinese medicinal materials (isatidis root), two Mu of potato and two Mu of Alfalfa. At the same time, he changed the massive farmland into water-saving small ones. During the first round of irrigation, his WUR amount was 800 L. He just used 600L to irrigate all the farmland, which saved 200L of water resource. Then, he sold the residual water to “Sunkaorong”, who lived in the same village, at the water price of 0.2 yuan. During the second round of irrigation, he need 100L more water resource. So, he bought 100 L of water resource from his brother at the water price of 0.1 yuan. Figure 3-12 is showing the crop pattern adjustment from 2000 to 2002.

Zhuhong bought the water amount of WUR by 80 yuan at the first round of irrigation and sold the WUR by 40 yuan; but he just spent 10 more yuan at the second round of irrigation. After the second round of irrigation, he saved 30 yuan of water fees. Figure 3-13 illustrates one case of water trading occurred in Zhangye city.

![Figure 3-14 Crop pattern adjustment from 2000 to 2002](image-url)
Farmer A

Farmer B

Brother of Farmer A

**Figure 3-15 One case of WUR trading with water tickets**

From this case, it illustrates that the rudiment of water trading worked out, while just one case between the farmers can not represent the whole water trading. There is a long road and a long time to undertake wide range of water trading between different sectors. Currently, a few farmers become realize to save water to save money, the water trading in Zhangye city just happened between farmers; meanwhile, the essence of the water trading is to encourage different sectors, such as between agriculture and industry, to do trading to advance the efficiency of water utilization, which can promote the economic development and put the water in the more efficient circulation system.

### 3.3.4.1 Water Tickets

In Zhangye city, WUR certificate and water ticket were introduced as symbols of water use rights. After getting the WUR certificate, the farmers can apply for water tickets to the Administrative Bureau of Irrigation District (ID) through a Water User Association (WUA). Thanks to the WUR certificate and water ticket, the farmers can trade the water resource more clearly and easily.
Water tickets issued correspond to the amount of water that a water user is entitled to in a particular year on the basis of his/her water use right. When the farmers want to irrigate farmland, they are obliged to show the water tickets, which are issued and sold by the Administrative Bureau of Irrigation District. The staffs of Water Administrative Department in each Irrigation District give the water according to the volume of the water tickets. The water tickets of a particular irrigation district have their own style. The following sample of water ticket is from Liyuanhe ID. (Figure 3-6)

<table>
<thead>
<tr>
<th>Name of ID</th>
<th>Symbol of water conveyance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water volume</td>
<td>Year</td>
</tr>
</tbody>
</table>

![Water Ticket Sample](source)

Taking LiYuanhe irrigation district as example, the smallest denomination water ticket is 10 m$^3$ and the largest one is 100 m$^3$. According to the rules and regulation issued by the local government, water tickets can be sold between water users.

### 3.3.4.2 Rules of WUR Trading

In order to promote the WUR trading activities and build the water market, the water authority of Zhangye city formulates rules for the WUR trading, which make WUR trading more standardized. There is a regulation of “Guiding Opinion for agricultural water trading”, which is followed by the “Chinese Water Law”, “Implantation Measures for the Abstraction Water”, and “Detailed Rules for the water Abstraction in Gansu Province”. The principle, range, condition, procedure, ways and water price of WUR trading are regulated by the rules as followed.

#### Principle of WUR trading

- Followed by the Chinese Water Law
- Water-saving and high-efficiency utilization
- Government regulation
- Market-based instrument

#### Range of WUR trading

The trading range of WUR trading is just limited within the agricultural irrigation water, and includes appropriate proportional agricultural irrigation water transferring to non-agricultural water utilization.
Condition of WUR trading

- **Condition 1**: Water users have to pay off the water fees, water resource fees and other water resource fees
- **Condition 2**: Agricultural irrigation must adopt water-saving measures, such as crop patterns adjustment, high-technical irrigation methods adoption, to improve water use efficiency; the water resource saved by these measures can be traded.
- **Condition 3**: Water resource must meet the need of irrigation first
- **Condition 4**: The traders should reach the oral-agreement if the water amount of trading is below 200 m\(^3\); The traders should reach the written-agreement if the water amount of trading is between 200 and 1000 m\(^3\); The traders should sign the water trading contract if the water amount of trading is above 1000 m\(^3\)

Procedure of Regional WUR trading

- Between county and county: If the amount of water trading is below five million m\(^3\), it needs to be approved by the water affair bureau of prefecture level; If the amount of water trading is above five million m\(^3\), it needs to be checked by the water affair bureau of prefecture level, then approved by the government.
- Between ID and ID: If the amount of water trading is below 0.5 million m\(^3\), it needs to be approved by the water affair bureau of county level and reported to the high level; If the amount of water trading is above 0.5 million m\(^3\), it needs to be checked by the water affair bureau of county level, then approved by the water affair bureau of prefecture level.
- Between village and village: If the water trading happened in the same canal part, they should apply for the ID to get approval. If the water trading happened in the different canal part, they should apply for each ID; the IDs have to discuss and negotiate each other and reach an agreement.

Ways of WUR Trading

Water ticket is taken as the symbol of WUR, which can be traded directly by the water users. Moreover, there are several ways for the trading in Zhangye city:

- Invite public bidding
- Auction
- Negotiation
- Buy-back by Water Authority

Until now, there is no statistics on the percentage of four ways of water trading in Zhangye city.

The first two ways of WUR trading is barely used in Zhangye at present, as the current main subject of water resource is the farmers, they don not have the economic condition to enter a bid or take the auction to get more water. Generally speaking, the public bidding and auction are used under the massive water resource trading; while in Zhangye city, according to the Zhang’s survey (2007) the average area of farmland per household is 1.22 ha, there is no need for farmers to call for water
resource through such economic activities. On the other hand, during the experimental period of WUR trading, under the government interference, the government can transfer the water resource from the agriculture to industry without any compensation for the farmers; there is no need for water organizations or industries to take water resource through bidding or auction.

The water authority can buy back the water resource by two times price of water ticket to encourage water users save water; this way of water trading has ever happened, however, due to the fiscal problem and barely residual water for farmers every year, the buy-back way is not popular.

The most popular way of water trading is negotiation between the farmers. The water trading is done by the water tickets, each person who holds the water tickets also is will to sell water resource to others can negotiate with the buyer to do such a trading, although it is difficult for the farmers to find a buyer or seller.

**Water Price for WUR Trading**

The trading price is based on the water price formulated by the Price Department. The trading price of the agricultural irrigation should be no more than 3 times of the normal water price. The trading price of the industrial water should be no more than 10 times of the normal water price. The revenue of regional water trading should be taken as the water-saving fund to support the water-saving techniques.

**3.3.5 Water Market**

Thanks to the emergence of water use right and water tickets, water market can be set up easily. Theoretical speaking, water markets can be formed in Zhangye city. But the existing water markets are not wide enough to cover all sectors due to legal and economic constraints. Water markets in Zhangye city can be defined as spot markets (Chen, Zhang et al. 2005). The water market has their own physical boundary that coincides with the irrigation district boundary. There are some reasons constrained the development of water market. Firstly, the farmers hardly sell their water to another irrigation district due to the layout of the system and the poor connection of the secondary and tertiary canal. Secondly, it is hard to find the trading partner for the buyers and sellers; thirdly, there are some trading rules and terms limited the trading; the buyer and seller cannot negotiate the water price freely. Fourthly, water ticket can be regarded as the symbol of WUR, but this right is temporary not permanent. Farmers must completely utilize their water quotas or sell them every year. Otherwise, they will forfeit them. In China, the creation of water market is still in the exploration process. Creating water markets is complicated, and the markets themselves take years to develop fully. The new institutional arrangements now being put in Zhangye city can in fact be regarded as intermediate steps toward water markets. Clear water allocation mechanisms and water user rights are parts of an institutional framework that needs to be in place before a market can function (Chen, Zhang et al. 2005).

**3.3.6 Irrigation District (ID) and Water User Association (WUA)**

In Zhangye city, there are 23 irrigation districts located in the different counties, which are under supervision of the county level bureau. They are responsible for the water allocation from the main canals and secondary canals to agricultural irrigation land, the operation and maintenance of the main canals and branches. Water administration departments in ID make and operate the water supply plans for the water users following the applying plans from the Water User Associations.
Water User Association (WUA) is the non-government organization. Until 2006, there are 788 WUA in the Zhangye city, which is responsible for above 90% of irrigation land (ZYWAB 2006). It is a democrat platform of participatory decision-making, thoughts expression and information knowing for the water users. Any farmer in the specific irrigation district could be the member of the WUA after applying. The establishment of WUA is based on the canal unit or village unit. It should choose one member in each family and 10 to 15 families generate one reprehensive for the WUA. Then through the general meeting, the members select the header and associated header by the secret vote for the executive board of the WUA. They are paid a symbolic salary. The decisions of WUA are made by the majority vote in the general meeting. The main responsibilities of WUA are the operation and maintenance of the tertiary canal and branches, and application of water use plan for the current year to the ID. They are also responsible for the water fee collection and WUR trading management, water conflicts resolution. Figure 3-15 shows the framework and duties of water users association.

3.4 Experiences and Deficiencies

It is meaningful to investigate and study the WUR system and WUR trading in Zhangye city. Firstly, the theory of “Water Use Right” and “WUR trading” is just the initial and exploratory phase during the water resource management in China. The Zhangye city, which is the first experimental water-saving site in China, has been experienced six years of agricultural institution innovation. The good experiences and deficiencies can be used and learned by the other parts of the semi-arid and arid regions of northwest of China due to the similar physical environment and situations. Moreover, the south of China, which does not temporarily suffer from the water shortage problems, also need to adopt the concept of “Water Use Right” and “WUR trading” as the incentive for water-saving to resolve the water-stress problems. Therefore, in order to make sustainable water resource development, China should specify and make clear “water right” for each sectors and water users, and contribute more to the
water resource management, even up to social-economic development. There are some good experiences and deficiencies in Zhangye city are summarized as followed:

1. **Experience**

   1. **Two systems of “total water amount control” and “water quota management”**

      Distribute the water resource up to down. From the river basin, province level to prefecture level and county level, from the town level, village level to water user association level and ends to water user level, the water use right has been quantized levelly. Each level is clear of the amount of water resource distributed, which is controlled in the macro-scopical level. And each level regulates the utilization of water resource internally, which is called “water quota management”. “Water quotas” for the unit of the industrial products, population, livestock, irrigation areas and eco-utilization are regulated. The water users are clear how much water supposed to be used in one year. Water users can adjust the crop patterns and adopt water-saving measures, then control the amount of water resource within water quota and limited amount.

   2. **Adjust crop patterns changing from “grain-based site” to “economic-top site”**

      In 2002, the Zhangye government put forward the policy of the “three forbid, three reduce, and three expand”, which is “forbid immigration, forbid water-intensive crop planting, forbid wasteland open up”, “reduce farmland area, reduce grain crop area, reduce water-intensive crops”, “expand forest and graze area, expand cash crop area, expand water-saving crops”. Moreover, the government strongly supports the leading domains involving water saving and high-efficiency economically: graze and livestock, fruit and vegetables, seed-making and raw materials of light-industry.

   3. **Water Use Right Trading**

      The emergence of water tickets makes water become the commodity in the mind of farmers, makes water market coming into being and also strengthens the awareness of agricultural well-management for the farmers. The functions of water tickets are promoting water fees collection, facilitating water trading, and improving efficiency of water utilization. The WUR trading can strengthen the awareness of water saving; the farmers began to try hard to save water , such as adjusting crop patterns or employing high-technical irrigation methods, to make money by trading water, which can balance the utilization of irrigation water in the specific region.

   4. **Emergence of WUA**

      WUA is playing the role of connecting link between the government and end users, which is one part of the participatory irrigation management. WUA makes water affair transparent, makes the farmers assured and makes the water management more easily.
1. **Deficiencies**

1. **Unclear validity of the water right**

Due to the fluidity and not-easily controllability of the water resource, it is hard to determinate the utilization of water amount annually. The temporal validity of the WUR certificate is five years. The validity of the water ticket is one year. What is on hell the validity of water right? The water authority has not clarified it. The farmers worried if they saved water, the water authority would reduce the water quotas later, then the water use right would be decreased quantitatively.

On the other hand, it is advisable to fix the long-term water quotas, which can protect the interest of the farmers. The government should abandon the policy of reducing the water quotas for agricultural sectors, which was intend to transfer water resource from the agriculture to other sectors; while the farmers should transfer the water resource to other sectors by the market-oriented method, not through the government intervention, which can not only improve the efficiency of water utilization but also protect the interests of farmers.

2. **Immature water market**

Until now, the WUR trading is not popular in Zhangye city. And the trading cases just happened between farmers with little transaction volume. In order to foster the vivid water market, the government should build the platform for the trading. The subject of trading should expand to village, irrigation district and even river basin. The government should do the research about buy-back of the water use right, water bank building and make use of the lever of water price to promote water to high-efficiency sectors (Wang 2003).

3. **Who pays for the water of ecosystem?**

The water of ecosystem was in the charge of the Administrative Bureau of Irrigation District (ABID). According to the personal interview, every year the ABIDs have to allocate 10%-30% of the total water resource to ecosystem, but nobody pay for them, which create the financial burden for these ABID. Taking the Hongshuihe ID as example, it has to allocate 25% of the total water resource to ecosystem according to annual plan, which cost 2 million Yuan every year. While there are just 0.5 million water management fees per year without subsidy, the annual agricultural water fees make up for it.

The government should pay attention to the ecosystem paid, because this is a vicious circle. The irrigation district has to use agricultural water fees to compensate the eco-expenditure. This will result in the more water be supplied to the farmers to get more agricultural water fee, which does not encourage farmers to save water; on the contrary, it stimulates more water use. This is contradictory to the principle of water-saving society.

4. **Market for the new crop**
The farmers are worrying if they plant the water-saving crops, how to find the market for the new crop. In the past, they just planted grain crops which can be self-supported, and also sold to the acquired-company every year no matter how much the acquired price was. The problem at present is if they plant fruits or vegetables or other cash crops, they cannot self-disposing, and it is difficult to find suitable acquired-company in Zhangye city.

The government should provide the subsidies for planting the water-saving crops for the farmers, which can reduce the risk of crop regulation; and arrange the acquired-companies of the new crops for them in Zhangye city or in other areas to provide the incentive for the new crop planting farmers to save water.
Chapter 4

Scenario analysis based on WEAP modeling

This chapter is the analysis of different scenarios based on the WEAP modelling, to explore the impacts of the WUR system and WUR trading in the middle reaches of Heihe River Basin, then to make recommendations for Heihe River Basin to improve current situation. The scenarios will be considered based on the changing of demand priorities, changing of supply preference, and the reaction of the water users for the demand-side management activity. And the impacts of the scenarios will be elaborated. The following research questions will be addressed as follows:

- What kind of water right allocation is recommendatory for the study area in the near future?
- What will be the positive and negative consequences of the alternatives?

In this chapter, “Liyuanhe Irrigation District” was chosen as the study and modelling site. Since the “Liyuanhe Irrigation District” is one of the biggest ID and which was chosen as the first testing ID site of WUR right and WUR trading in Zhangye city, in middle reaches of Heihe River Basin, the modelling of “Liyuanhe Irrigation District” for the alternatives making has typical and instructional significance in the middle reaches of Heihe River Basin.

4.1 Introduction of WEAP Modeling

WEAP (Water Evaluation and Planning System) is a software programme developed by the Stockholm Environment Institute Boston’s centre at the Tellus Institute. It operates at a monthly step on the basic principle of water balance accounting. The user represents the system in terms of its various sources of supply (e.g. rivers, groundwater, and reservoirs), withdrawals, water demands, and ecosystem requirements. The model of WEAP intends to carry it simulation considering the various variables listed in figure 4-1.
4.1.1 Features

WEAP can perform a wide variety of functions that build on three main components (Sorisi 2006):

1. **Water Balance**: By simulating the various natural components of the hydrological cycle (i.e. rainfall, runoff, groundwater recharge, surface-groundwater interaction), combined with human and engineered activities (i.e. pollution, hydropower generation, reservoir operations, water transfer). WEAP accounts for the water available in the hydro-geological system and it provides information regarding water demand and supply balance.

2. **Scenario Generation**: Building on a specific data set (reference scenario) the software allows simulations to be generated representing the response of the system to various events, either natural or generated by humans, such as climate variations, increase in pollution load or new policy which in turn conditions water availability, quality and use.

3. **Policy analysis**: WEAP allows for the evaluation of the impact of different policy and management options on the availability of water resource. It can also perform this function by prioritizing specific water uses, and consequently representing the level of water allocated among competing uses.

WEAP applications generally involve the following steps (SEI 2001):

1. Study definition including time frame, spatial boundary, system components and configuration;

2. Establishing the ‘current accounts’, which provides a snapshot of actual water demand, resources and supplies for the system;

3. Building scenarios based on different sets of future trends based on policies, technological
development, and other factors that affect demand, supply and hydrology;

- Evaluating the scenarios with regard to criteria, such as: adequacy of water resources, costs, benefits, and environmental impacts.

### 4.1.2 Scenario Analysis

In the WEAP, “Current Account” of the water system under study is created firstly. Then, based on a variety of economic, demographic, hydrological, and technological trends a “reference” scenario projection is established, referred to as a “Reference Scenario”. Then one or more policy scenarios are developed with alternative assumptions about future developments.

- **Reference Scenario**

The reference scenario is the base scenario that uses the actual data, to help in understanding the best estimates about the studied period. The objective of a reference scenario is to help planner and water resource manager understand what likely could occur if current trend continue and to understand the real situation. Reference scenarios can also be useful for identifying where knowledge is weak in analyzing likely trends and where more information needs to be collected. They can be useful for designing contingency plans where there is a lot of risk and uncertainty. In this study the basic model has been build using WEAP through reference scenario, which replicates the real situation.

- **Other Scenarios**

In the WEAP, “Other Scenario” is a set of alternative assumptions about future impacts of policies, costs, and climate, for example, on water demand, supply, hydrology, and pollution. The scenarios can address a broad range of "what if" questions, such as: What if population growth and economic development patterns change? What if reservoir-operating rules are altered? What if water conservation is introduced? What if new sources of water pollution are added? What if a water-recycling program is implemented? What if a more efficient irrigation technique is implemented? What if ecosystem requirements are tightened? What if various demand management strategies is implemented? What if climate change alters the hydrology? (Olusheyi 2006)

The reference scenario and “Other scenarios” can be viewed simultaneously in the results for easy comparison of their effects on the water system. An intuitive graphical interface provides a simple yet powerful means for constructing, viewing and modifying the system and its data. WEAP is flexible to accommodate the evolving needs of the user, such as, availability of better information changes in policy, planning requirements or local constraints and conditions.

### 4.2 WEAP Modeling in Study Area

A WEAP model of “Liyuanhe Irrigation District (ID)” was developed according to the current situation of water demand and supply, potential assumption of policy, climate and demographical development and future trends. The interface of “Liyuanhe ID” model in its last version is represented in figure 4-2.
The red points represent a demand node for agriculture, forest & graze, industry, domestic and livestock. The numbers in the brackets are the demand priorities for each demand site (the lower digit indicates higher priority). The natural source supplying water to these nodes is the Liyuanhe River, which is the big branch of Heihe River, and groundwater, which graphically represented in a green square. Green arrows indicate the withdraw water from both the river and groundwater. Red arrows indicate the return flow to rivers. The green triangle represents the reservoir of Yinggezui, which is regulating river water supply of Liyuanhe ID. The purple anchor shape shows the flow requirement which is allocated to the main river, Heihe River, to ensure the “water right” allocated to the Heihe River.

4.2.1 Modelling Demand and Supply in WEAP

The initial tasks in modelling with WEAP are to define the quantities of demand and supply of water. Modelling demand and supply using the WEAP software mainly depends on the current year that is defined as the starting year for the simulation. The characteristic of this “current year” is that it has all the available data for demand and supply: the hydrological data as supply and the consumptions of all kinds as demand.

To start modelling demand and supply, the following must be identified:

- The Current Accounts represent the basic definition of the water system, as it currently exists. For this model the current account and the starting year for all scenarios is 2000 as the exploitation data is available.

- The last year of the model is 2015 in this case study.

- The trend for simulations will be modelled in WEAP by the available data which should be defined for each component separately.

This research focuses on the period between 2000-2015 for scenario building and analysis. This period was selected since WUR system and WUR trading are implemented in Liyuanhe ID during this period as the experimental experience and the data was available.
 Demand Modelling

In the demand modelling, there are five demand sites categorized into “Agriculture”, “Forest & Graze (ecosystem)”, “Industry”, “Domestic”, and “Livestock”; moreover, the “Domestic” is classified into “urban” and “rural”, which stands for the urban and rural domestic water use; the “Livestock” is classified into “big” and “small”, which represent the big livestock and small livestock, respectively. The annual water demand of demand site (DS) is calculated as the sum of the consumptions for all the demand site’s bottom-level branches (Br). A bottom-level branch is one that has no branches below it.

\[
\text{Annual Demand } DS = \sum (\text{Total Activity Level } Br \times \text{Water Use Rate } Br)
\]

The supply requirement is the actual amount needed from the supply sources. The supply requirement takes the annual water demand and adjusts it to account for internal reuse, demand side management strategies (DSMS) for reducing demand, and internal losses.

\[
\text{Supply Requirement } DS = \frac{(\text{Annual Demand } DS \times \text{Reuse Rate } DS \times \text{DSM Savings } DS)}{(1 - \text{Loss Rate } DS)}
\]

Annual Activity Level

In Liyuanhe Irrigation District (ID) in 2000, there are 14,580 ha irrigation farmland and 6,133 ha forest& graze needed to be irrigated. The industry produced 90.053 million Yuan in 2000. The big and small livestock account for 20% and 80%, respectively, in the total of 127,400 pieces. There are 46,600 people lived in the Liyuanhe ID with the population growth rate of 0.8% in the future years. The parameters and variables of annual activity level in the WEAP modelling and the future trends for the successive years are shown as follows:

<table>
<thead>
<tr>
<th>Demand Site</th>
<th>2000</th>
<th>2001-2015</th>
<th>Scale</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest &amp; Graze</td>
<td>6.133</td>
<td>Interp(2005,6.93, 2010,7.73, 2015,8.53)</td>
<td>Thousand</td>
<td>ha</td>
</tr>
<tr>
<td>Industry</td>
<td>90.053</td>
<td>GrowthFrom(12.7%,2000,90.053)</td>
<td>Million</td>
<td>Yuan</td>
</tr>
<tr>
<td>Livestock</td>
<td>127.4</td>
<td>GrowthFrom(7%,2001,127.4)</td>
<td>Thousand</td>
<td>person</td>
</tr>
<tr>
<td>Domestic</td>
<td>46.6</td>
<td>Growth(Key\Population Growth Rate/100)</td>
<td>Thousand</td>
<td>person</td>
</tr>
</tbody>
</table>

Figure 4-3  Annual activity level for the five demand sites
On one hand, the agricultural water use rate will decrease because of the adoption of the high irrigation technology and scientific management measures. Meanwhile, the industrial water use rate will decrease as well. On the other hand, the domestic water use rate will increase in order to ensure the improvement of living standard for the people with social-economic development, but the increasing extent is small as the small potential of water-saving in domestic aspect. As for the lower water use rate of ecosystem compared to that of agriculture, the water use rate of ecosystem is set to keep same level during the successive years.

According to the document of Administrial Department of Irrigation District (WAZC 2003), the water use rate for each demand site in 2000 and the following years are indicated in the table 4-1:
Table 4-1 Water use rate for each demand site

<table>
<thead>
<tr>
<th>Demand Site</th>
<th>2000</th>
<th>2001-2015</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canal Irrigation</td>
<td>6615</td>
<td>6225</td>
<td>m³/ha</td>
</tr>
<tr>
<td>Sprinkle Irrigation</td>
<td>3000</td>
<td>3000</td>
<td>m³/ha</td>
</tr>
<tr>
<td>Pipe Irrigation</td>
<td>5175</td>
<td>5175</td>
<td>m³/ha</td>
</tr>
<tr>
<td>Urban</td>
<td>21.9</td>
<td>Interp(2005,25.2;2010,29.2;2015,32.8)</td>
<td>m³/person</td>
</tr>
<tr>
<td>Rural</td>
<td>18.25</td>
<td>Interp(2005,20;2010,21.9;2015,23.7)</td>
<td>m³/person</td>
</tr>
<tr>
<td>Big</td>
<td>16.43</td>
<td>Interp(2005,17.52;2010,18.25;2015,20)</td>
<td>m³/piece</td>
</tr>
<tr>
<td>Small</td>
<td>8.03</td>
<td>Interp(2005,8.76;2010,9.46;2015,10.22)</td>
<td>m³/piece</td>
</tr>
<tr>
<td>Industry</td>
<td>0.018</td>
<td>0.013</td>
<td>m³/Yuan</td>
</tr>
<tr>
<td>Forest and Graze</td>
<td>2700</td>
<td>2700</td>
<td>m³/ha</td>
</tr>
</tbody>
</table>

Expression Interp: Calculates a value in any given year by linear interpolation of a time-series of year/value pairs.

Demand priority

Demand priority represents the urgency of the demand site for the water use. The lower digit indicates higher priority. WEAP will attempt to supply all demand sites with highest demand priority, then moving to lower priority sites until all of the demand is met or all of the resources are used, whichever happens first. Before 2001, the new water right system in Heihe river basin had not implemented yet, there is no flow requirement for Liyuanhe River during the water allocation program. The demand priority is 5, which indicated flow requirement in Liyuanhe River has not been taken into account. While after 2001, the new water right system in Heihe River Basin required Liyuanhe River, the branch of Heihe River, to contribute to increasing 42 million m³ of flow water annually into the Heihe River; hence, the demand priority of flow requirement changed into 1.

![Flow Requirement Water Right](image)

Figure 4-7 Demand priority for Flow Requirement

As mentioned in Chapter 2, in China, the priority of water extraction is as follows: domestic water, agricultural water, industrial water, eco-environmental water, and navigating water, and in arid and semi-arid areas, the eco-environmental water needs to be taken into account. Therefore, the demand priorities in Liyuanhe ID for all the demand sites in 2000 and the following years are shown in figure 4-8. Since the demand priority of flow requirement changed to “1” after 2001, the demand priorities of all the demand sectors add 1, correspondingly.

![Demand priority for demand sites](image)

Figure 4-8 Demand priority for demand sites
Demand management saving

Demand management saving is the percent of reduction of total water demand due to demand-side management programs. For example, when the water price is increasing at 10%, the amount of water using will cut down 5%; when the water price is increasing at 40%, the amount of water using will cut down to 10% (Guo, Feng et al. 2006). The 5% and 10% are the demand management saving for water use.

Lose rate

Loss rate is the loss in the demand which results in an increase in water demand. The table 4-2 indicates the loss rate of each sector in demand water.

Table 4-2  Loss rate for each sector in demand water

<table>
<thead>
<tr>
<th>Item</th>
<th>Agriculture</th>
<th>Forest &amp; Graze</th>
<th>Industry</th>
<th>Livestock</th>
<th>Domestic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss Rate</td>
<td>2000</td>
<td>55%</td>
<td>55%</td>
<td>8%</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>2000-2015</td>
<td>50%</td>
<td>50%</td>
<td>6%</td>
<td>3%</td>
</tr>
</tbody>
</table>

Following the above water demand items, Water demand and Supply requirement for the five demand sites are calculated by WEAP and are shown in Figure 4-9 and Figure 4-10.

Figure 4-9  Water demand for the five demand sites during 2000-2015 in WEAP
Supply Modelling

There are two main supply sources for the demand sites. “Liyuanhe River” supplies water to two demand sites: “Agriculture” and “Forest & Graze”; and all the five demand sites withdraw water from the “Groundwater”. The Yinggezui reservoir is the regulating project for the river water, which can store water during high flows and release water during low flows for the down part of reservoir. The supply preference is the preference of the water supply sources to meet the demand consumption. The supply preferences of river and groundwater for the five demand sites are shown in table 4-3:

Table 4-3 Supply preference of the river and groundwater for demand sites

<table>
<thead>
<tr>
<th>Demand sites</th>
<th>Source</th>
<th>Supply Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>From river</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>From groundwater</td>
<td>2</td>
</tr>
<tr>
<td>Forest &amp; Graze</td>
<td>From river</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>From groundwater</td>
<td>4</td>
</tr>
<tr>
<td>Industry</td>
<td>From groundwater</td>
<td>3</td>
</tr>
<tr>
<td>Domestic</td>
<td>From groundwater</td>
<td>1</td>
</tr>
<tr>
<td>Livestock</td>
<td>From groundwater</td>
<td>1</td>
</tr>
</tbody>
</table>

River Flow

In WEAP, river is considered to be made up of nodes connected by river reaches that have to be draw (Olu sheyi 2006). In Liyuanhe ID, “Liyuanhe River” is the river flow, which graphically included two withdrawal nodes and five return nodes, in addition, Yinggezui reservoir and the icon of flow requirement are put on the river as well in the upstream and downstream of Liyuanhe River, respectively. The nine icons separate the river into eight reaches. Based on the monthly flow of...
Liyuanhe river during 1959-2007 (Appendix B)(LYHID 2008), the naturalized monthly flows during each reach were provided in an electronic format directly based on WEAP.

n **Groundwater**

The groundwater is the main supply source in Liyuanhe ID, which has to provide water to all the five demand sites. Under the condition of the demand priority and supply preference, the groundwater can not be sustainable as shown in the figure 4-11 below:

![The Annual Available Groundwater Supply to all demand nodes](image)

As we can see from the above figure, the zero storage capacity of groundwater in Zhangye city is almost approaching. However, here emphasises the trend of “declining” not the exact year of exhaustion. As the interaction between surface water and groundwater does not modelled in WEAP due to non-availability of data, the only recharge way in WEAP modelling for groundwater is the precipitation (usually irrigation recharge is the biggest recharge way for groundwater), which leads to more or less the deviation on the storage capacity: Apparently, if plus the interaction between surface water and groundwater, the terrible situation will be deferred may be to the year of 2070 or 2080, but it is inevitable that the dropping trend of storage capacity will be keeping followed by this trend.

n **Reservoir**

Generally, the operating strategies of Yinggezui reservoir on Liyuanhe River are to release the river water down from late spring to early fall to meet the peak demand period and ensure adequate storage to capture the winter and early spring flood flows. The supply data of Yinggezui reservoir is shown in the table 4-4, which is reflecting the initial storage, storage capacity, priority, operating data and net evaporation in sequence.
Reservoir storage is divided into four zones, which is including, from top to bottom, the flood-control zone, conservation zone, buffer zone and inactive zone (Figure 4-12). The conservation and buffer zones, together, constitute the reservoir's active storage. WEAP will ensure that the flood-control zone is always kept vacant, i.e., the volume of water in the reservoir cannot exceed the top of the conservation zone. Buffer zone defines a portion of the reservoir where system demands are restricted and downstream demands can only be met as a percentage (the buffer coefficient) of the available storage within the buffer zone. Below the buffer zone is the inactive storage that cannot be available to meet demands.

Table 4-4  The supply data for Yinggezui reservoir

<table>
<thead>
<tr>
<th>STORAGE</th>
<th>Initial storage( (m^3) )</th>
<th>Storage capacity ( (m^3) )</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOLUME</td>
<td>20,170,000</td>
<td>25,000,000</td>
<td>99</td>
</tr>
<tr>
<td>ELEVATION (m)</td>
<td>1938</td>
<td>1942</td>
<td></td>
</tr>
<tr>
<td>OPERATION DATA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOLUME</td>
<td>19,360,000 ( m^3 )</td>
<td>13,500,000 ( m^3 )</td>
<td>0.78</td>
</tr>
<tr>
<td>VOLUME</td>
<td>4,000,000 ( m^3 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NET EVAPORATION</td>
<td>109.9 ( m^3 ) per month</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Before establishing the scenarios, it is necessary to do the WEAP validation first. The supply requirement of water resource in Agriculture, Industry, Forest & Graze and Domestic & Livestock sectors in WEAP was comparing to the actual observation in 2000. The results is shown as below:
Table 4-5  Comparing actual observation and WEAP modelling for validity in supply requirement

<table>
<thead>
<tr>
<th>Items</th>
<th>Supply Requirement</th>
<th>Unit: Million m³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Agriculture</td>
<td>Industry</td>
</tr>
<tr>
<td>WEAP Modelling</td>
<td>200.6</td>
<td>1.7</td>
</tr>
<tr>
<td>Actual observation</td>
<td>193.98</td>
<td>1.62</td>
</tr>
<tr>
<td>Differences</td>
<td>+6.02</td>
<td>+0.08</td>
</tr>
</tbody>
</table>

As we can see from this table, the digit in WEAP modelling is a litter bigger than the actual observation, the difference may results from the non-available data of “reuse date” in each sector and the “savings for demand-side management” in 2000 was set as “0” in WEAP software due to the hypothesis of no measures for demand-side management in 2000.

4.2.2 Scenario Building

Scenarios can be built to address a set of “what if” questions to consider futures with fundamentally different development and environmental assumptions and policies. In this section, the scenario about “water right system” will be built with regard to high population growth, water price raising, demand priority changing and supply preference changing to assess the water sustainability in the study area.

- **High population growth**

The current population growth in Liyuanhe ID is 0.8% (ZYWAB 2006). As population development is taken as the main threatening reason for the water crisis and population growth is bound to occur in the human society, it is curious for the people to see “what if population growth rate excess 1.12% will happen to water sustainability?”

- **Water price raising**

In the study area, the current water price is 0.067 Yuan/m³, which just accounts for 79.7 % of 0.084 Yuan/m³ of net cost water price (Guo, Feng et al. 2006). According to research of “Discuss on Water Price of Irrigation Area in middle reaches of Heihe River”, the acceptable water price for the farmers in middle reaches of Heihe River Basin is 0.12Yuan/m³. Therefore, increasing water price into 0.12Yuan/m³ is the desirable objective for the water-saving society. Guo (2006) points out when the water price is increasing at 10%, the amount of water using will cut down 5%; when the water price is increasing at 40%, the amount of water using will cut down to 10%. Hence, if current water price of 0.067 Yuan/m³ increases by 25% reach to the net cost water price of 0.084 Yuan/m³, the amount of water using will cut down to 7.5 %.( The process of calculation is in the Appendix C)
As we can see in the Figure 4-11 of groundwater resources, it is observed that the storage capacity of groundwater from 2000 is represented the decline trend and the groundwater is close to exhaustion until 2015. In addition, from the figure 4-14 and figure 4-15, it is shown that the demand is not fully met and the trend of unmet demand is ascending year by year after 2002 although the water-saving measures have been taken. As mentioned before, the flow requirement (make contribution of 42,000,000 m³/a to Heihe River) for Liyuanhe River is mandatory by the government. So, the demand priority of flow requirement has to set as “1” all the time. For the five demand site, there is a need to take measure by changing the policy of assigning the different priority levels to demand sites to see the unmet demand impacts on them. In Liyuanhe ID, in order to ensure the stability of society and desired human health and hygiene, the second priority is given to “Domestic” and “Livestock” all the time. How to set the demand priorities for “Agriculture”, “Forest & Graze” and “Industry” is the exploratory question in the following scenarios.
In this Scenario, the priorities assigned are shown in table 4-6 as follows:

**Table 4-6  Demand priorities assigned in Demand Priority changing 1**

<table>
<thead>
<tr>
<th>Demand sites</th>
<th>Reference Priority</th>
<th>Priority Changing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Forest &amp; Graze</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Industrial</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Livestock</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Domestic</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

In this Scenario, the priorities assigned are shown in table 4-7 as follows:

**Table 4-7  Demand priorities assigned in Demand Priority changing 2**

<table>
<thead>
<tr>
<th>Demand sites</th>
<th>Reference Priority</th>
<th>Priority Changing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Forest &amp; Graze</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Industrial</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Livestock</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Domestic</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**Demand Priority changing 3**
In this Scenario, the priorities assigned are shown in table 4-8 as follows:

### Table 4-8  Demand priorities assigned in Demand Priority changing 3

<table>
<thead>
<tr>
<th>Demand sites</th>
<th>Reference Priority</th>
<th>Priority Changing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Forest &amp; Graze</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Industrial</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Livestock</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Domestic</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

In this Scenario, the priorities assigned are shown in table 4-9 as follows:

### Table 4-9  Demand priorities assigned in Demand Priority changing 4

<table>
<thead>
<tr>
<th>Demand sites</th>
<th>Reference Priority</th>
<th>Priority Changing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Forest &amp; Graze</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Industrial</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Livestock</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Domestic</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

In this Scenario, the priorities assigned are shown in table 4-10 as follows:

### Table 4-10  Demand priorities assigned in Demand Priority changing 5

<table>
<thead>
<tr>
<th>Demand sites</th>
<th>Reference Priority</th>
<th>Priority Changing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Forest &amp; Graze</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Industrial</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Livestock</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Domestic</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

As mentioned before, the priority of “Livestock” and “Domestic” are keeping as “2” just below the “flow requirement” after 2001. These priority changing focus on the priority adding upon the agriculture, industry and ecosystem and priority exchanging between industrial part and ecosystem part. By changing the priorities of the other three sectors, the impacts of unmet demand and storage capacity of groundwater could be observed. The expectation is to see what could happen if the agriculture part, industry part and ecosystem part were put on more emphasis respectively than the other two.

#### Supply Preference Changing
The assumption of supply preference changing is just based on the theoretical tentative vision. Supply preference is weaker than the demand priority on the condition of man-made flexible policy, which is non-man-control assumption that is not easy to be changed by human-being. So, the scenarios of supply preference changing are theoretical assumptions. The following tables are shown the Changing of supply preference in WEAP: (Table 4-11---Table 4-12)

### Supply preference Changing 1

**Table 4-11** Supply preference assigned in Supply preference Changing 1

<table>
<thead>
<tr>
<th>Demand sites</th>
<th>Source</th>
<th>Reference Supply Preference</th>
<th>Changing Supply Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>From river</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>From groundwater</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Forest &amp; Graze</td>
<td>From river</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>From groundwater</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Industry</td>
<td>From groundwater</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Domestic</td>
<td>From groundwater</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Livestock</td>
<td>From groundwater</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

### Supply preference Changing 2

**Table 4-12** Supply preference assigned in Supply preference Changing 2

<table>
<thead>
<tr>
<th>Demand sites</th>
<th>Source</th>
<th>Reference Supply Preference</th>
<th>Changing Supply Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>From river</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>From groundwater</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Forest &amp; Graze</td>
<td>From river</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>From groundwater</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Industry</td>
<td>From groundwater</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Domestic</td>
<td>From groundwater</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Livestock</td>
<td>From groundwater</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

The purpose of the supply preference changing is to see if the supply source could meet the needs of ecosystem or agriculture first, what will happen to the impacts of unmet demand and storage capacity of groundwater?

### 4.2.3 Scenario analysis and Results

In this section, the results of scenarios built previously will be shown and will be analyzed to see the possible impacts on unmet demands and storage capacity of groundwater.
High population growth

From the chart below, the unmet demand of “Domestic” side on the high population growth is shown more than the reference scenario’s. It is obvious that the bigger population, the more demand on water resource. However, the extent of unmet demand increasing is not quite distinct; the population rate increased to 1.12% will not influenced a lot on the unmet demand on domestic. (Figure 4-16)

Water price raising

If the current water price rises to 0.084 yuan/m$^3$, the people will save water which contributes to the savings of demand-side management of 7.5%, the supply requirement for all the demand sites decreases 20 million m$^3$ of water resource (Figure 4-17); therefore, the unmet demand of the demand sites decreases almost 8 million m$^3$ of water resource compared to reference scenario (Figure 4-18).
When the weightage of demand priority is given more to the “Agriculture”, “Forest & Graze” and “Industry”, that is, the demand priorities of the five demand sites are set equally, the unmet demand of “Agriculture”, “Forest & Graze” and “Industry” are less compared to reference scenario, which shows if the demand priorities of the five demand sites are set to the same, “some pay some gain”. The following figures show that the unmet demand of “Domestic” and “Livestock” is much more compared to reference scenario, while the unmet demand of Forest & Graze” and “Industry” is declining and the unmet demand of “Agriculture” is more or less keep same level till 2008 compared to the reference scenario, after 2008 the unmet demand of “Agriculture” is more than that of reference scenario. (Figure 4-19----Figure 4-21)
Owing to the eco-environment degradation in middle reaches of Heihe river Basin, it is essential to pay more attention to the ecosystem recovery. This scenario is giving more weightage to “Forest & Graze”. When the demand priority of “Forest & Graze” changed to as the same level as “Domestic” and “Livestock”, the unmet demand is declining a lot in WEAP from the figure 4-22, meanwhile the coverage of the requirement met is better than the reference scenario which can be shown in figure 4-24,
while the unmet demand of other demand sites is increasing slightly compared to the reference scenario. (Figure 4-23)

Figure 4-22  Unmet demand of “Forest & Graze” compares reference with priority changing 2

Figure 4-23  Unmet demand of other demand sites compares reference with priority changing 2
This scenario focuses on observing the changing of unmet demand of “Industry” and “Forest & Graze”. When the demand priorities of both “Industry” and “Forest & Graze” are raised, that is, the demand priority of “Industry” is given to the high weightage as same as “Domestic” and “Livestock”, and the demand priority of “Forest & Graze” is changed to as same level as “Agriculture”, just lower than the “Industry”, “Domestic” and “Livestock”, the unmet demand of both is decreasing a lot till 2015. Figure 4-25 and Figure 4-26 show the changing of unmet demand. Referring to the other three demand sites, the unmet demand rises (figure 4-27) due to the prior consumption of the “Forest & Graze” and “Industry”.

Figure 4-24 Coverage of the requirement met of Forest & Graze in WEAP

Figure 4-25 Unmet demand of Industry compares reference with priority changing 3
As the increase in population is bound to occur, a proportionate increase in production of food grains is essential to save the humanity from starvation. Hence, under such consideration more weightage is to be given to “Agriculture” as the same as “Domestic” and “Livestock” level, and its impact on unmet Demand for all demand sites are to be observed. The unmet demand of “Agriculture” in Priority Changing 4 is declining, while the unmet demands of “domestic” and “Livestock” in Priority Changing 4 are increasing year by year. Figure 4-28---Figure 4-29 show these trends.
In the scenario of Priority Changing 5, the priority of “Forest & Graze” is higher than the demand site of “Industry”, which shows the unmet demand of “Industry” is higher compared to the reference scenario while the unmet demand of “Forest & Graze” almost retains the same level in the future years. Referring to the other three demand sites, the unmet demand of theirs keeps the same level as that of reference scenario. (Figure 4-30--Figure 4-32)
Figure 4-30  Unmet demand of “Industry” compares reference with priority changing 5

Figure 4-31  Unmet demand of “Forest & Graze” compares reference with priority changing 5
The desertification and degradation of ecosystem has threatened the living standard of people for a long time, so the recovery of ecosystem has become the first attention for the local government. Changing the supply preference of “Forest & Graze” to “1” is fit for the requirement of local ecosystem. The impact of groundwater capacity is observed according to result in WEAP. (Figure 4-33) When the supply preference of “Forest & Graze” changed to 1, which means the Liyuanhe River and groundwater should supply to “Forest & Graze” first, the groundwater capacity is going to be exhaustion in 2013. On one hand, the “Agriculture” will use more groundwater to make up the “lose” of river water; on the other hand, the eco-part use more groundwater due to the urgent need of eco-part in this scenario.
Supply preference changing 2

As Zhangye city is the big grain production base in China, it is essential to ensure the production of grain food. The supply preference of “Agriculture” changed to “1” is fit for the requirement of food security. Since the “Agriculture” is the biggest consumer of water resource in Heihe river basin, also in Liyuanhe ID, “Agriculture” consumes the groundwater more in this scenario. The groundwater capacity is going to be exhaustible until 2011 which show in figure 4-34.

Figure 4-34 Groundwater capacity of supply preference changing 2 in WEAP

4.3 Summary

We can see that with the population growth rate increasing to 1.12%, the demand priority changing among the “Forest & Graze”, “Agriculture” and “Industry”, and the supply preference changing of “Forest & Graze” and “Agriculture”, the impacts of unmet demand, groundwater capacity and demand coverage changed subsequently. The objective of building these scenarios is to see how the impacts will happen in the future if the governmental policy changed or natural trends changed, then to make alternatives for the case study area to improve current situation of “water right system”. The table 4-13 summarizes the results of the scenarios and the corresponding recommendations.

The summary of the scenario analysis will be elaborated as follows:

1. It is obvious that increasing population growth rate to 1.12% results in the increasing of the unmet demand of domestic not marginally. The population is bound to occur in the future which is an inevitable trend in the study area; consequently, adoption of high technical water-saving measures is advisable for the domestic sector to ensure the stable water utilization.

2. Raising the water price by 25% to reach to the net cost water price (0.084 Yuan/m$^3$) can cut down the unmet demand of demand sites a lot. According to the Guo’s (Guo, Feng et al. 2006) research on water price in middle reaches of Heihe River Basin, the acceptable water price for the farmers is 0.12 Yuan/m$^3$; thus raising the water price to 0.084 Yuan/m$^3$ is advisable and acceptable, which is just the first step for Zhangye city to raise up water price. The second step
### Table 4-13 The results of the scenarios and the corresponding recommendations

<table>
<thead>
<tr>
<th>Items</th>
<th>High population growth</th>
<th>Water price raising</th>
<th>Scenarios</th>
<th>Demand</th>
<th>Priority Changing</th>
<th>Supply Preference Changing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Results</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unmet demand of domestic meeting not marginally</td>
<td>Unmet demand of demand sites be cut down a lot</td>
<td>Unmet demand of “Forest &amp; Graze” is declining a lot, without affecting other demand sites</td>
<td>Unmet demand of “Forest &amp; Graze” and “Industry” increase year by year</td>
<td></td>
<td>Exhause of groundwater capacity more quicker</td>
<td></td>
</tr>
<tr>
<td>Recommendations</td>
<td>Acceptable and advisable</td>
<td>Not acceptable and advisable</td>
<td>Advisable</td>
<td>Not advisable</td>
<td>Not advisable</td>
<td>Not satisfactory</td>
</tr>
</tbody>
</table>

may be raising the water price to 0.12 Yuan/m³. Thereby, the recommendation is to increase the water price to 0.084 Yuan/m³, and then raise to 0.12 Yuan/m³ step by step and year by year continuously can ensure the requirement of water-saving society building in the future.

3. If the demand priorities of all the demand sites changed to be the same level, “some pay some gain”. The unmet demand of “Domestic” and “Agriculture” rise in the future till 2015 which is contrary to the stipulation of meeting the domestic water needs firstly in China, although the unmet demand of “Industry” and “Forest & Graze” drop down a lot. Hence, this scenario is not adoptable and advisable.

4. If the demand priority of “Forest & Graze” changed to as the same level as “Domestic” and “Livestock”, the unmet demand of “Forest & Graze” is declining a lot; while the unmet demand of other demand sites rises slightly. Followed by the instructional principle of recovery of the eco-environment in the study area, this scenario is fit for the governmental guideline which is contributing to the improvement of “water right system” and ecosystem.

5. If the demand priorities of “Forest & Graze” and “Industry” are both given to increasing two high level, the unmet demand of the other three demand sites increase year by year while the unmet demand of “Forest & Graze” and “Industry” decrease slightly. The improved effects are not desirable.

6. If the priority weightage is given more to the “Agriculture”, the unmet demand of “Agriculture” falls down and the speed of increasing slow down than other scenarios. Unfortunately, the unmet demand of “domestic” and “Livestock” rise almost three times till 2015 compared to the year of 2000, which is not desirable to the society stabilization and human health.

7. If just switching the priority of “Forest & Graze” and “Industry”, the impact of unmet demand for
all the demand sites will almost maintains as the same level compared to that of reference scenario, which is not satisfactory to the original intent.

8. If the supply preference of “Forest & Graze” and “Agriculture” change to “1” respectively in the scenarios, which means the supply source will meet the requirement of the two demand sites firstly; this leads to the exhaustion of groundwater capacity in the year of 2013 and 2011, respectively, which is more quicker than the reference scenario referring to exhaustion. This scenario will not adoptable and advisable.

All in all, as explained before, the scenario of “water price raising” and the demand priority changing are advisable and feasible for the requirement of improvement of current water right system, and with the inevitable population growth, the adoption of high technical water-saving measures is recommendatory. Therefore, one recommendation is to raise the water price to 0.084 Yuan/m³; another recommendation is paying more attention to the “Forest & Graze” up to as the same level as “Domestic” and “Livestock” is not only contributing to the recovery of eco-environment but also maintain the social-economic stable in the study area.
Chapter 5

Discussion, Conclusions & Recommendations

This thesis discussed three important issues: ① what is Water Right in the study area? ② how the current WUR system & WUR trading are working? ③ what could be the alternatives of WUR system and WUR trading to improve the water shortage problem? This chapter discussed the issues followed and draw the conclusions from the results of the research questions, then make recommendations for the future related research.

5.1 Discussion

There are seven research question posed in the Introduction. This section will discuss the results of the research questions and discuss them one by one.

Research question 1: Who are the subjects of the water right?

In Zhangye city, the water demand bodies are agriculture, industry, urban and rural households, livestock and ecosystem. Therefore, the farmers, citizens, livestock, industrial bodies and other organizations are the subjects of water right. Although the proprietary right of the water right belongs to the state or the agricultural collective economy, this research focus on the secondary ownership of the water right; these subjects have the secondary ownership to the water resource followed by the law or legal contract within the limited time.

Research question 2: What is water right in the middle reaches of Heihe River Basin?

Water right in Zhangye city has the attributes of possession, utilization, disposing and earning. The subjects of the water right in Zhangye city possess the water right. The farmers can sell or lend to the other people along with land right; the citizens and livestock can use the water right, for instance: irrigate farmland, drink water, swim in the river, wash clothes, clean the street, etc; the industrial bodies and other organizations can develop the water right, for instance, the waterworks can cleanse the water resource to make water commodity; the farmers can transfer the water right, for instance, water tickets can be exchanged freely between them.

Research question 3: What is the situation of water resource utilization in Zhangye City?

Since above 2/3 of the population is living by the farming in Zhangye city, agriculture irrigation is the biggest consumer of water resource, which accounts for above 80% of water utilization. The other consumer parts: industry, domestic and ecosystem account for 2.7%, 2.4%, 11%, respectively. How to transfer the water resource from the agriculture to other sectors to utilize water more efficiently and create more value for the society is the focal point of the water reallocation of the new WUR system.

Research question 4: How the water rights are allocated?
Water right is allocated through the amount of water resource level by level. From the river basin, province level to prefecture level and county level, from the town level, village level to water user association level and ends to water user level, the water right has been quantized levelly. Each water user should use water resource according to the water resource distributed. The water right allocation is giving the owners of water right the decision-making power to dispose the water resource distributed to them, also giving them the incentive to save water resource, which can make water flow to the high-efficiency using part.

| Research question 5: How the water use right trading is doing? |
| Water tickets play the important role during the WUR trading. And such kind of trading just happened between the farmers currently. It is crucial to make the WUR trading between different sectors, which can promote the economic development and put the water in the more efficient circulation system. |

| Research question 6: What kind of water right allocation is recommendatory for the study area in the near future? |
| One recommendation is to raise the water price to 0.084 Yuan/m³; another recommendation is paying more attention to the “Forest & Graze” up to as the same level as “Domestic” and “Livestock” is not only contributing to the recovery of eco-environment but also maintain the social-economic stable in the study area. Meanwhile, as the population growth in Zhangye city is bound to occur, it is advisable to adopt high technical water-saving measures, such as water-saving washing machine. |

| Research question 7: What will be the positive and negative consequences of the alternatives? |
| Raising the water price to the net cost water price (0.084 Yuan/m³) cut down the unmet demand of all the demand sites, while it is controversial to implement it officially; the current price (0.067 Yuan/m³) has been executed for ten years, what will be the real reaction for the water users for this price raising? This recommendation is just the alternative for improving the current WUR system. |

When put more weightage to the “Forest & Graze” as the same level as “Domestic” and “Livestock”, the unmet demand of “Forest & Graze” is declining a lot; while the unmet demand of other demand sites rises slightly. The dark side for this recommendation is the unmet demand of the other demand sites still keep slight rise; so, to get the win-win solution is still under the exploratory process.

5.2 Conclusion
This section is the summary of these results and discussions, which can be drawn in three aspects which are “water right”, “current situation of water right allocation and WUR trading” and “Alternatives for improving the current WUR system”:

| Water Right in Zhangye city can be defined as the subjects of WUR who possess the WUR to use, to trade, to transfer and to develop the water resource, which is split to the land right (some attached) and proprietary right of water resource; water use right is subordinate to proprietary right of water resource, which is granted by the state to the subjects of water resource so as to get the secondary ownership of water resource, then can exert the attributes of water right (possession right, use right, disposing right and earning right). |
In Zhangye city, water right was allocated through the amount of water resource level by level. From the river basin, province level to prefecture level and county level, from the town level, village level to water user association level and ends to water user level, the water use right has been quantized levelly. Each water user should use water resource according to the water resource distributed. And there are the water quotas stipulated for each sector (agricultural irrigation, industry, ecosystem, domestic water use), which provides the technical standard for the water utilization. The good combination of “water right allocation” and “water quota management” in Zhangye city stimulates the water-saving and water-using regulation in all the water use sectors.

Water use right certification and water tickets make the water trading carry through smoothly, although the current water trading just happened between the farmers. The good combination of “water use right certification” and “water tickets” make clear the water use right in Zhangye city and also are worth to be learned by the other areas in the northwest of China.

It is advisable to raise water price to 0.084 Yuan/m$^3$ currently and take the consideration to further raise water price to 0.12 Yuan/m$^3$ step by step and year by year. Apart from this alternative, paying more attention to the ecosystem part is crucial and essential for Zhangye city which is not only contributing to the recovery of eco-environment but also maintain the social-economic stable in the study area.

5.3 Limitation of the Research and Recommendations

Every research has the limitations because of the non-availability of data or the sample-study only for the research purpose; this research, of course, has its own limitations. They are presented with relevant recommendations as follows:

As the reason of limited research time, the field work in Zhangye city to distribute the questionnaires and do the interviews is not deeply enough. The WEAP modelling area is just one irrigation district in the middle reaches of Heihe River Basin. Hence, modelling all the irrigation districts in middle reaches of Heihe River Basin can provide more reliable and accurate alternatives and recommendations.

Since Heihe River is the closed inland river, the interaction of surface-ground water could be modelled further in WEAP to get more accurate model results in order to draw the reliable alternatives in the future.
Appendix A

Interview questions and Questionnaire

A.1 Interview for Director of Water Affair Department

1. Could you please introduce the responsibilities (duties) of the Heihe River Basin Administrative Bureau when implementing WUR system and WUR trading? How is centralized management working for water right system?

2. What is the water quantity measuring system and monitoring system? How do they system work? Do they satisfy the water users?

3. How much is the water fee per cubic meter? How the farmers think of the present water fee? What kind of role the ‘water fee’ play important in WUR system and trading?

4. What kind of water conflicts will happen frequently? What are the main reasons for the water conflicts?

5. How are WUR (Water Use Right) system and WUR trading working in Heihe River Basin these years (2002-2008)? What are the positive aspects and negative aspects? What are the measures for promoting the popularity of the WUR system and trading?

6. Are there any steps for water users to get the water use rights? Please introduce them.

7. Why choose Zhangye City as the first experimental city for the implementation of WUR system and WUR trading?

8. What are the main reasons of failure in water use right trading in 2002-2004?

   Social □  Technical □  Administrative □  Historical and cultural □  Legal
   Fiscal □  other □

   If it is “other”, please specify it:

9. What factors will affect the determination of water quotas for farmers?

   Area of farmland □  History usage □
   Laws and regulations □  Crops □  Income □  other □
If it is “other”, please specify it:

10. Are there the groundwater quotas?

Yes □ No □
If it is ‘yes’, please specify how it is defined?

11. Does the water quota can meet the actual water use? If not, why? How to deal with this problem for Heihe River Administrative Bureau? Are there any measurements or any contingency plans?

12. Please introduce the Overall Water Quantity Control and Water Quota Management in Water Use Right system.

13. Why we use symbols (water rights cards and water tickets) to represent WUR? Do the water rights cards and water tickets work at present? How do the symbols (water right cards and water tickets) work? How to get the water rights cards and water tickets?

A.2 Interview for Irrigation District Leader

1. What is farmland area in your irrigation district? What is the actual irrigation area? How many households in your irrigation district?

2. What crop the farmer plant? How much are the product revenue and household income in one year?

3. How do the farmers think of the current water price? If the water price doubles as the present, how they will react to it?

4. Which irrigation methods you are applying? How much is the efficiency?

5. What is the main water source? Is there any dam or reservoir?

6. Do the farmers know about the WUR system and water trading? Are there any methods applied to the publicity of the WUR system? Do they accept the system? Do they trade the water? What about the water-trading situation? Please introduce it.

7. How is the WUR system working these years（2002-2008）? Where are the problems? What are the difficulties for implementation of the WUR system and WUR trading?

8. What aspects needed to be improved?

9. What kind of water conflicts happen frequently? What are the main reasons?
A.3 Interview for Farmers

1. What are the areas of the farmland? What kind of crops you plant? How much irrigations area for each crop?

2. How much are the product revenue and household income in one year?

3. Which irrigation methods you are applying? How much is the efficiency?

4. What is the main water source? Is there any dam or reservoir?

5. What about the water quality? Do you think it is necessary to add wastewater treatment plant?

6. Do you think the water quantity measuring system is accurately measuring the allocated quota? Are there any monitoring system? How do the two system works?

7. Do the water quotas can meet the requirement?

8. Do you get the entire water quota? Do you get it on time? If there is water shortage, will you use groundwater to substitute the unmet surface water?

9. What do you think of the current WUR system and WUR trading? How you get the water right card and water tickets?

10. Do you accept the current system? Can you save water for water trading? (If not, Why not?) What kind of water users you are willing to trade with?

11. What are the problems you have experienced?

12. What kind of improvements you hope to be taken?

13. How do you think of the current water price? If the water price doubles as the present, how you will react to it?
A.4 Interview for Academic Expert

1. Under what situation the WUR system and WUR trading developed?

2. What are the positive and negative effects in water allocation when developed the WUR system and water trading in China? What do you think of the improvements for this system?

3. How is the working of WUR system and trading in China in recent years (2002-2008)?

4. What factors will affect the implementation of Water Use Right system and Water Trading?

5. What measures needed to be taken to improve current WUR system and WUR trading? What measures have been taken? What measures have not been taken?

6. Why choose Zhangye City as the first experimental site of WUR system and trading?

7. What are the main reasons for the not-success in implementation of WUR system and trading in 2002-2004?
A.5 Questionnaire for Farmers

Dear Sir/Madam:

I am Qian Ke, a postgraduate in Chang’an University and in pursuit of Master of Science Degree in Geo-information Management (GIM) at ITC, the Netherlands. The topic of my research is “Analyzing Water use right system and Water use right trading in China: case study in Heihe River Basin, Northwest of China”.

Heihe River Basin has chosen as the first experimental water use right trading area in China since 2002, till now, the Water use right system has experience six years. I want to know how this system and WUR trading works these years and to identify what changes needed to improve the current situation.

Now, I kindly ask you to fill the questionnaire and answer the following questions. I really appreciate your help. If you have any questions, please don’t hesitate to contact me.

Because of the limited time for me to finish my thesis, please send me back your answers as soon as you finish it. Thank you for your cooperation again.

Best regards

Qian Ke
Please fill this form first (personal information and basic information)

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Irrigation District</th>
<th>Educated Level</th>
<th>Farmland (Mu)</th>
<th>Annual water use (L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. How much will cost for planting these crops? (Fertilizer +water fees+ human resource) What about the water fees? How much revenue you can get by planting these crops?

<table>
<thead>
<tr>
<th>Item</th>
<th>Fees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total fees for planting Crops and fruits (fertilizer +water fees+ human resource)</td>
<td></td>
</tr>
<tr>
<td>Average water fee for one year (yuan)</td>
<td></td>
</tr>
<tr>
<td>Revenue for planting crops and fruits (yuan)</td>
<td></td>
</tr>
</tbody>
</table>

2. What are the water sources for irrigating the farmland?
Heihe River □ Well □ Fountain □ Reservoir □ Others □
If it is “Others”, Please specify them: __________________________

3. How much amount of water resource distributed to you annually?

_________________________
Is it enough?
Yes □ No □

Does the water distributed to you affect the income of you family?
Affect □ (Income better □ Income worse □ ) No affect □

Can you save water then sell to other people?
Yes □ No □

4. Has it happened the water shortage period?
Yes □ No □
If it is” yes”, how long the period of water shortage will last?

Within 5 days □ Within 10 days □ Within 15 days □
Within 20 days □ Within 25 days □ Above 25 days □

5. How do you think of the water resource distributed to you?
More □ Adequate □ Not enough □

6. What is the water price?

Water price: ________Mao (unit)_________Fen (unit)

If the water price is increasing by one Yuan(unit), will you save water?
Yes □ No □

7. Do you think the water user association good or bad?
Good □ Bad □

8. Do you think the process of applying and getting the water certificate is complicated or not ?
Complicated □ A little complicated □
Not complicated □ Simple and convenient □

9. Do you think the water measuring system accurate or not enough?
Accurate □ Not accurate enough □

Do you hope to improve the measuring system?
Yes □ No □

10. Are you satisfied with the current water use right system? Please add some suggestions and advice.

Satisfied □ Basically satisfied □ Not satisfied □

__________________________________________________  

__________________________________________________
Appendix B

Month Average streamflow of Liyuanhe River from 1959-2007

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Ave. Streamflow (m³/s)</th>
<th>Annual Streamflow (10⁸ m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1959</td>
<td>0.35</td>
<td>0.44</td>
<td>1.22</td>
<td>3.02</td>
<td>4.23</td>
<td>11.2</td>
<td>28.2</td>
<td>18.5</td>
<td>5.77</td>
<td>2.42</td>
<td>1.35</td>
<td>0.52</td>
<td>6.44</td>
<td>2.06</td>
</tr>
<tr>
<td>1960</td>
<td>0.41</td>
<td>0.38</td>
<td>0.55</td>
<td>1.13</td>
<td>5.78</td>
<td>8.03</td>
<td>21.5</td>
<td>20.1</td>
<td>4.38</td>
<td>2.95</td>
<td>0.87</td>
<td>0.60</td>
<td>5.59</td>
<td>1.77</td>
</tr>
<tr>
<td>1961</td>
<td>0.37</td>
<td>0.55</td>
<td>0.55</td>
<td>1.99</td>
<td>5.24</td>
<td>10.9</td>
<td>19.1</td>
<td>13.3</td>
<td>3.70</td>
<td>2.28</td>
<td>1.08</td>
<td>0.63</td>
<td>4.97</td>
<td>1.65</td>
</tr>
<tr>
<td>1962</td>
<td>0.19</td>
<td>0.29</td>
<td>0.52</td>
<td>1.08</td>
<td>2.75</td>
<td>7.19</td>
<td>21.3</td>
<td>18.4</td>
<td>8.48</td>
<td>6.61</td>
<td>1.88</td>
<td>0.49</td>
<td>5.76</td>
<td>1.82</td>
</tr>
<tr>
<td>1963</td>
<td>0.29</td>
<td>0.49</td>
<td>0.57</td>
<td>1.32</td>
<td>7.95</td>
<td>10.0</td>
<td>25.1</td>
<td>20.5</td>
<td>13.5</td>
<td>4.33</td>
<td>2.08</td>
<td>1.72</td>
<td>7.32</td>
<td>2.33</td>
</tr>
<tr>
<td>1964</td>
<td>0.44</td>
<td>0.24</td>
<td>0.65</td>
<td>2.06</td>
<td>14.9</td>
<td>22.9</td>
<td>40.3</td>
<td>21.0</td>
<td>7.32</td>
<td>4.00</td>
<td>1.51</td>
<td>0.59</td>
<td>9.66</td>
<td>3.06</td>
</tr>
<tr>
<td>1965</td>
<td>0.41</td>
<td>0.42</td>
<td>0.44</td>
<td>0.79</td>
<td>5.01</td>
<td>14.2</td>
<td>22.9</td>
<td>11.4</td>
<td>3.76</td>
<td>1.42</td>
<td>0.76</td>
<td>0.80</td>
<td>6.03</td>
<td>1.60</td>
</tr>
<tr>
<td>1966</td>
<td>0.55</td>
<td>0.55</td>
<td>0.43</td>
<td>0.68</td>
<td>2.61</td>
<td>10.4</td>
<td>24.3</td>
<td>26.8</td>
<td>15.9</td>
<td>4.56</td>
<td>1.7</td>
<td>0.89</td>
<td>7.45</td>
<td>2.37</td>
</tr>
<tr>
<td>1967</td>
<td>0.49</td>
<td>0.50</td>
<td>0.40</td>
<td>1.76</td>
<td>13.3</td>
<td>13.3</td>
<td>25.0</td>
<td>24.9</td>
<td>7.62</td>
<td>2.32</td>
<td>1.4</td>
<td>0.69</td>
<td>7.64</td>
<td>2.43</td>
</tr>
<tr>
<td>1968</td>
<td>0.34</td>
<td>0.26</td>
<td>0.51</td>
<td>1.28</td>
<td>2.25</td>
<td>5.90</td>
<td>14.6</td>
<td>10.4</td>
<td>9.02</td>
<td>1.37</td>
<td>0.37</td>
<td>0.78</td>
<td>3.97</td>
<td>1.26</td>
</tr>
<tr>
<td>1969</td>
<td>0.30</td>
<td>0.29</td>
<td>0.75</td>
<td>1.83</td>
<td>7.76</td>
<td>15.6</td>
<td>25.1</td>
<td>15.1</td>
<td>3.60</td>
<td>2.15</td>
<td>1.44</td>
<td>0.83</td>
<td>6.23</td>
<td>1.98</td>
</tr>
<tr>
<td>1970</td>
<td>0.39</td>
<td>0.43</td>
<td>0.51</td>
<td>1.32</td>
<td>7.39</td>
<td>8.90</td>
<td>14.6</td>
<td>20.0</td>
<td>5.18</td>
<td>1.38</td>
<td>0.85</td>
<td>1.19</td>
<td>5.26</td>
<td>1.68</td>
</tr>
<tr>
<td>1971</td>
<td>0.37</td>
<td>0.28</td>
<td>0.58</td>
<td>0.87</td>
<td>1.62</td>
<td>2.15</td>
<td>19.3</td>
<td>28.3</td>
<td>24.8</td>
<td>4.82</td>
<td>2.0</td>
<td>1.84</td>
<td>6.41</td>
<td>2.03</td>
</tr>
<tr>
<td>1972</td>
<td>0.91</td>
<td>0.61</td>
<td>0.29</td>
<td>1.96</td>
<td>11.3</td>
<td>10.0</td>
<td>29.3</td>
<td>30.8</td>
<td>7.75</td>
<td>2.42</td>
<td>1.59</td>
<td>1.42</td>
<td>8.24</td>
<td>2.63</td>
</tr>
<tr>
<td>1973</td>
<td>0.35</td>
<td>0.25</td>
<td>0.83</td>
<td>1.02</td>
<td>1.64</td>
<td>6.93</td>
<td>8.06</td>
<td>12.1</td>
<td>5.47</td>
<td>2.72</td>
<td>1.51</td>
<td>0.57</td>
<td>3.48</td>
<td>1.47</td>
</tr>
<tr>
<td>1974</td>
<td>0.45</td>
<td>0.39</td>
<td>0.29</td>
<td>1.51</td>
<td>2.68</td>
<td>9.10</td>
<td>10.7</td>
<td>17.2</td>
<td>8.75</td>
<td>2.96</td>
<td>1.62</td>
<td>0.43</td>
<td>4.67</td>
<td>1.33</td>
</tr>
</tbody>
</table>
### II: Month Average streamflow of Liyuanhe River from 1975-1991

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Ave. Streamflow</th>
<th>Annual Streamflow (10^8 m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>0.2</td>
<td>0.36</td>
<td>0.36</td>
<td>0.62</td>
<td>2.19</td>
<td>19.32</td>
<td>20.3</td>
<td>10.0</td>
<td>3.78</td>
<td>2.25</td>
<td>3.3</td>
<td>0.6</td>
<td>5.21</td>
<td>1.65</td>
</tr>
<tr>
<td>1976</td>
<td>0.53</td>
<td>0.46</td>
<td>0.38</td>
<td>1.28</td>
<td>3.91</td>
<td>17.94</td>
<td>23.22</td>
<td>26.12</td>
<td>3.7</td>
<td>3.31</td>
<td>2.28</td>
<td>0.92</td>
<td>7.5</td>
<td>2.38</td>
</tr>
<tr>
<td>1977</td>
<td>0.56</td>
<td>0.38</td>
<td>0.53</td>
<td>1.21</td>
<td>3.26</td>
<td>16.6</td>
<td>42.21</td>
<td>19.22</td>
<td>17.66</td>
<td>5.95</td>
<td>2.23</td>
<td>1.16</td>
<td>9.25</td>
<td>2.94</td>
</tr>
<tr>
<td>1978</td>
<td>0.66</td>
<td>0.52</td>
<td>0.74</td>
<td>3.19</td>
<td>3.94</td>
<td>9.32</td>
<td>20.51</td>
<td>16.84</td>
<td>22.96</td>
<td>3.87</td>
<td>2.09</td>
<td>1.15</td>
<td>7.15</td>
<td>2.30</td>
</tr>
<tr>
<td>1979</td>
<td>0.77</td>
<td>0.71</td>
<td>0.68</td>
<td>1.88</td>
<td>3.04</td>
<td>14.33</td>
<td>31.77</td>
<td>26.12</td>
<td>3.7</td>
<td>3.31</td>
<td>2.28</td>
<td>0.92</td>
<td>7.5</td>
<td>2.38</td>
</tr>
<tr>
<td>1980</td>
<td>0.77</td>
<td>0.64</td>
<td>0.83</td>
<td>2.5</td>
<td>9.3</td>
<td>22.93</td>
<td>25.7</td>
<td>15.79</td>
<td>8.0</td>
<td>3.2</td>
<td>1.93</td>
<td>0.90</td>
<td>7.66</td>
<td>2.46</td>
</tr>
<tr>
<td>1981</td>
<td>0.63</td>
<td>0.47</td>
<td>0.68</td>
<td>2.12</td>
<td>4.4</td>
<td>11.76</td>
<td>33.18</td>
<td>39.21</td>
<td>26.37</td>
<td>6.03</td>
<td>2.77</td>
<td>1.2</td>
<td>10.74</td>
<td>3.41</td>
</tr>
<tr>
<td>1982</td>
<td>0.88</td>
<td>0.74</td>
<td>10.8</td>
<td>2.14</td>
<td>14.24</td>
<td>21.76</td>
<td>18.9</td>
<td>14.10</td>
<td>3.93</td>
<td>2.06</td>
<td>1.07</td>
<td>7.65</td>
<td>2.41</td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>0.62</td>
<td>0.53</td>
<td>0.54</td>
<td>1.18</td>
<td>7.82</td>
<td>19.33</td>
<td>34.17</td>
<td>42.05</td>
<td>13.49</td>
<td>6.2</td>
<td>2.72</td>
<td>1.43</td>
<td>10.94</td>
<td>3.45</td>
</tr>
<tr>
<td>1984</td>
<td>0.74</td>
<td>0.53</td>
<td>0.62</td>
<td>1.86</td>
<td>3.72</td>
<td>25.6</td>
<td>35.28</td>
<td>18.75</td>
<td>6.22</td>
<td>2.81</td>
<td>1.54</td>
<td>0.82</td>
<td>8.25</td>
<td>2.61</td>
</tr>
<tr>
<td>1985</td>
<td>0.55</td>
<td>0.46</td>
<td>0.48</td>
<td>1.81</td>
<td>3.89</td>
<td>16.6</td>
<td>19.12</td>
<td>15.44</td>
<td>8.43</td>
<td>2.68</td>
<td>1.42</td>
<td>0.74</td>
<td>6.03</td>
<td>1.90</td>
</tr>
<tr>
<td>1986</td>
<td>0.46</td>
<td>0.41</td>
<td>0.47</td>
<td>0.7</td>
<td>9.81</td>
<td>23.68</td>
<td>29.3</td>
<td>20.03</td>
<td>4.7</td>
<td>2.53</td>
<td>1.64</td>
<td>0.76</td>
<td>7.89</td>
<td>2.49</td>
</tr>
<tr>
<td>1987</td>
<td>0.45</td>
<td>0.41</td>
<td>0.47</td>
<td>1.9</td>
<td>6.67</td>
<td>43.55</td>
<td>20.66</td>
<td>17.36</td>
<td>5.33</td>
<td>2.67</td>
<td>1.79</td>
<td>0.95</td>
<td>8.5</td>
<td>2.69</td>
</tr>
<tr>
<td>1988</td>
<td>0.48</td>
<td>0.43</td>
<td>0.44</td>
<td>1.99</td>
<td>10.31</td>
<td>25.42</td>
<td>25.79</td>
<td>25.77</td>
<td>9.49</td>
<td>4.83</td>
<td>2.9</td>
<td>1.06</td>
<td>9.08</td>
<td>2.86</td>
</tr>
<tr>
<td>1989</td>
<td>0.60</td>
<td>0.58</td>
<td>0.62</td>
<td>2.92</td>
<td>16.72</td>
<td>20.53</td>
<td>35.4</td>
<td>16.19</td>
<td>16.84</td>
<td>3.91</td>
<td>2.56</td>
<td>1.10</td>
<td>9.83</td>
<td>3.12</td>
</tr>
<tr>
<td>1990</td>
<td>0.61</td>
<td>0.47</td>
<td>0.73</td>
<td>1.01</td>
<td>7.9</td>
<td>11.23</td>
<td>26.06</td>
<td>18.29</td>
<td>6.96</td>
<td>1.75</td>
<td>1.45</td>
<td>0.98</td>
<td>6.51</td>
<td>2.06</td>
</tr>
<tr>
<td>1991</td>
<td>0.56</td>
<td>0.48</td>
<td>0.53</td>
<td>0.96</td>
<td>4.84</td>
<td>11.49</td>
<td>11.05</td>
<td>18.89</td>
<td>5.17</td>
<td>2.08</td>
<td>1.83</td>
<td>0.89</td>
<td>4.9</td>
<td>1.56</td>
</tr>
</tbody>
</table>
### Month Average streamflow of Liyuanhe River from 1992-2007

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Ave. Streamflow (m³/s)</th>
<th>Annual Streamflow (10⁸ m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>0.48</td>
<td>0.43</td>
<td>0.48</td>
<td>0.82</td>
<td>2.96</td>
<td>12.73</td>
<td>18.35</td>
<td>14.81</td>
<td>5.7</td>
<td>2.68</td>
<td>1.5</td>
<td>0.86</td>
<td>5.18</td>
<td>1.64</td>
</tr>
<tr>
<td>1993</td>
<td>0.49</td>
<td>0.53</td>
<td>0.69</td>
<td>3.64</td>
<td>4.22</td>
<td>16.98</td>
<td>36.81</td>
<td>31.00</td>
<td>9.82</td>
<td>3.52</td>
<td>2.42</td>
<td>1.09</td>
<td>9.35</td>
<td>2.95</td>
</tr>
<tr>
<td>1994</td>
<td>0.65</td>
<td>0.66</td>
<td>0.57</td>
<td>1.34</td>
<td>3.10</td>
<td>12.82</td>
<td>27.53</td>
<td>12.15</td>
<td>9.13</td>
<td>5.87</td>
<td>2.09</td>
<td>0.94</td>
<td>6.40</td>
<td>1.94</td>
</tr>
<tr>
<td>1995</td>
<td>0.52</td>
<td>0.48</td>
<td>0.57</td>
<td>1.34</td>
<td>4.48</td>
<td>5.39</td>
<td>22.62</td>
<td>16.71</td>
<td>20.99</td>
<td>3.79</td>
<td>2.19</td>
<td>1.02</td>
<td>6.68</td>
<td>2.11</td>
</tr>
<tr>
<td>1996</td>
<td>0.63</td>
<td>0.48</td>
<td>0.55</td>
<td>2.41</td>
<td>5.78</td>
<td>10.36</td>
<td>29.56</td>
<td>27.08</td>
<td>8.94</td>
<td>3.13</td>
<td>1.69</td>
<td>1.05</td>
<td>7.04</td>
<td>2.42</td>
</tr>
<tr>
<td>1997</td>
<td>0.68</td>
<td>0.46</td>
<td>0.85</td>
<td>1.5</td>
<td>6.31</td>
<td>10.38</td>
<td>16.21</td>
<td>15.46</td>
<td>5.76</td>
<td>2.12</td>
<td>1.54</td>
<td>0.86</td>
<td>5.18</td>
<td>1.65</td>
</tr>
<tr>
<td>1998</td>
<td>0.48</td>
<td>0.46</td>
<td>0.53</td>
<td>1.52</td>
<td>7.12</td>
<td>16.18</td>
<td>39.16</td>
<td>31.12</td>
<td>17.81</td>
<td>5.77</td>
<td>2.56</td>
<td>1.39</td>
<td>10.34</td>
<td>3.29</td>
</tr>
<tr>
<td>1999</td>
<td>0.9</td>
<td>0.74</td>
<td>0.68</td>
<td>1.33</td>
<td>2.26</td>
<td>10.05</td>
<td>26.36</td>
<td>23.96</td>
<td>10.39</td>
<td>3.44</td>
<td>2.09</td>
<td>1.13</td>
<td>6.99</td>
<td>2.20</td>
</tr>
<tr>
<td>2000</td>
<td>0.74</td>
<td>0.53</td>
<td>0.68</td>
<td>1.07</td>
<td>2.55</td>
<td>20.02</td>
<td>25.49</td>
<td>19.74</td>
<td>10.25</td>
<td>5.2</td>
<td>2.57</td>
<td>1.26</td>
<td>7.56</td>
<td>2.38</td>
</tr>
<tr>
<td>2001</td>
<td>0.74</td>
<td>0.58</td>
<td>0.67</td>
<td>1.23</td>
<td>3.14</td>
<td>6.92</td>
<td>14.55</td>
<td>12.88</td>
<td>17.22</td>
<td>5.15</td>
<td>2.58</td>
<td>1.12</td>
<td>5.59</td>
<td>1.76</td>
</tr>
<tr>
<td>2002</td>
<td>0.78</td>
<td>0.6</td>
<td>0.66</td>
<td>1.16</td>
<td>4.58</td>
<td>19.27</td>
<td>29.39</td>
<td>21.95</td>
<td>11.59</td>
<td>3.33</td>
<td>2.01</td>
<td>1.26</td>
<td>8.1</td>
<td>2.56</td>
</tr>
<tr>
<td>2003</td>
<td>0.79</td>
<td>0.62</td>
<td>0.75</td>
<td>1.96</td>
<td>8.67</td>
<td>12.93</td>
<td>19.46</td>
<td>24.06</td>
<td>12.93</td>
<td>7.5</td>
<td>3.47</td>
<td>1.42</td>
<td>7.93</td>
<td>2.50</td>
</tr>
<tr>
<td>2004</td>
<td>0.83</td>
<td>0.63</td>
<td>0.76</td>
<td>3.4</td>
<td>6.97</td>
<td>12.85</td>
<td>17.47</td>
<td>20.97</td>
<td>8.02</td>
<td>3.2</td>
<td>1.98</td>
<td>1.2</td>
<td>6.56</td>
<td>2.07</td>
</tr>
<tr>
<td>2005</td>
<td>0.76</td>
<td>0.55</td>
<td>0.71</td>
<td>2.88</td>
<td>6.28</td>
<td>15.66</td>
<td>27.27</td>
<td>30.30</td>
<td>16.25</td>
<td>6.96</td>
<td>2.64</td>
<td>1.41</td>
<td>9.37</td>
<td>2.95</td>
</tr>
<tr>
<td>2006</td>
<td>0.93</td>
<td>0.73</td>
<td>0.71</td>
<td>1.70</td>
<td>6.35</td>
<td>9.87</td>
<td>29.42</td>
<td>27.66</td>
<td>11.51</td>
<td>5.0</td>
<td>1.83</td>
<td>1.63</td>
<td>8.19</td>
<td>2.58</td>
</tr>
<tr>
<td>2007</td>
<td>0.83</td>
<td>0.72</td>
<td>0.75</td>
<td>1.86</td>
<td>10.5</td>
<td>16.57</td>
<td>33.22</td>
<td>24.14</td>
<td>16.86</td>
<td>13.08</td>
<td>3.69</td>
<td>2.12</td>
<td>10.45</td>
<td>3.29</td>
</tr>
<tr>
<td>Ave</td>
<td>0.57</td>
<td>0.49</td>
<td>0.60</td>
<td>1.67</td>
<td>5.60</td>
<td>14.28</td>
<td>24.85</td>
<td>21.42</td>
<td>8.43</td>
<td>3.91</td>
<td>1.97</td>
<td>1.04</td>
<td>7.27</td>
<td>2.30</td>
</tr>
</tbody>
</table>
Appendix C

Water Price for the Savings of Demand-side Management

1. Suppose an equation: \[ y = ax + b \]
2. Condition: When the water price is increasing at 10\%, the amount of water using will cut down 5\%; when the water price is increasing at 40\%, the amount of water using will cut down to 10\%.
   
   \[ 10 = 5a + b \quad (1) \]
   \[ 40 = 10a + b \quad (2) \]

3. Resolve the coefficients:
   
   \[ a = 6 \]
   \[ b = -20 \]

4. Equation: \[ y = 6x - 20 \]

5. Relate to the current situation: current water price of 0.067 Yuan/m\(^3\) increases by 25\% reach to the net cost water price of 0.084 Yuan/m\(^3\).
   
   \[ 25 = 6x - 20 \]

5. Conclusion: \[ x = 7.5 \]

The amount of water using will cut down to 7.5\%. 
Reference


RCWR (2001). The current situation, problems and countermeasures for water right trading: water rights and water market. 2. w. r. a. regulations.


