"Making do with what we have"

Understanding drought management strategies and their effects in the Zayandeh Rud Basin, Iran.

M.Sc. Thesis by Jaime D. Hoogesteger van Dijk

June 2005

Irrigation and Water Engineering Group (IWE)
International Water Management Institute (IWMI)

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Master thesis Irrigation and Water Engineering submitted in partial fulfillment of the degree of Master of Science in International Land and Water Management at Wageningen University, the Netherlands.

Jaime D. Hoogesteger van Dijk

June 2005

Supervisor(s):

Linden Vincent

Irrigation and Water Engineering Group
Centre for Water and Climate
Wageningen University
The Netherlands
www.dow.wau.nl/iwe

Francois Molle

International Water Management Institute
P.O. Box 2075
Colombo
Sri Lanka
www.iwmi.cgiar.org

Research done as part of the Basin Synthesis Study of the Zayandeh Rud Basin, Iran, within the Comprehensive Assessment of Water Management in Agriculture Program (CA) of the International Water Management Institute (IWMI).

Each morning a thousand Roses brings you say;
Yes, but where leaves the Rose of yesterday?
And this first summer that brings the Rose
Shall take Jamshyd and Kaikobad away.

Well let it take them! What have we to do?
…

Some sigh for the glories of this world;
And some sigh for the prophet's paradise to come.
Ah take cash and let the credit go
And do not heed the rumble of a distant drum!
…

Myself when young did eagerly frequent
Doctor and Saint, and heard great argument
About this and that; but evermore
Came out by the same door where in I went.

With them the seed of Wisdom did I sow,
And with mine own hand wrought to make it grow;
And this was all the Harvest that I reaped
"I came like Water, and like wind I go."
…

Ah Love! Could you and I with Him conspire
To grasp this sorry Scheme of Things entire,
Would not we shatter it to bits ---
And then remould it nearer to the Heart's Desire!

Rubaiyat of Omar Khayyam

"The only ethical decision is to take responsibility for our own existance and that of our children."

- Bill Mollison (2004; p. 1)

… dedicated to all the people that depend on agriculture for the provision of their day to day basic needs as it is their sweat and toil that fills our bellies…

Foreword and acknowledgements

As you read this, the words I have written come alive and in the process give my thesis a reason for being. Although this is my second thesis, the process of writing a research proposal, doing field work and finally writing a thesis has once again been a long learning process for me. During the process I have had a lot of time to reflect about reality and how we interpret and think about it; as a result, during the writing process I always kept the following quote in the back of my mind.

> "*In the process of thinking about the world, we categorize and interpret experience and events according to the structures available to us, and, in the process of interpreting, we lend these structures solidity and a normality which is often difficult to question.*"

-Sarah Mills 2003, 56

I got involved in this thesis because water management greatly interests me and because for me it was a great challenge to do my thesis in a country that was totally strange and new. The project in Iran was a place which met my personal interests and goals. Doing research and living in Iran was a very hard and instructive experience full of personal growth. The first day I got there, the only thought that went through me was "I want to go home and out of here". I greatly want to thank Flip Wester, Linden Vincent and my parents for convincing me to push on through and stay in Iran.

My fieldwork in Iran was challenging. The day to day struggles to get the information I needed often disappointed me, the language barrier frustrated me and the cultural differences impressed me but I am thankful for these hurdles as I greatly learned from them. The long walks I took along the calm waters of the Zayandeh Rud (that passes through the city of Esfahan), or a visit to the cultural heritages of the city were great moments of reflection after a day of field work. Esfahan is a beautiful city and I really enjoyed its sphere and its people.

I want to sincerely thank my translators and above all friends Ali and Reza Mahbod. Both of you always had so much patience with me during the interviews, and long walks during the field observations that it kept me pushing on. Ruzbe (my driver) I always appreciated your good humor and hearty laugh; it was great to drive in the freshness of the early morning to the fields and return home in the midst of the afternoon heat. Ali, Reza, Ruzbe, Amir, Fathema and Edo I greatly thank you, as friends, for your support and wonderful moments together. The family Mahbod I also want to thank for taking me into their family and home (the volleyball matches on Thursdays were awesome!).

Iran Ghazi my sincere appreciation goes to you as without your support during the field work it would not have been possible to conduct the work I did. As a person I learned a lot from your dedication in making your society a better place to live in. Alireza Mamanpoush, I spent a great time with you discussing my preliminary results and sharing our ideas on water management. Asad Qureshi, although we only met shortly in Tehran, I really appreciated your support and our time and conversations together as it made me understand my personal and research struggles much better.

I also want to thank my supervisors Francois Molle and Linden Vincent. Francois, although we only saw each other for a couple of days in Esfahan, I learned a lot from your joy of living, your enthusiasm, dedication and analytical insights. Your sharp comments on my draft

version I also really appreciate. Linden, I really enjoy working with you; your soft yet very sharp comments on my work have given me great insights and motivation to develop my ideas on irrigation and water management.

As I write these last words of my thesis I want to thank everybody for the patience you have had with me during the process of writing this thesis. Through personal struggles and circumstances it has taken me a lot more time to finish this project than was planned. Nevertheless I am happy with the results of this long process of learning, reflecting and writing. As a last thought, (even though it is hard to acknowledge during the process), I am convinced that the purpose of achieving something is embedded in the process involved in getting there and not in the end result itself. As I look back on it, I see a difficult but good time of which the nice moments will be remembered!

I have written at times in the first person, to indicate that it is not a detached, impersonal or even unbiased document. "Every book or publication has an author, and what that author chooses to write about is subjective, for that person alone determines the subject, content and the values expressed or omitted" (Mollison, 2004 p. 1).

I hope that as reader, you enjoy reading the material and results presented in this thesis!!!

Jaime Hoogesteger
June, 2005
Wageningen, The Netherlands

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Abstract

Droughts usually lead to scarcity of water resources and create challenges for water managers and farmers. In the Zayandeh Rud basin, in the past five years, a historical low rainfall in the head of the basin, combined with a growing demand for water, has triggered changes in water management at basin and irrigation system level. At basin and irrigation system level these changes basically imply creating a broader decision making body at basin level and reducing the allocations to agriculture while spreading the remaining water among other water use sectors. In view of such measures, farmers have been forced to find strategies to cope with water scarcity at field level. The used strategies are mainly increasing groundwater use, adapting the production strategies, or shifting their livelihoods to other activities. This study is based on the analysis of institutional and irrigation practices within the basin and the Abshar Irrigation System. Based on this analysis some options to increase the 'room to maneuver' at outlet level are explored.

Summary

The management of water resources poses a great challenge for water management agencies because, as the population of a specific area increases, competition for water intensifies. Droughts usually lead to or accentuate scarcity of water resources. As a consequence water managers are forced to devise coping strategies to manage a reduced water supply. Which strategies are used and how these develop is location specific and determined by the context in which water managers operate. This study explores and analyzes the responses developed by water managers and farmers to deal with drought under conditions of conjunctive water use in the Zayendeh Rud Basin.

The Zayandeh Rud basin in central Iran, with an area of 41,500 km^2, is dealing with an increased pressure on water resources since at least the 1980's. Because the majority of the basin is a typical arid and semi-arid desert, agriculture depends almost entirely on irrigation water from surface and groundwater resources. The bulk of surface water in the basin flows through the Zayandeh River which is controlled by the Chadegan Dam (with a 1,500 million cubic meter (MCM) capacity in its reservoir) and by two major diversion weirs at Nekoabad and Abshar. Each diversion weir controls both a Left Bank and Right Bank Main Canal. The main irrigation systems are characterized by institutionally managed large scale canals with automatic upstream control through NEYRPIC systems and volumetric water delivery regulated with 'modules a masque'. Presently about 21,200 tube wells, 1,726 qanats and 1,613 springs exploit a total of 3,619 MCM of groundwater a year. Studies conducted by the Esfahan Water Authority (EWA) in 2000 reveal that several aquifers are being over-exploited, especially in some of the irrigated areas. The city of Esfahan, with almost two million inhabitants, and its fertile plains, form the main socio-economic area of the basin.

In the Zayandeh Rud basin, in the past five years, a historical low rainfall in the head of the basin, combined with a growing demand for water, has triggered great changes in water management at basin and system level. In view of these changes, farmers have been forced to find strategies to cope with water scarcity at field level. The responses and strategies designed to manage the drought that started in 1999 are studied in this document at three different levels. The levels are the basin level, the irrigation system level and the outlet or field level.

At basin level water is managed by the EWA that is in turn administered by the Ministry of Energy. At this level the responses that have developed as a reaction to drought are the creation of a basin council that decides the main lines of water allocation in the basin,

the division of the basin in two main irrigation zones, the reduction of the diversions to agriculture and the reallocation of the little surface water there is while turning a blind eye on groundwater exploitation. In order to spread the scarcity of the basin and ensure agricultural production the irrigation systems of the basin have been divided in two zones; the upper basin (up to the city of Esfahan) that receives water in the summer season for the production of rice, and the lower basin which receives water in the winter season for the production of wheat and barley. Beside this measure, the EWA has allocated water to newly constructed irrigation systems to compensate for the loss of groundwater supply that originates from the lowering of the aquifer levels due to over-exploitation and drought. The main political strategy, which is aimed at preventing social unrest and massive migration flows from rural areas to the cities which are not able to absorb these population flows, has led to a "sharing of the cake" to as many beneficiaries as possible.

The Mirhab (decentralized irrigation network management institution) is responsible for irrigation water management in the basin. It has a very effective control over canal water up to the outlet and all irrigation networks are very well operated, managed and maintained. In the Abshar Irrigation System (AIS), the Mirhab has managed a reduced water inflow by reducing the allocations to the outlets. The reductions made are based on: the degree of groundwater use in the outlet, the kind of water rights the outlets have and the special conditions and socio-political networks that exist in these outlets. Once these reductions per outlet are made, all outlets are reduced in proportion to the main canal inflows.

At outlet level most farmers operate in a conjunctive water use setting in which they have access to both surface and groundwater. At this level farmers have adopted several coping strategies that are, in first instance, aimed at maintaining their full water supply level, mostly by the increased use of groundwater. Only when this possibility is non-existent, do farmers search other solutions to 'make do with what they have'. The strategies developed to deal with water scarcity include; selling land, water stealing, sharing water within the outlets, and reducing the area cropped, changing the crop pattern, renting land elsewhere or moving to other activities outside of agriculture. These strategies are guided and shaped by the context in which the farmers operate and by the personal rationale every individual follows.

The study of the institutional and irrigation practices of an irrigation system gives a basis to assess the possibilities to install seasonal reallocation mechanisms between outlets. The study of the practices in the AIS shows that there are opportunities for the introduction of market mechanisms for the introduction of seasonal reallocations between outlets. The technical design of the irrigation system, strict control over surface water, accurate volumetric water delivery through the use of 'modules a masque', and strict administration by the Mirhab enable an easy transfer of water from one outlet to another in which the Mirhab would have a role as mediator. At outlet level the present practices of water sharing and groundwater transactions also set a good basis for the management of seasonal surface water markets. There are basically two possibilities to establish water transactions between outlets per season: a) trade water before the start of the season; and b) trade water during the season. At the moment the most restricting factor is that the idea of selling surface water is not culturally accepted. This can be attributed to the fact that water is not treated as an economic good as it has several cultural values. Nevertheless a pilot project could be started in a large secondary canal and if successful expanded to the whole system.

Conjunctive water management, which is often advocated as a 'pandora box' solution to increase water management and use efficiency in irrigation systems with surface and groundwater use is, under present circumstances, in AIS still not a feasible solution. The main constraining factors at the moment are that there is too little knowledge on aquifer dynamics, the management of surface and groundwater is disjoint and there is little control over groundwater use.

With regards to groundwater use it is expected that once the drought ends, the wells installed during the drought will become permanent sources of water even if normal water flow conditions return to the irrigation network because there is no strict control on pumping levels. As the number of farmers with access to groundwater through the installation of new wells has increased, so groundwater use will also be higher after the drought. This process of groundwater development and the increase of its use might lead to ever increasing levels of over-exploitation even in years of normal surface water supply unless an effective regulation mechanism is used.

Glossary

AIS	Abshar Irrigation System used as the research site for the field work. It consists of a Left Bank and a Right Bank (See annex 2 for a map).
IAERI	Iranian Agricultural Engineering Research Institute
IS	Irrigation System.
IWMI	International Water Management Institute
IWE	Irrigation and Water Engineering Group at Wageningen University.
EWA	Esfahan Water Authority, dependent of the national Ministry of Energy and responsible for water management in the Zayandeh Rud Basin.
Jerib	Persian land measuring unit which compromises 1000 m^2.
Jough	In the traditional irrigation rules one of the six irrigated areas in a six day rotation of irrigation water.
MCM	Million Cubic Meters
MD	Manager Director of an institution
Mhadi	Old irrigation canals used to divert water from the Zayandeh River.
Mirhab	The institution charged with the management of the irrigation systems within the Zayandeh Rud Basin.
O&M	Operation and Maintenance within the irrigation context.
Qanat	Qanats consist of horizontal wells dug to reach groundwater at the base of hills, and consist of a "mother well" that reaches a water table followed by a gallery with a gentle slope that transports the water to the surface of the ground. In Iran qanats have been used for centuries.
Rial	The official Iranian currency is the Rial which is € 0.0001; a Toeman is 10 Rials (See Toeman).
Toeman	Iranian currency with an equivalent of €0.001; one toeman is the equivalent of 10 Rials which is the official Iranian currency (See Rials).

Chapter 1 The Zayandeh Rud basin, an introduction

The objective of this chapter is to provide the introduction and background of the present study. This MSc thesis deals with the adaptation strategies water managers at basin and Irrigation System (IS) level and farmers at field level have developed since 1999 as a result of drought induced water scarcity in the Zayandeh Rud Basin, Iran. The drought placed pressure on water resources, agriculture and society in general. In Iran the drought affected 60% of the rural population, caused severe reductions in agricultural and livestock production and also greatly affected the environment (90% of the wetlands of the countries dried up) (Qureshi, 2004). Nevertheless little is known about how society has adapted to such a situation of water scarcity. This thesis explores how in the Abshar Irrigation System (AIS) farmers and the authorities have managed drought.

1.1 The study in a broader perspective of water management

The growing knowledge of the interrelated nature of anthropogenic water uses and of the natural water cycle within a basin have led to the awareness that water management needs special attention in water short basins. As irrigation is the major water user worldwide, with an average consumptive use of 70%, managing surface- and groundwater resources in irrigation systems for optimal productivity under conditions of drought is an essential issue. Constraints to the availability of water are increasingly evident in many countries as river basins close, environmental degradation accelerates and competition for water intensifies. (Perry and Narayanamurthy, 1998; Molle, 2003; Wester, 2003; Oranje, 2002).

Today the challenge for water managers is to handle water resources of a basin in a manner that is pro-poor and sustainable. This becomes hard in situations where the water supply is reduced either by a natural drought, the intensification of water use or the dependence of fossil groundwater resources and/or the combination of these two. In the Zayandeh Rud basin, in the past five years, a historical low rainfall in the head of the basin, combined with a growing demand for water, has triggered great changes in water management at basin and system level. In view of these changes, farmers have been forced to find strategies to cope with water scarcity at field level since the irrigated agricultural sector is the water use sector that has taken the brunt of this scarcity.

The present MSc Thesis studies the responses of farmers and the government to drought induced water scarcity through a case study of irrigation practices in a conjunctive water use setting in the AIS, in the Zayandeh Rub Basin, Iran. In this study, the strategies farmers have devised to manage scarcity through the use of surface and groundwater in a tertiary irrigation unit play a central role.

This study is executed as part of the Comprehensive Assessment for Water Management in Agriculture (CA) that is conducted by the International Water Management Institute (IWMI) and its partners. Its aim is to contribute to the creation of a knowledge base for use by practitioners, planners, resource managers (at local level), and by development agencies, policy makers, donors and researchers in addressing the complex issues of integrated water resources management.

1.2 Iran, agriculture and water

Iran, or Persia, as it was known until 1935, has an area of 1.65 million km², with an estimated population of 71.4 million, and a Gross Domestic Product of US$110 billion. At present Iran is the second largest OPEC oil producer and has the world's largest reserves of natural gas. The economy of the country is mostly based on the export of crude and refined petroleum[1].

[1] http://www.unicef.org/infobycountry/iran.html, 01-06-2005).

The territory of Iran, with the exception of the northern Caspian region and the high elevations of the mountain ranges, consists mainly of desert and is one of the most arid regions of the world.

The history of population settlement in Iran goes back to the earliest periods of world civilization. In 550 B.C. Cyrus brought the Medes and the Persians together to make Iran, for the first time, the dominant power in Asia and the Near East. In the next thousand years, Iran remained one the richest and most powerful countries of the ancient world. It came to an end with the Arab conquest in the middle of the seventh century A.D. The new period of Islamic civilization has characterized Iran's history for the last thirteen centuries. In 1906 the reform movement known as the constitutional revolution made an end to a tradition of absolute rule dynasties. In 1925 power was sized by an army officer, Reza Khan, but effective power remained highly concentrated in the hands of the Shah until the 1979 revolution (guided by Ayatollah Khomeini) that set the religious leaders at the head of the country.

It was only after 1930 that an administrative structure was established in the country. The aim of this structure was to promote development through fiscal and monetary control, expenditure on public infrastructure, modern education and health, the establishment of industries and the encouragement of trade. The period coincided with the first large-scale development of Iran's huge oil reserves, which provided the resources for investment[2].

The development of the oil sector was seen by the central governments as the ‘road to modernity’ during the twentieth century. Starting in 1949 the country started off with its first Development Plan. In this first plan as well as in the ones that followed agriculture played and important role, especially the irrigation sector. The dedication of the government to hydraulic engineering was evident in the different development plans that appeared in the period between 1949 and 1983. In this period the construction of large scale dams for the expansion of the irrigated frontier was a high priority and the single highest investment post in the agricultural sector. The first dams built where in the Sefid Rud, the Dez and Karaj rivers. These three projects marked the starting point of a dam construction period that continues to the present. Beside these developments several land reform programs aimed at reducing the landlord holdings, modernizing agriculture and improving the rural conditions were implemented in the country. The results of these land reform programs are contested as they did not significantly raise agricultural production and the effects of them varied a lot from region to region (McLachlan, 1988).

The revolutionary movement that overthrew the monarchy at the beginning of 1979 did not bring the expected changes to the agricultural sector and continued almost on the same path as had been followed by the Shah. The new regime lacked the ability to construct a thorough development strategy as it was overtaken by the management of the day-to-day problems of domestic agriculture and the county’s food import needs. One of the largest consequences of the revolution on agriculture is that it turned the focus of production towards self-sufficiency and the internal market as Iran was put under US trade sanctions. This internal orientation is slowly shifting again as the government turns toward more liberal policies.

At present agriculture contributes just over 20% to the gross national product and employs a third of the labour force. The main food-producing areas are in the Caspian region in the north and in the valleys of the northwest. As mentioned above, the total area under irrigation has been increasing since the turn of the century. In 1994, 27 storage dams were in operation with a total regulation capacity of 39.2 km^3. At the same time, 24 storage dams were under construction with an added design regulation capacity of 11.5 km^3[3]. In 1980 the

[2] http://www.undp.org.ir/iran-facts.asp, 05-06-2005

[3] http://www.fao.org/ag/agl/aglw/aquastat/countries/iran/index.stm 05-06-2005

irrigated area was 4.9 million ha. and it has expanded to 7 million ha. in 1990 and 7.5 million ha. in 2000 (FAOSTAT, 2003 in UNDP, 2003). The total agricultural, domestic and industrial water withdrawal was estimated at about 70 km³ in 1993 (of which 91.6% is used for agricultural purposes, 6.3% for domestic use and 2.1% for industrial use); total consumption of water in 2000 was around 1,000 m^3 pp/year.

1.3 The Zayandeh Rud Basin

The Zayandeh Rud basin (Figure 1.1) is situated in the centre of Iran and covers an area of 41,500 km^2. The basin originates in the Zagros Mountains at altitudes of around 2300 m, where rainfall and snow are abundant[4], and closes in the Gavkhuni swamp at an altitude of 1466 m. The majority of the basin is a typical arid and semi-arid desert. The city of Esfahan, with almost two million inhabitants, and its fertile plains[5], form the main socio-economic area of the basin. Esfahan lies at an altitude of around 1800 m and has an average annual precipitation of 130 mm, concentrated in the November-April period. Temperatures are hot in the summer, reaching an average of 30°C in July, but are cool in the winter dropping to an average minimum temperature of 3°C in January. Annual potential evapo-transpiration is 1500 mm (Molle *et al.*, 2004).

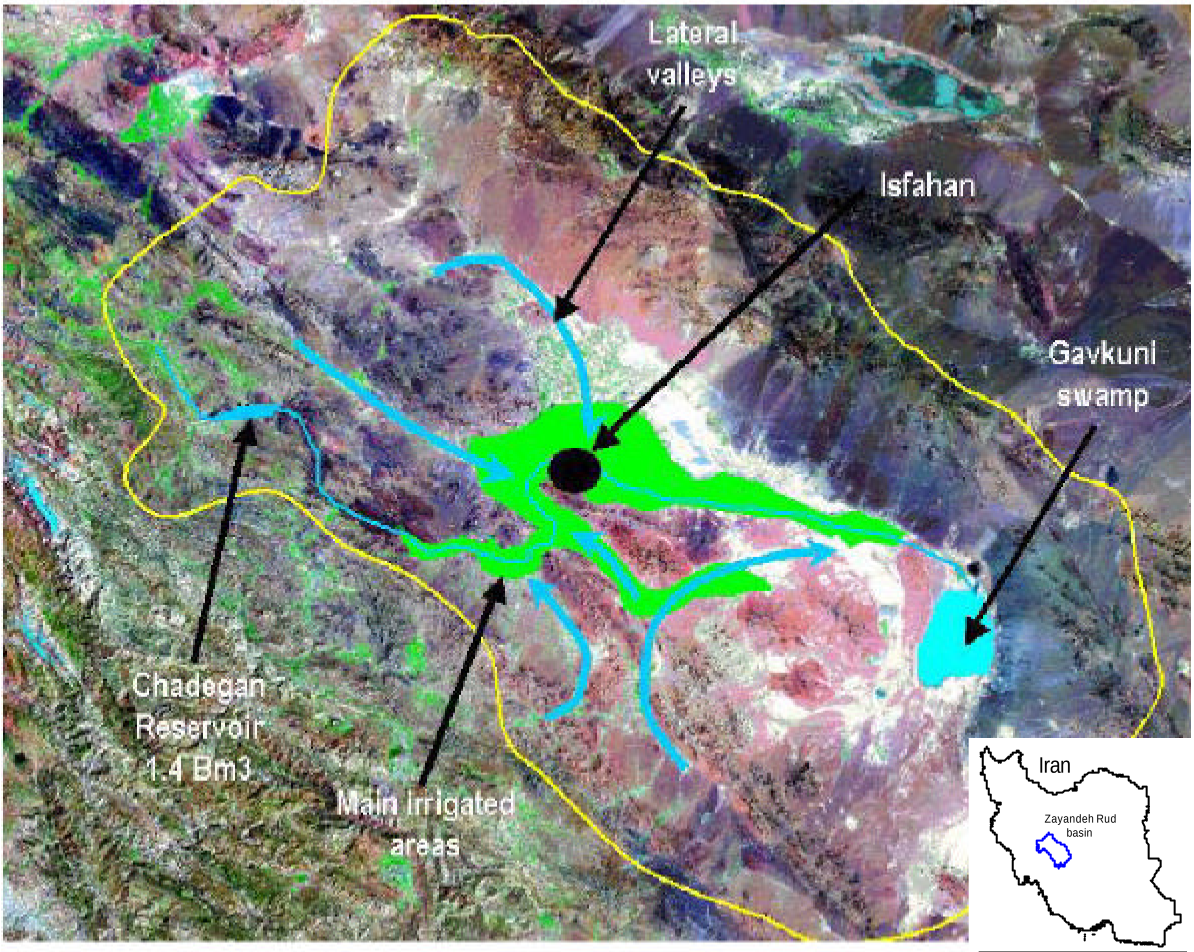

Figure 1.1 The Zayandeh Rud basin in central Iran with its irrigate areas

4 In the head of the basin at high altitudes precipitation averages at around 1700 mm a year.

5 The fertile plains are constituted by alluvial deposits flanking the Zayandeh Rud where slopes are gentle and soils have good soil moisture holding capacities (Salemi *et al.,* 2000).

In the lower and dryer parts of the basin, irrigation is a must for agricultural production. For centuries, water from the Zayandeh Rud River has been diverted to supply the city of Esfahan with water and to irrigate its gardens and neighboring areas. The peak flows from April to June provided the basis for widespread downstream irrigation using simple diversion structures, called *mahdis*, to make productive use of floodwaters (Salemi *et al.*, 2000). Beside surface water, most downstream areas have groundwater supplies close to the surface. The recharge of these is mostly direct recharge from the Zayandeh Rud River (idem, 2000).

Although irrigation has been practiced since 1500 AD, today most irrigation is characterized by institutionally managed large scale canals with automatic upstream control through NEYRPIC systems and volumetric water delivery through the use of 'modules a masque'. Traditional canals have been absorbed into the large-scale systems, while many qanats[6] have either fallen into disrepair or have dried up because of adjacent drilling of deep boreholes. In 1970 the Chadegan reservoir, with a 1,500 million cubic meter (MCM) capacity, was completed and started to function in 1971. This dam allowed the regulation of the water flows in the Zayandeh Rud River, which, coupled with the construction of modern[7] irrigation networks, allowed for the expansion of the already existing irrigated area to its present 270,000 ha (Morid, 2004).

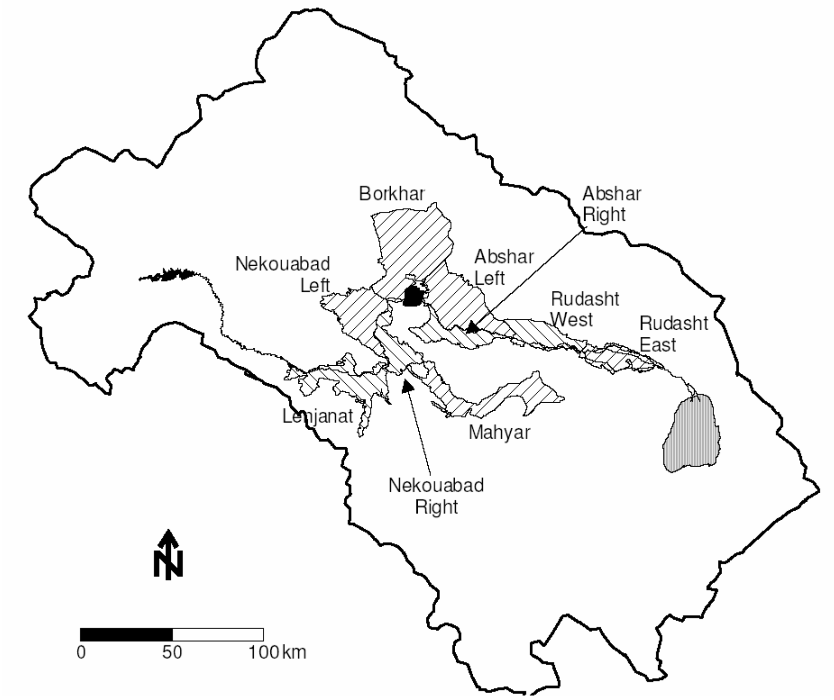

Figure 1.2 The main irrigation systems of the Zayandeh Rud basin (Salemi *et al.,* 2000)

To augment the water supply in the basin, and to keep up with the increasing demand, inter-basin transfers have been implemented. Two tunnels that can deliver 540 MCM a year have been constructed and are in operation since 1986 (Murray-Rust *et al.*, 2000). A third tunnel, expected to be put in operation in 2006, is planned to deliver a further 250 MCM annually. The total augmentation of around 790 MCM per year will increase the original available surface water by nearly 50% (Salemi *et al.*, 2000). The diverted water has its origins in the

6 Qanats consist of horizontal wells dug to reach groundwater at the base of hills, and consist of a "mother well" that reaches a water table followed by a gallery with a gentle slope that transports the water to the surface of the ground. Every 25-50 m shafts are provided for the removal of spoil and ventilation of the gallery. In Iran qanats have been used for centuries to provide water for cities and irrigations (Molle *et al.,* 2004).

7 With modern irrigation I refer to irrigation systems with lined canals, upstream control through NEYRPIC systems and water delivery with 'modules a masque' and controlled by a central water management authority.

Kuhrang River in Chaharmahal-va-Bakhtiari province and is delivered into the upper reaches of the Zayandeh River.

Beside surface water, groundwater is one of the most reliable water sources in the Zayandeh Rud Basin. In the basin twenty unconfined and two confined aquifers have been identified. Presently about 21,200 tube wells, 1,726 qanats and 1,613 springs exploit a total of 3,619 MCM of groundwater a year. Studies conducted by the Esfahan Water Authority (EWA) in 2000 reveal that several aquifers are being over-exploited especially in some of the irrigated areas (Morid, 2004).

Surface irrigation is controlled by two major diversion weirs at Nekuoabad and Abshar, each diversion weir controlling both a Left Bank and Right Bank Main Canal (Figure 1.2). These four systems have provided the bulk of irrigated agriculture for the past 30 years (Salemi *et al.,* 2000).

The above mentioned inter-basin transfers made it possible that, in recent years, three areas of irrigation were added: the Mahyar system that is south of the main valley, and is fed by a canal from a diversion on the Zayandeh Rud upstream of Nekuoabad; the Borkhar system north of Esfahan town; and the extension to the Rudasht system in the eastern part of the basin (See Table 1.1). All three systems have had extensive groundwater development, which can now be supplemented by canal water deliveries from the Zayandeh Rud (Murray-Rust *et al.*, 2000). The systems have been designed to operate as a conjunctive use system in which the use of rainfall, groundwater and surface water are integrated.

The irrigation season in the basin commences around the 1st of April, and reservoir releases remain more or less constant in May, June, July and August. In the later parts of the irrigation season discharges are reduced as demand drops. Typically there is a two-season cropping pattern in all of the irrigation systems in the Zayandeh Rud basin. Summer crops include silage corn, rice, onion, potatoes and other vegetables while winter crops are dominated by wheat, barley and vegetables. In addition there are some orchards, biannual and other perennial crops, including alfalfa and sugarcane.

Table 1.1 Basic information on irrigation systems in Zayandeh Rud basin (Salemi *et al.,* 2000)

	a) Old Systems				*b) New Systems*		
Name of System	Nekouabad Right Bank	Nekouabad Left Bank	Abshar Right Bank	Abshar Left Bank	Borkhar	Rudasht Left & Right	Mahyar
Date of Construction	1970	1970	1970	1970	1997	(a)	In Progress
Designed Command Area (ha)	13,500	48,000	15,000	15,000	36,000	47,000	24,000
Design Discharge (m^3/sec)	13	45	15	15			
Length of Main Canal (km)	35.30	59.35	33.50	36.00	29.00	209.20	120.00
Length of Secondary Canals (km)	45.0	76.6	38.0	33.0	Not Finished	Not Finished	Not Finished

Note: (a) Rudasht is an ancient system being replaced with a new system
All new systems have conjunctive use of surface water and groundwater

Large increases in population, expansion of the surface water irrigated area and increased industrial activity in the recent past have augmented demand for water, and the Zayandeh Rud is showing typical signs of a closing basin, which means that all the renewable water in the basin is being used and reused to a point where there are no more 'usable' (non-polluted) flows reaching the final sinks of the basin (Seckler, 1996). Beside the increasing demands for water, there is a growing concern over environmental degradation and pressure to maintain higher base flows to dilute pollutants and to maintain the Gavkhuni swamp have increased in the last decade.

1.4 Previous studies done in the basin

In the period 2000-2002 the Iranian Agricultural Engineering Research Institute (IAERI), together with IWMI, did several, mostly quantitative studies on the situation of water and the irrigated agricultural sector in the basin. These studies basically describe: the surface water hydrology of the basin (Salemi *et al.*, 2000; Murray-Rust, 2000); the basin as a closed basin in which all available water is being used and thus any reduction in primary water flows will mean a reduction in the use of water (Murray-Rust *et al.*, 2002 and Salemi and Murray-Rust, 2002); that salinity and pollution problems of surface water are increasing (Droogers *et al.*, 2000a and Droogers *et al.*, 2000b) and that in general the management of the major irrigation systems functions well (Sally *et al.*, 2001; Salemi *et al.*, 2000). Beside this some models of the Lenjanat aquifers were made (Gieske and Miranzadeh, 2002; Gieske *et al.*, 2000) as well as some satellite image interpretations for the assessment of irrigated area and land use (Droogers *et al.*, 2001; Gieske *et al.*, 2002a; Gieske *et al.*, 2002b). Although these studies give a good description of the hydrology, agriculture and water use changes of the basin they have a technical orientation in which human agency and socio-politics are omitted. There is a general lack of published information and research on the social aspects of the agricultural and irrigation sector in the basin. Added to this lack of information, there is no documented data on the effects of the drought.

1.5 The onset of scarcity in the basin

Coupled to the described increasing pressure on water utilization, the Basin has suffered a drought characterized by several consecutive years of low inflows into the main reservoir since 1999 (Molle and Mamanpoush, 2004). This has triggered a severe reduction in the amount of water released from the reservoir and an even more severe reduction in the volumes of water allocated for the irrigation systems. The dam releases in the period of 1988 to 1998 ranged around the 1500 MCM per year with some years far above this value; nevertheless the releases were greatly reduced to 1284 MCM in 1999, 987 MCM in 2000 and a historical low of 613 MCM in 2001. The percentage of diverted water to agriculture got greatly decreased as well in these years to 55%, 33% and 3% respectively, while the values in the previous 10 years ranged between 50 and 75 % (Molle and Mamanpoush, 2004).

As a result of this low water availability and the reduced diversions to agriculture, farmers in the irrigation systems have been hit hard. The responses (to this reduced water supply) on the hand of the water authorities at different levels and the farmers compromise several coping strategies, especially in areas where farmers have access to both surface and groundwater.

The objective of this study is to unravel and understand the different responses that have emerged in the Basin (at basin-, irrigation-system-, and field level) as a response to the drought that started in 1999. Special attention is given in the study to field situations of conjunctive water use in the AIS and the context in which responses to drought have evolved. Based on this background, below the research question is presented followed by a description and some considerations about the research methodology and the role of research in general.

1.6 Research question

Which strategies have the water authorities and farmers developed to cope with drought induced water scarcity in a conjunctive water use setting in the Abshar Irrigation System?

One of the main objectives of this thesis is to understand how the water management agency and farmers take actions to deal with a reduced surface water supply. In order to get to this objective and to answer the main research question I used sub questions. The different themes of the sub-questions are: the basic agrarian structure, technical water control, organizational water control, socio-economic and political water control, conjunctive water use, irrigation practices and the possibilities for implementing reallocation mechanisms in the system. It is clear that, although divided for this study, in the field these different areas are not dichotomous but intertwined (in other words one affects the other). By addressing these different themes I present the situation in the AIS irrigation area and the strategies that have developed to cope with surface water scarcity. The following section addresses the methodology that was followed.

1.7 The research methodology

The field work was done during a 10 week stay in the Islamic Republic of Iran. During these two and a half months I gathered data from observation in the field and offices; interviews with farmers, the water management agency staff and some researchers, supplemented by literature research.

The tool I used for the field research was a comparative case study as it presents a valid tool to gain a profound insight into processes that are restricted by time and space (Verschuren and Doorewaard, 1999). The study of farmers' rationality demands the use of qualitative, unstructured, and open way of gathering data, such as open interviews, (participatory) observation, and interpretation of secondary data (Verschuren and Doorewaard, 1999). Observations on location by just walking along the canals and in the fields and conducting interviews gave me a good insight into the way processes take place and the reason why they develop in one way instead of another.

The first step of the field research was a survey of the Abshar Right and Left Bank with a staff member of the Mirhab[8]. This survey gave me an idea of the diversity of the water availability and cropping patterns in the irrigation system. Based on this first survey three case study outlets were chosen. The choice was based on several factors such as: the accessibility of the site, the quality of groundwater supply and the degree of conjunctive water use. Because the study is aimed at studying the responses of farmers to surface water scarcity under different degrees of groundwater use, the outlets were chosen mainly based on the quality of the groundwater supply. The three chosen areas are:

- Right Bank outlets P-9 and P-10: this area has a very good groundwater supply and a lot of privately owned wells.
- Left bank outlet P-5-1 (In the text often referred to simply as P-5): Although this outlet has a very small command area (20 ha) it is interesting because of its long history, its groundwater use that is regulated by just one private well and the strong social cohesion.
- Left bank outlet P-4: This outlet was chosen because it has only access to surface water after the two wells that used to supply groundwater dried up during the drought.

[8] The Mirhab is the institution charged with the management of the irrigation system (see Chapter 4).

Beside the case study areas several interviews and field visits were held outside of these areas in order to better understand the heterogeneity that prevails in the command area. Furthermore I do not consider the different outlets as separate and independent entities as they form a part of the irrigation system which is built up of all the interdependent outlets.

The interviews held both with the staff of the water agencies and with the farmers were semi-structured interviews as I strongly believe that we can understand people the best by listening to them; their accounts, their way of talking. Their priorities reveal how their rationale is shaped. Although such interviews are usually long they provide a fuller picture of farmers and the agrarian structure in general. I experienced that interviews often work in a cyclic manner, in which every loop brings us deeper into the realities that exist. What I mean to say with cyclic loops is that, in an interview, the researcher treats one subject several times from different angles, because of the interrelatedness of all things and because, in most cases, answers give way to new questions. As the researcher, gets a better picture of a situation the questions become more and more detailed. Furthermore, in some cases it is necessary to have several interviews with the same person. This often becomes clear only after an interview is worked out and the information arranged because then the researcher can see the gaps that are missing in the information.

Often the search of information is overlapping in the way that on one subject you interview several people. This is referred to as triangulation, and is used to confront and confirm information on one subject from different sources. A list with the interviewed people can be found in Annex I.

Secondary data was also a major source of information for this research. This data consists of the more general data with regards to formal water allocation and distribution rules and rights, scheduling of canal water flows, water quality, groundwater depths, groundwater regulations, how the water agency deals with scarcity at basin level and costs of water.

1.8 Demystifying the role of the researcher

As I have chosen to do a case study research for this thesis the people interviewed represent a very small cohort of the population and thus of the different realities that exist. This affects the results, conclusions and discussion of the research. The people I interviewed, the informants and the supervisors also set their print on the information. Thus we create and interpret the world according to our own set of beliefs, choices and social interactions (Hoogesteger, 2004).

In this thesis, as in every research, I see myself as an actor that interprets phenomena according to my own views and ideas and the time and place where the research takes place. Furthermore, as an actor every interview or other form of communication (even my presence) already belongs to the interactional domain (van der Zaag, 1992). I myself take part in interface situations of interaction. These interactions which are needed for research are always a two way process that changes both parties a bit (idem, 1992). When I ask a farmer why certain things are the way they are, in his answer he is trying to externalize the implicit; explicate the taken for granted. Such a process boils down to a self-investigation (for me as researcher and for the informants) of the (im) possibilities for changing that state of affairs.

1.9 The Sketch of the Thesis

This thesis is built up in seven chapters. The first and present chapter is an introduction to the Zayandeh Rud basin, and the thesis. It presented the objectives of the study, the research question, the research methodology and the role of the researcher in the study.

The second chapter presents the theoretical framework that is used for this study. This framework deals with some theoretical considerations about how water scarcity is managed at different levels within a River Basin and the theoretical concepts and approach that is used for the study. In this study water management is seen as socio-technical phenomenon in which people are the main actors. To study how these actors devise and implement strategies at different levels within the basin, the use of the concept *practices* and *water control* are used as core elements. Lastly some theoretical considerations on conjunctive water use and conjunctive water management are explained. The following three chapters present the field data.

Chapter three explains how, at Basin level water management has evolved in the last years as a response to water scarcity. It deals with the strategies used by the EWA to deal with on the one hand increasing pressure on water resources and on the other hand a drought with extremely low surface water supplies.

Chapter four narrows down to water management at IS level. It first explores the institutional setting in which water management at IS level takes place. After this setting is presented, the strategies used to manage scarcity and how they respond to water management decisions at basin level are described. In this analysis special attention is given to the AIS.

Chapter five analyzes the different dimensions of water control in AIS which are technical, organizational and socio-political water control. Later it analyzes some factors that are determining in the choice of farmers to use surface and/or groundwater. It wraps up with a description of the strategies designed by farmers at field and outlet level to deal with drought within a conjunctive water use setting accompanied by some theoretical considerations.

Chapter six explores the "room to maneuver" that exists as IS level to manage the scarce yet precious liquid. It discusses the possibilities there exist for the introduction of water sharing mechanisms between outlets and some considerations on conjunctive water management.

Chapter 7 closes the thesis with the revision of some concepts used and it revises some methodological and theoretical considerations.

Chapter 2 Water Scarcity, irrigation practices and water control, a theoretical framework

This chapter deals with the concepts and theoretical framework used for this study. The concepts that are explained are river basin development, drought, water scarcity and society's responses to it. To create a framework for analysis for water management and how it adapts to scarcity the concepts of *practices*, *water control* and conjunctive water use are explained.

2.1 Basin development and its triggers

Descriptions on basin development are based on the evidence that water resources gradually come under growing pressure, and that society devises strategies to cope with the new situation. Molden *et al.*, (2001) distinguish three phases of river basin development which are development, utilization and allocation (Fig. 2.1). The Zayandeh Rud has clearly achieved the allocation phase, which is characterized by an increased competition within irrigated areas, a tense and competitive, yet 'inevitable', sectoral allocation in which efforts are directed at allocating water towards economically valuable uses while new institutions evolve to address inter-sectoral competition and manage river-basin resources. A stage which goes one step further and which has emerged as a result of the drought in the Zayandeh Rud is described by Turton and Ohlsson (1999). In this stage, which they call the adaptive phase; the society of a river basin has to cope with absolute water scarcity and must bring water demand in line with a sustainability level defined by annual renewable resources. This implies that the total water supply is reduced and thus society has to manage with less water at basin level which inevitably brings with it a need for adaptation both at basin and field level. This becomes especially challenging when in a basin great sectors of society have become dependent on groundwater mining and this source gets exhausted as is the case of the Borkhar, Mayhar and Garguye irrigation systems[9]. In these areas as in most of the basin, the continued water mining has caused a water deficit in the Basin as resources rapidly move towards a point of exhaustion. When these resources get exhausted water availability becomes a problem because there are no new sources of water to replace the mined resources. This situation creates conflicts and forces users to develop strategies to manage the new situation.

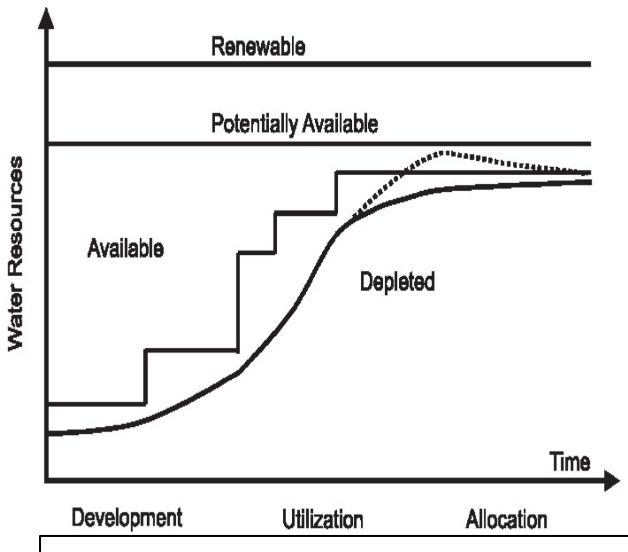

Figure 2.1 River Basin Development (Molden *et al.*, 2001)

Molle (2003) describes several factors that are determining in the development of water use and development within basins. He identifies the following as critical elements that drive changes within a basin:

- *Agrarian pressure*: Individual and societal responses are strongly governed by the alternatives of livelihoods offered to people. If strong population growth occurs in a context where non-agricultural sectors are unable to absorb the excess rural labor, then the pressure upon land and water resources increases. If the water supply to agriculture is squeezed, then the social consequences on the rural population are likely to trigger state responses. On the other hand, if favorable

[9] Shah *et al.* (2003) present a good analysis of the emergence and development of such groundwater dependent groundwater socio-ecologies and the different stages which usually develop.

alternatives are supplied within the wider economy, water users with deficient supplies will be encouraged to diversify their activities or to simply give up farming, thus easing the tension on resources.

- *Economic rationality*: It would be naive to assume that the constraints faced by a society give way, through a perfect, market-like mechanism, to a solution that minimizes transaction costs and improves efficiency. The distribution of power, embodied in the access to (water) resources, is a societal, historical construction, where equity and efficiency might not be the chief aspects. This takes us beyond the economics of transaction costs, to include political economy and rent-seeking behaviors.
- *Political Economy*: It is necessary to go beyond a model of rationality and towards a political and economic approach, where decisions are understood not only on the basis of their actual financial costs, but also on the benefits and increased power that accure to the different categories of actors within society. The conflicts between politicians, construction firms, consultants, local population and environmentalists, provide a good example of how the decisions on water management at different levels are debated in a political arena, where financial or political interests coexist with environmentalism, communitarianism and concerns for local livelihoods. Thus it is necessary to understand that strict economic logic is not the best criteria to understand the succession of state investments and responses.
- *Political Culture*: The nature of the state and its relationships with the citizenry defines the scope and the room for maneuver and adjustment allowed to the different actors in the system. Generally authoritarian states are associated with large-scale development and centralized management, while weak states usually leave more scope for local initiatives. The degree of decentralization and democratization obviously influences how negative impacts are both perceived and addressed.
- *Technology available*: Societal response to water scarcity, are obviously shaped by the physical/climatic context (aridity, humidity, variability in precipitation, etc.), the available and the pre-existing socio-cultural and institutional context as well as the 'know how' to be applied to the specific conditions. *Shock events:* The responses of water users and society at large, regarding water use and water-related problems depend on their perception of the magnitude and severity of these problems. This perception is often sharply influenced by extreme natural events which disrupt the livelihoods of (part of) society. Shock events often allow politicians to impose policies that would have been otherwise unpopular and opposed.

These different elements shape for a great part the evolution of basin development with its corresponding strategies. Acknowledging that societal responses to scarcity of resources, at both local and institutional level, are not driven solely by economic considerations or locally perceived needs (Molle, 2003, Oorthuizen, 2003, Wester and Warner, 2002). They must be understood not only on the basis of hydrological, physical or economic constraints, but within a wider political economy framework that considers the distribution of human agency and power among actors, as well as their respective interests and strategies. Thus;

> *"societal responses to water scarcity comprise a set of strategies, defined both at the individual/community level and at the state level, and is elaborated or induced, based on several location-specific factors, without any other assumption about a possible 'natural' order or sequencing" (Molle, 2003; p. 10).*

Hence, responses to scarcity are formed in processes of constant renegotiation of policy, politics, personal interests and preferences at different levels. The renegotiations and processes can not be taken as black box responses but have to be studied at empirical level, because it is the renegotiation process that shapes the outcomes.

To study the variety of societal responses to water scarcity and the complexity of determining which particular response appears at a certain point in time, Molle (2003) made a schematization seen in Fig. 2.2. The schematization presents the general evolution towards basin closure. The implementation or the inducement of a range of individual, collective and state responses shape basin development at different moments in time.

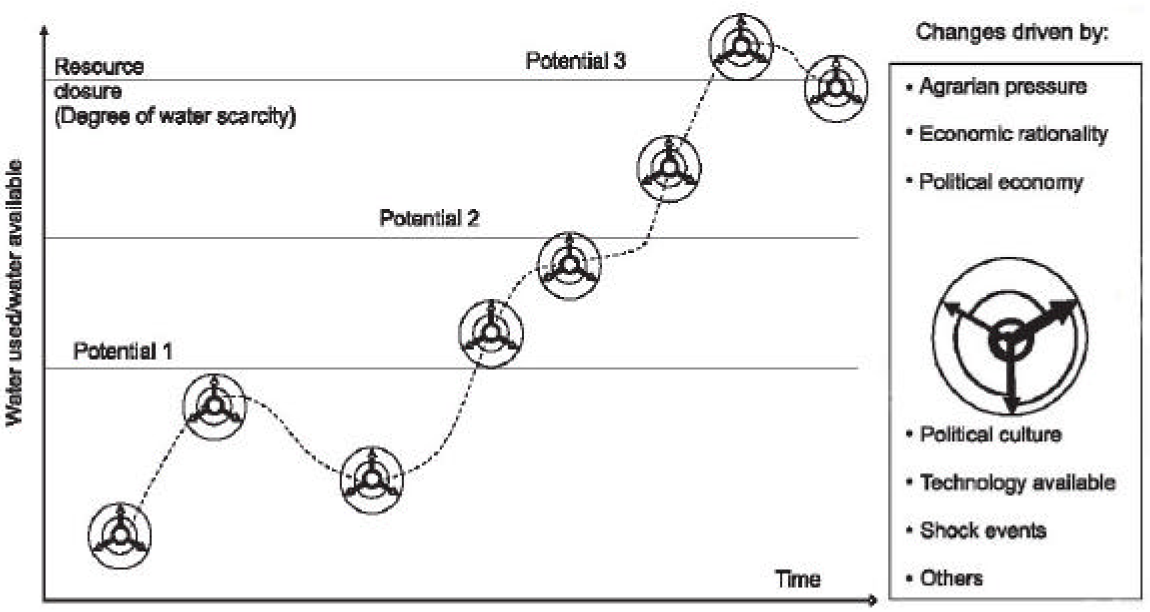

Figure 2.2 Basin closure and its development trajectories (Molle, 2003)

2.2 Water scarcity, drought and adaptation strategies

As societies move towards potential ceilings they usually respond through adaptation strategies (Molle, 2003, Molden et al., 2001). The development of adaptation strategies is often triggered by scarcity. In this thesis water scarcity is conceptualized as 'the lack of available water needed to fulfill a certain degree of socioeconomic activities that rely on this resource'. This means that scarcity is directly related to the degree of water use for socio-economic activities in a region. Thus; if the socio-economic activity of the society or group of users of a region is limited by its water resources, be it by a reduced water supply or by an increase in the demand for water, there emerges a situation of scarcity. This implies that scarcity is directly related to the degree of use of the resource instead of the natural water supply of a region.

Drought is considered in this thesis as a meteorological phenomenon of below average rainfall conditions in the areas where the water resources that are used by a specific society of a region originate (this can be direct rainfall in the region itself but in most watersheds societies downstream are dependent on water resources that originate upstream). The consequence of these definitions is that scarcity may include drought but drought may not necessarily result in scarcity conditions. Drought induced scarcity then refers to a situation in which, through a meteorological phenomenon that results in low water availability for a society that depends on a specific water source, the socio-economic activities of that society are reduced or imperiled and become a limiting factor for these activities. In this thesis I analyze the effects drought induced water scarcity has had on the society of the Zayandeh Rud Basin.

As mentioned in the forgoing chapter, the Zayandeh Rud Basin and its society have been confronted with drought induced water scarcity in the past few years. This scarcity has triggered several adaptation strategies at different levels of water management within the Zayandeh Rub Basin. Here some theoretical considerations about how society responds to water scarcity are treated. These conceptual ideas are later used for the analysis of the data.

Molle (2003) establishes a theoretical framework for the analysis of the strategies developed at different levels to cope with water scarcity. In this framework it is assumed that population growth puts pressure on water resources and this, in turn, creates challenges for society and leads to a gradual closure of the basin with consequent conflicts and adjustments as general phenomena. In order to adjust there is a need for ingenuity which is defined as "ideas applied to solve practical technical and social problems" (Homer-Dixon, 1999; p. 109) or in other words: Can societies be smart enough to minimize the negative effects environmental scarcity has on their well being? Molle (2003) describes three different kinds of general responses which are usually followed by societies at different levels of water management and use.

Supply responses: These consist of solving water scarcity by augmenting the supply from existing sources (foremost, increasing the quantity of controlled water), as well as from tapping additional sources. Typically, this is done by constructing new reservoirs, digging more tube wells, diverting water from neighboring basins or by desalinizing seawater. At the local level, farmers may tap groundwater, and invest in local storage facilities broadening their access to a variety of sources and augment their individual potential supply of water.

Conservation responses: These are usually focused on increasing "efficiency in use". It implies making a better use of existing resources, without increasing the supply of water. To achieve this goal the state often devises policies that may create water savings, such as water pricing, rationing and quotas or supply innovations. These measures can imply, at basin and irrigation system level, lining canals, controlling leakages in pipe systems, the reuse of wastewater, but may also include managerial measures, such as improving dam or canal management. At farm level water may be saved by shifting calendars, adopting different cultivation techniques or by choosing other crop varieties or other crops. Farmers or groups of farmers may also invest in water-saving technologies, such as micro-irrigation or work on better water management at field level.

Allocation responses: These consist of reallocating water from one user to another, either within the same sector or across sectors. This reallocation may be justified by the need to raise water productivity, but may also be aimed at easing tension on the resources. Within the agricultural sector, water can be shifted from one area to another with comparative advantages regarding water productivity. Reallocation can also occur at the irrigation-system level and can be more or less even in terms of water duty per hectare, but it can also be driven by other considerations. At farm level water users often redistribute their water to optimize its use either on one individual plot or amongst users in a community. Allocation decisions/strategies are potential sources of conflicts and tension, but can also be mediated by market mechanisms or negotiations[10].

Droughts, which refer to conditions of low rainfall over prolonged periods, can denote extreme scarcity of water resources (Qureshi, 2004). Hence it triggers ecological, social, political and economic responses. Figure 2.3 shows that actors within the system respond individually and collectively to water scarcity through different responses at diverse levels. The two existing levels can be broadened and split up into more levels. Furthermore, although a differentiation in levels is very useful for analysis, it is necessary to keep in mind that these are interrelated. As the closure of river basins results in a growing interdependence of the users within it, it is necessary to analyze how a local intervention modifies the quantity,

[10] For example groups of users within an area may agree to renegotiate rights in order to ease tension.

the quality or the timing of the flows within the basin and how decisions taken at one level work out in the other levels.

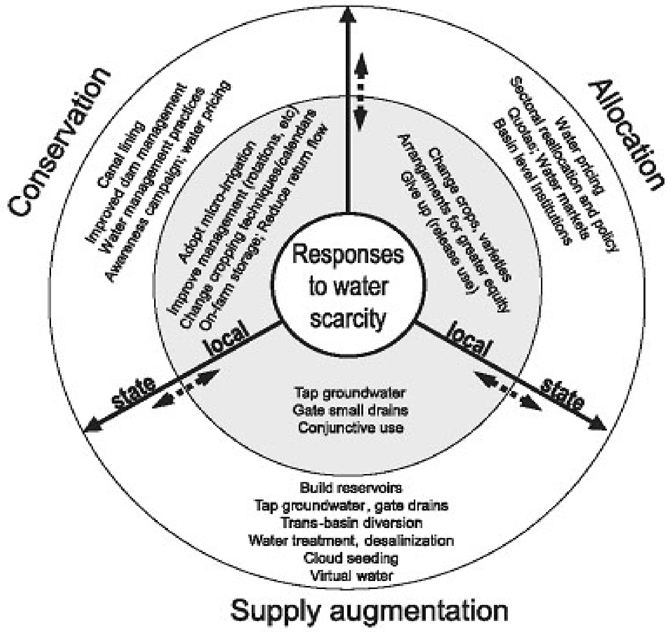

Figure 2.3 Responses to water scarcity (Molle, 2003)

This thesis explores the coping strategies and ‘room to maneuver’ that have developed in the basin’s society at different levels as a response to a drought induced scarcity. In this analysis I study the changes that have taken place at basin, irrigation agency and local level through, on the one side the study of the state and public institutions and on the other side the negotiations at local level in which the state is not directly involved. In this study I recognize that, although not directly involved, the state remains the promoter and/or provider of the overall negotiation space (Vincent, 2000). The following section of the chapter focuses on how negotiations and decision making at individual level are approached in this thesis.

2.3 Irrigation; a socio-technical phenomenon

In this thesis water management, allocation and use for irrigation or other uses, which reflect the adaptation strategies used at the different levels to deal with scarcity, are seen as socio-technical phenomena. This means that the technological, organizational and social context in which water use dynamics evolve in an irrigation system are an important element of study. Furthermore water management is seen as a process of interaction between different human actors which centers on the transformation of water. The results of this process are the distribution of water, the reproduction of infrastructure, crop production and in a broader context agrarian development (Wester, 2002; Mollinga, 1998).

While emphasis is often placed on state policies, adjustments made by local actors are also very significant (Molle, 2003), thus, when analyzing adaptation strategies there is a need to distinguish between responses devised at different levels such as the state at the national level, those taken at basin level, at irrigation system level and finally those of individual farmers and small groups or communities. An important concept that gives a better understanding of these different dimensions of irrigation and water management is the study of practices and water control (Mollinga, 1998, Knegt 2000, Hoogesteger 2004). In such an approach ‘people-people relations are an inherent part of irrigation because irrigation systems in most cases involve more than one user. Cooperation among users, and often of users and government or other agencies' personnel, is necessary to make use of the infrastructure' (Mollinga, 1998; 14).

Mollinga (1997) presents irrigation activities as part of a wider process and as activities that are subject to conditions of possibility within a network that consists of interrelated elements. People are the most important elements in the network, because they are the builders of it by following certain objectives. For achieving their objectives people try to put all the social and material elements in the right place. Material and social conditions of possibility refer to circumstances that enable conduct of irrigation and management activities in their context. To understand the dynamics of an irrigation system and to enable qualitative analysis of irrigation and water management activities, two concepts are used; (1) practices, and (2) water control.

2.4 Practices

Practices are what people do in a structured and structuring fashion (Mollinga, 1998). These practices are shaped by human behavior that is determined by several intrinsic and extrinsic factors. The results of practice are constituted by action. Thus although an action is "purposeful and effective, it is not, in essence, rule driven or the product of conscious reflection."(Wagenaar and Cook, 2003; p. 145). This implies that practice takes place in a field of dispositions that function as generative schemes (domain) in which actors have a certain degree of 'room to maneuver' in which improvisation and contingency play a key role.

The concept of human agency, which is used to understand practices, aims at understanding what motivates people's behavior (what drives them and what governs their encounters) and how that behavior should be analyzed (Mollinga, 1997). People are knowledgeable and capable actors that interact with their environment and other people; they are active players in creating new social and material environments, even when they have to operate within a context that is only partially of their own making, and with motivations that are only partly conscious (Mollinga, 1998; van der Zaag, 1992). Thus people's behavior is shaped by the interaction of intrinsic personal values such as culture and routines[11] and extrinsic motivations such as external pressures and the context.

In general it is assumed that farmers seek to maximize returns to the resources applied to their activities. In particular they try to maximize returns of those resources that are scarce. How water is allocated among farmers will strongly affect their individual responses. Farmers enjoying unrestricted access will irrigate as if land is the constraining resource, choosing crops that have high returns to land while if all farmers face shortage they are likely to pursue strategies that result in high returns to water (Perry and Narayanamurthy, 1998).

Although such generalizations might hold sway in some cases, the rationality of the behavior of actors cannot be reduced to a single characteristic such as 'people as profit maximisers' and can not as such be taken for granted (Mollinga, 1998). The relationships, strategies and resources which an actor has at his/her disposition both constrain and enable his/her possibilities of action; therefore, people's behavior can never be assumed (Mollinga, 1998). Van der Ploeg (1991) in the analyses of agricultural development sums up human agency on farm level in the term calculus that is defined as "a specific socially determined set of aims and devices, which are found legitimate and valid for the farmer" or in this case any person working to achieve his objectives within a specific context, which can be a water user group, a governmental institution, or any other arena or domain of interaction.

[11] Specific cultural routines are practices that have regular patterns and consist of behaviour that is structured by local cultural rules.

In this thesis I consider a domain to be a place defined by specific boundaries within which practices take place. The boundaries can be technological, social/institutional and are defined by space and time. Interactions within domains entail specific links to institutions, resources, relevant outsiders, and politics. It is within these areas of social life that power networks are created and legitimated in accordance to shared understandings. The boundaries of domains are not fixed but can be flexible and operate at different levels simultaneously. The different domains are constantly negotiated in the practices going on within them (Mollinga, 1998). Technological and social boundaries define the first level of the arenas/domains. An arena or a domain can be the outlet, an institution, a specific political, commercial, or economic arena. For instance the irrigation arena is the place where different actors employ strategies and resources to acquire access to water or certain technologies to access and apply water and use it for irrigation. This arena is embedded in other arenas of institutional, social, economic and power domains that influence the irrigation arena.

To further understand the behavior of the different actors it is imperative to recognize what Oorthuizen (1995) identifies as blurred boundaries. This concept recognizes that actors are not simply irrigators or ditch tenders within one domain, but that actors are "deeply embedded in society as members of a kin group, as villagers, as farmers, entrepreneurs, or politicians at the same time" (Oorthuizen, 2003; p. 160). This implies that to understand how and why actors take decisions and how and why they relate to each other in diverse circumstances one has to understand the different roles one individual has within a certain domain in which he operates. It becomes evident that one individual can posses diverse roles at different times during varied encounters and within specific domains.

It is imperative to recognize that people will act only within the borders of the possibilities they have to devise plans that meet their objectives and these are determined by the domains in which they act. To implement plans and to achieve their objectives, actors make use of certain strategies, resources and intermediaries. Intermediaries are material and non-material objects, including technologies and people (Mollinga, 1998). For example, people extract groundwater and use it for irrigation (strategy), with their knowledge framework (resource) and a specific technology (intermediary), in order to produce crops (objective). This analysis can be extrapolated to encounters, markets and institutions.

From the considerations and views on practice presented here it is possible to deduce two main aspects that determine practices:

- *Human agency*: that boils down to actions with their purpose, own logic, origins and demands that can not be reduced to a simple following of rules, and;
- *The context*: actors operate within and recreate a specific context in which the social order within and across domains is constantly reproduced as actions take place upon and within it.

To operationalize the study of practices it is crucial to study the people, their behavior and their encounters. Furthermore, in the study of irrigation it is fundamental to identify the different intermediaries actors use to interact with each other. These can be technologies and/or social relations and can be studied by analyzing the behavior of actors during their encounters. By getting a clear picture of the relations of the different actors, what binds them and how they relate to each other it is possible to slowly unravel the water management black box.

2.5 Water control; a political process of contested resource use

To operationalize the practices in the struggle over access to water for irrigation, the core concept to be used is water control. This concept is above all important to understand "how and why water flows flow the way they do". Mollinga (1998) uses the concept of water control to analyze processes within irrigation systems and their connections with the wider context. Mollinga (1997) defines water control as a **"politically contested resource use"** (p. B-19), a concept that is analyzed below:

1. The use of the resource is *contested;* the use of water creates conflicts, struggles, negotiations, and other confrontations.
2. Water control is about the *use of a natural resource*. Water use implies the appropriation of a limited natural resource which implies that if one individual uses the resource, others will not be able to do so. This has implications for the development of society and ecology in the widest sense.
3. Water control is a *political process,* in the broad sense of the term, politics should be understood as:

   "*… the debates, conflicts, decisions, and cooperation among individuals, groups and organizations regarding the control, allocation, and use of resources and the values and ideas underlying these activities*" (Mollinga, 1998).

The three dimensions of *water control* that can be distinguished are technical water control, organizational water control and socio-economic and political water control.

- *Technical water control*: Physical control of water flow by means of irrigation technology.
- *Organizational water control*: Organizational control is about regulation and control of human behavior in which processes of conflict management, communication, resource mobilization and decision making are needed. To achieve these, forms of co-operation are necessary to make irrigation systems function. Such forms of co-operation can be formal or informal institutions and water management practices at different levels within an irrigation system or basin.
- *Socio-economic and political water control*: Addresses the conditions of possibility for technical and organizational control. This type of control is about the domination of people's labor and the regulation of social processes (Mollinga, 1998). This level of water control defines the conditions that give access to the technical factors determining *water control*.

To understand water control one has to study first of all the technologies used and the social dimensions of these (Mollinga, 1998). To understand the technologies it is crucial to study how these technologies are operated and how decisions are taken over the use of them. Thus, studying the institutions (in the broadest sense of the word) that manage water and the way these relate to farmers and how farmers affect these interaction is important. Such a study involves analyzing the nature of the institutions, their history, their context and internal functioning structure (Hoogesteger, 2004).

2.6 A framework for analysis

Acknowledging that people are knowledgeable and capable actors that interact with their environment and other people within a specific context, we need to analyze what decisions actors take at different levels within the basin and how these decisions are shaped as in this process the possibilities for devising reallocation mechanisms are found. For this thesis, in the Zayandeh Rub basin, three levels of decision making are studied. These levels are the Basin level, the IS level and the outlet/farm level. These different levels affect each other as they are interdependent, yet the focus of this thesis is on how decisions taken on Basin and IS level have developed in the last years as a response to drought induced scarcity and how these in turn affect irrigation practices of farmers within a water scarcity setting (See fig. 2.4).

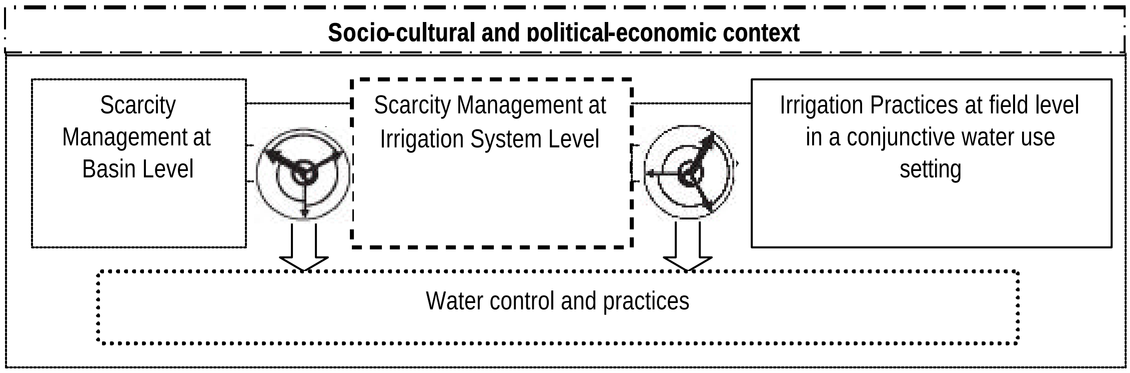

Figure 2.4 Framework of analysis to better understand drought induced water scarcity responses at different levels

In this framework, I consider decisions taken at basin and irrigation system level to be determining in shaping the context in which farmers have to operate. This choice is made partly because it makes analysis easier but above all because in Iran society functions in an authoritarian manner characterized by decision making systems that dictate policy and decisions from 'the top to the bottom'.

In the analysis of farmer strategies to manage their water resources, special attention is given to scarcity management of farmers with access to other water sources (a conjunctive use setting). In order to study this, an important tool of analysis is the water control concept which reveals the concrete result of the different decisions taken with regards to water management at different levels. As irrigation is not only dependent on the decisions taken at different levels of water management, the context in which the different responses to drought induced water scarcity develop are also included as an important aspect of study (See fig. 2.3). To better understand why and how certain decisions are taken and if these offer scope for the introduction of water reallocation mechanisms between outlets both irrigation and institutional practices are studied.

Now that the general framework of analysis is presented, I give some attention the theoretical and conceptual issues that have developed around the term conjunctive water management/use.

2.7 Conjunctive water management vs. conjunctive water use

Conjunctive water use and management are widely used terms. As many authors mean different things with the two concepts, here I define both in the way they are used in this thesis. The term conjunctive water use is used simply to refer to situations where, in an irrigation system, farmers have access to and use several sources of water, which in most cases is canal- and groundwater. Other authors narrow the definition down to situations in which both ground- and surface water are available and used jointly (Shuck and Green, 2002; O'Mara, 1988).

The term conjunctive water management goes a step further as it implies an active management of both surface and groundwater resources with the aim to 'optimalize' the use of the two different water resources often within an irrigation system (O'Mara, 1988; Shah, 1991). In the section below some assumptions and theoretical discussions on conjunctive water management are analyzed.

In this thesis I will refer to the term conjunctive water use simply as "situations where, in an irrigation system, farmers have access to- and use canal- and groundwater for the irrigation of their fields". The term conjunctive water management will be used for the cases where I refer to the active management of both surface and groundwater by an institution, in this case the EWA.

2.8 Shifting to groundwater in a conjunctive water use setting

As mentioned before conjunctive water use refers in this thesis to a situation in which farmers have access to both ground- and surface water for irrigation. In a conjunctive water use situation, when drought begins with a lack of precipitation, the rainfed agricultural sector is the first to be affected; as a drought gets prolonged also people dependent on surface water sources for irrigation begin to feel the effects of the drought as reservoirs and lakes dry up. Those who rely on groundwater are usually the last to be affected by this temporal insufficiency. Farmers that have both surface and groundwater, or the possibility to access groundwater, will, during a drought, increase their groundwater use to compensate for the 'lack' of surface water (Molle, 2004).

Figure 2.5 attempts to conceptualize the shift from canal water to well water use, depending on the relative water supply $q_{i,a}$(actual)/$q_{i,r}$(required) and its relation to the irrigated area. The figure shows two curves, one for the percentage of groundwater used and the other the potential water use by farmers. When q_a/q_r is higher than 1 (target demand satisfied), only a% of groundwater is used, occasionally or permanently. The access to surface water may be insufficient for some particular reason or farmers' crops may require a 100% reliable supply at any time and thus groundwater use will not drop to zero. The potential water use will approach 100% but not reach it because of crop rotations, personal choices of farmers and other circumstances which prevent a complete use of available resources.

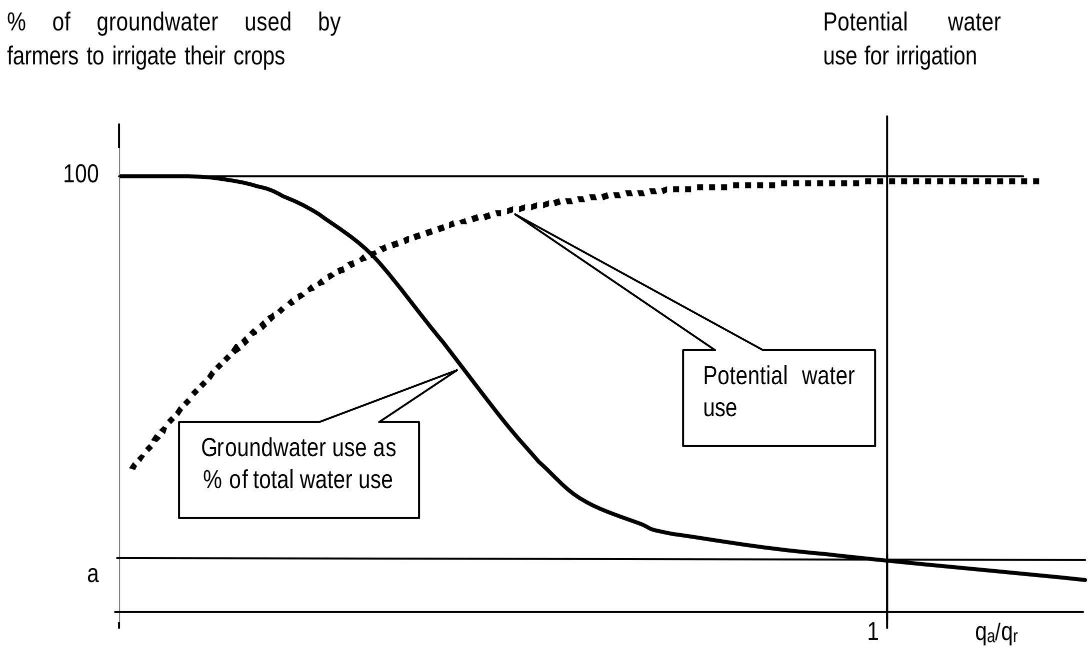

Figure 2.5 Conceptualization of the shift form canal water to groundwater and potential water use for irrigation related to relative water supply

Conversely, when actual supply decreases a growing number of farmers shift to groundwater use and increases its use. When surface water supply approaches zero the percentage of groundwater use is at 100% quite stable (because the time and resources required for acquiring surface water do not pay off for the benefits it brings). Not all farmers have access to or are able to/interested in gaining access to groundwater (nor might the capacity of the aquifer suffice); therefore the potential water use and thus the irrigated surface will be greatly reduced as surface water resources approach zero. The reduction of the potential water use and thus the form of the curve potential water use will be affected most of all by the volume of groundwater exploited which is dependent on aquifer yields, costs of fuel and the legal context.

In this conceptualization it is assumed that farmers have access to groundwater resources and that there is little or no control over groundwater exploitation and its use. Thus I conceptualize groundwater as an open access resource with its respective problems (See Ostrom, 1990) of overexploitation. It is assumed that farmers will be motivated to extract more and more groundwater under a rule of capture as they receive the direct benefit of ‘their own’ agricultural production and bear only a share of the costs resulting from overexploitation.

Although the conceptualization presented in figure 2.5 is based on the assumption that the fluctuations in groundwater use and area cultivated are only dependent on surface water availability, there are more factors determining the choices of farmers than only the availability of surface water. Hence, in order to get a better understanding of how farmers shift between canal and groundwater, it is crucial to understand farmers and their motivations (van der Zaag, 1992) and this is where the study of irrigation practices becomes relevant. In the section below some theoretical considerations on conjunctive water management are treated.

2.9 Conjunctive water management

It is assumed that there are potentially large benefits to be gained from efficient joint use of surface water and groundwater in those basins where the physical interdependence of the two water resources complicates allocation. Theoretically one of the most attractive benefits from efficient conjunctive use of surface and groundwater is the possibility of using the groundwater aquifer as an underground reservoir. In these situations both sources of water should be managed conjunctively so as to minimize fluctuations in total water supply caused by variations in rainfall patterns. Thus, ideally in a controlled and well managed conjunctive water use system, an increase in groundwater withdrawals occurs in times of drought and permits temporary mining of the aquifer to reduced surface supplies. In times of abundant surface water supplies, a greater than normal application of surface water (and diminished groundwater pumping) would enable aquifers to replenish their supplies. In such an ideal situation there should be sufficient capacity in both surface delivery and tube well pumping to meet peak requirements (O’Mara, 1988).

The basic issue in such situations becomes managing water demands from the supplies of multiple sources. Several studies emphasize the need of central management using quantity controls and focus primarily on the benefits of optimal water management and the use of conjunctive management to reduce the effects of water supply variability (Shuck and Green, 2002). Azaiez and Hariga (2001) for instance developed a model that presumably enables water authorities to regulate surface and groundwater flows in an irrigation system to work at an ‘optimum’. Peranginangin *et al.* (2004), based on work in Indonesia, emphasize the importance of surface and ground- water accounting in basins to determine the “optimal” volumes of each water source to be used in different seasons to enable the ‘best use of both resources’ taking into account the quantity of surface water use, groundwater pumping, the quantity of recharge, and the level of water in an aquifer. Shuck and Green (2002) propose to tackle the problem by the adoption of volumetric water rates in a structure that accommodates the different attributes of each water source. Thus, the customary motivation for operating a conjunctive use system is supply uncertainty for one or both of the water supplies which must be reflected in the rate structure.

These proposals and approaches assume a strong control and management 'know how' of a water agency over both surface and groundwater resources. It also implies that there is good and reliable data on the volumes and flows of both surface and groundwater within the system. Nevertheless more often than not, surface water delivery and tubewell pumping are controlled by different agencies or different departments within one agency which often creates problems of coordination. In most cases there is also a lack of understanding of the water flows of both surface and groundwater, let alone how these two are related and interact with each other. Even in cases where data is available there is often a lack of expertise that can use the data to design conjunctive water management plans.

Another obvious proposition is that "farmers and bureaucrats will seek a remedy only when they believe a remedy exists. An important implication is that neither farmers nor bureaucrats will accept proposed solutions that are beyond their understanding or experience" (O'Mara, 1988; p.15). The lack of interest and reluctance of water agencies to impose strict water management and control over water use is often another problem. Bureaucrats are often concerned with their own interest and embedded in specific contexts. According to Oorthuizen (1995), state bureaucracies' possess characteristics that hamper the quality of their work. Hoogesteger (2004), based on Oorthuizen (1995) presents some points of critique on management by state bureaucracies. These are: a) state bureaucracies are often hierarchical and centralistic; b) in most cases there is a lack of personnel at field level to exercise control; c) rent-seeking in the bureaucracy seems to be a worldwide phenomenon; and d) bureaucracies are often subject to political influences. As a result, the potential for efficient management is constrained by the context and institutional restrictions which define the range of choices available to water managers. In many developing countries the scope for immediately implementing an efficient and effective move toward more effective groundwater management is quite limited (O'Mara, 1988).

It is clear that efficient conjunctive water management is a complex issue. Maybe because of this most papers on conjunctive water management are policy papers that work with theoretical models and assumptions which often result in technocratic solutions. There are only very few empirical studies that explain operational strategies that work in specific contexts. In this thesis, I take a field level approach aimed at understanding the context and the people involved, in order to assess the (im) possibilities that exist to implement conjunctive management.

2.10 Conclusions

In short, this chapter has explained the concepts and frameworks that will be used for this thesis and also presented the approach I use to analyze drought induced water scarcity management strategies and decisions taken on different levels within the basin. In this approach practices (seen as actions with their purpose, own logic, origins and demands that can not be reduced to a simple following of rules within a specific context) take a central role.

Chapter 3 Water resources development in the Zayandeh Rud Basin

This chapter deals with water management and water resource development at basin level. It explores the institutional setting, the legal framework and the management strategies that have developed to manage an increasing pressure on water resources.

3.1 Water Management in the Zayandeh Rud Basin

The question of which types of institutional arrangements are best suited for water management in a basin context has received increasing attention (Wester and Warner, 2002). In this section I describe how water management is regulated in the Zayandeh Rud in the present and what changes have taken place in the past few years.

Regulation of water resource exploitation and distribution is the responsibility of EWA that is supervised by the Ministry of Energy. This institute is responsible for surface and groundwater management in the basin. Within the irrigation sector the responsibility of the EWA extends to the outlet level. Water distribution in tertiary and lower level channel networks gets coordinated by the Esfahan Agriculture Authority under the supervision of the Ministry of Jihad and Agriculture (Morid, 2004).

The EWA has historically, and still is, a centralistic water management agency which reflects the way in which the state in the whole country has operated for the last century; first under the dictatorship of the Shah and later under the strong command of the religious leaders. As is usual for such centralistic states that manage water, in Iran water resources development is characterized by large-scale development and centralized management. In the last decade the degree of centralization has moderately decreased and little by little some responsibilities have been decentralized from the central office in Tehran to the regional water offices. Nevertheless I was astonished by the frequency with which the staff at high level had to travel to Tehran.

The EWA is structured with a General Director which responds to the head offices in Tehran. Under the general director is the vice-general director who is responsible for the water resources exploitation at the basin level for both surface and groundwater. This person is the one that directly decides how the infrastructure is operated within the basin. To support him there is a department of research and studies which has one general director and two main consultants. There is one consultant responsible for groundwater resources and the other for surface water resources. This personnel has its support staff and often works together. There are also several other departments charged with the different responsibilities of the agency such as accounting, construction and control.

It is known that extremes can often trigger changes in management and decision making processes. In the basin, before the drought the EWA was responsible for taking decisions on water distribution to the different irrigation systems and for all the other uses determining how the dam was operated and how much water the different intakes were able to extract from the river. In 2000 however, because of the drought and the growing tensions about water distribution and use, a council was created to take decisions over water distribution. The council is formed by five members who are: a representative of the Regional Water Office (EWA) representing the Ministry of Energy; a representative of the Regional Irrigation Office of the Ministry of Jihad and Agriculture; a representative of the Mirhab[12]; a farmer representative and a representative of the provincial government. This council meets on a monthly basis to decide how the water will be managed and distributed. Once the decisions have been taken in the council the EWA is responsible to carry these out.

The creation of the council has helped the EWA to get a wider support by society now that it is supported by a council in which several sectors are represented. This shift has not

[12] A decentralized agency responsible for the operation and maintenance of the irrigation infrastructure in the basin. See next chapter for a further explanation.

developed without conflicts. For instance the environmental groups have been pushing hard to get water liberated for the environment while agriculturalists have created a great lobby for getting water freed for agriculture and the urban use keeps on expanding. There are even claims from cities outside of the Basin.

The EWA has vested a lot of hope in the construction of the third diversion tunnel and in better years of higher precipitation, yet it is conscious that in the near future a severe and sustained water scarcity can appear as usable good quality groundwater resources get reduced little by little, population keeps on increasing and ever more claims are made on the water resources.

3.2 Water laws and management in time

Water management in the Zayandeh Rud has been dominated to a great extent by its Islamic roots. The Moslem Customary Law had three basic rules determining water rights. These rules mainly established that the first users of water were entitled priority of use over users that later accessed water. Furthermore it established that upstream users of a stream or river had priority of use and that the individuals that dug a well were entitled to the full use of the groundwater (Ghazi, 2004).

In the era of Shah Abbas, the system of water distribution based on the Toomar edict was installed to regulate the water distribution of the Zayandeh Rud. The Toomar edict was principally concerned with the changing regime of the Zayandeh Rud and was designed to minimize the inequalities of time, place and water availability[13]. It consisted of rules determining how the water got distributed along the river and within the madhis. This system was enforced by locally elected officials who had to ensure the adherence to the rules and to settle and bargain over disputes over water. A lot of the principles established in the Toomar have had a very long legacy and are still present in the few remaining mahdis (Ghazi, 2004).
After several institutional changes of the government of Iran during the twentieth century, in 1964 the Ministry of Water and Energy was commissioned to draw up and carry out plans and projects concerning the provision of water to main consumption centers, to manage formerly autonomous or semi-autonomous authorities and to supervise the manner of utilization of water resources (*idem*, 2004). On the 18th of July 1968, the Iranian Water Law and the Manner of Water Nationalization was established and with it a new centralistic water management era started in the country. The 1968 water law declared that the water resources of Iran were to be held in public ownership as part of the national wealth (McLachlan, 1988).
This law was intended to end the traditional system of water rights, based primarily on riparian water law doctrine, and replace it with a system of rights based on water use permits emitted by a central authority. The Ministry of Energy was established and made responsible for safeguarding and utilizing all water resources. The law established that all the existing water rights had to be reviewed and replaced by water use permits which nullified the prior water rights. The Ministry of Energy was made responsible for determining the amount of water to be used for agricultural, industrial or municipal purposes. Also according to the law, after 1968, Regional Water Authorities, subordinate to the Ministry of Energy, were established for the management of water resources at regional level. Although the law established drastic changes, on in the field, most things remained unchanged.

In 1983, the law of 'fair distribution of water' was approved by the Islamic government of Iran. This law empowers the Ministry of Energy to an absolute control of all fresh and saline water resources of the country (Ghazi, 2004). During the past two decades

[13] For a detailed explanation of the rules and regulations of the Toomar see Ghazi, I., 2004. Legislative and Government Intervention in the Zayandeh Rud Basin, Iran. Department of Geography, University of Esfahan.

the water authority has been mostly involved in the construction of hydraulic structures such as reservoirs, diversion dams, irrigation networks and inter-basin water transfer schemes. This construction and civil engineering drive of the Iranian hydraulic engineering bureaucracy has led to the construction of obsolete irrigation canals in the basin at places where there is virtually no water or very little water while farmers have been highly charged for this infrastructure (Salemi, 2003).

3.3 Water availability and its development in the Basin

This section analyzes the adaptations made at basin level within the irrigated agricultural sector since the construction of the Chadegan Dam. Water availability in the basin is only followed for this thesis since the construction of the Chadegan Dam in 1970. Before this time little is known about the water flows as the water flows were not controlled. Accounts of some inhabitants suggest that there existed great variation in water flows between different years before the construction of the dam yet these are not confirmed with hard data. The analyzed data shows that there exists a great variation in the inflows to the dam since the construction of it with some years of abundance and others of scarcity (see figure 3.1). The increase in dam inflows starting in 1986 correspond to the completion and use of the diversion tunnels that import water form the neighboring basin to augment water availability in the Zayandeh Rud Basin.

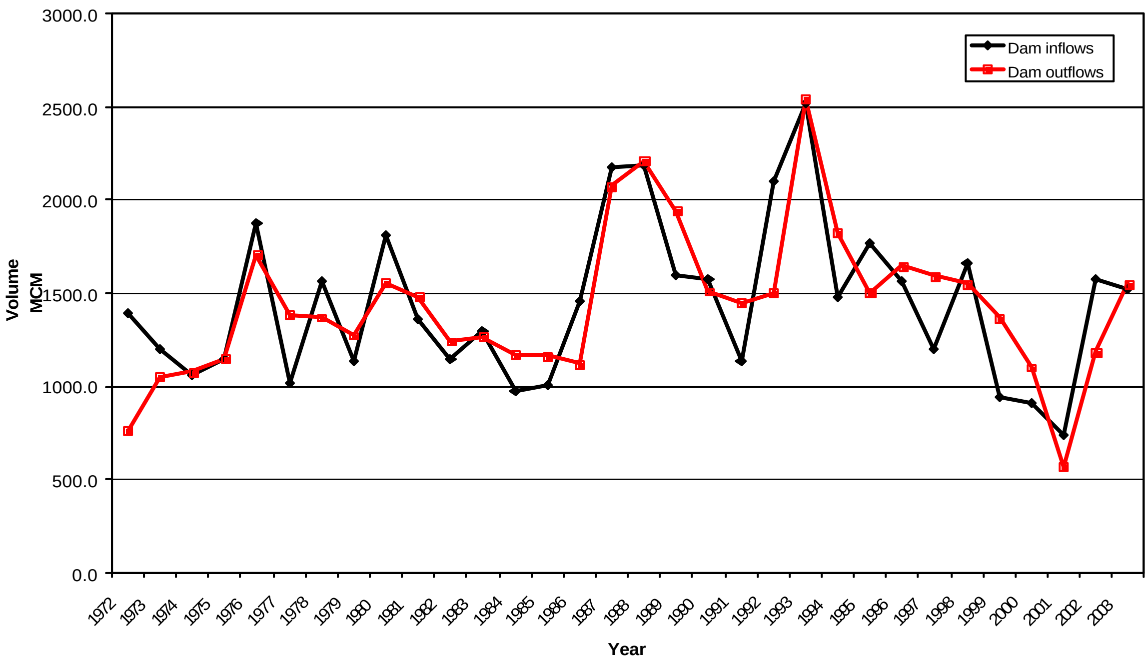

Figure 3.1 Chadegan dam inflows and releases since its construction (EWA, 2004)

As the Chadegan reservoir does not have any significant year-to-year carryover storage almost all the inflow during spring and early summer is released prior to the next flood season, making the reservoir (and the basin) susceptible to prolonged precipitation deficits (Murray-Rust *et al.*, 2000). This fact was confirmed during the 1999-2003 drought which saw the inflow to the dam reduced for several consecutive years. The three consecutive inflows of the drought years starting in 1999 were the three lowest values observed during the last 33 years, 2001 ending with an extreme low value of 739 MCM. The three-year spell can therefore be characterized as exceptional (Molle and Mamampoush, 2004). The result was reduced water availability in the basin. This reduced water supply brought with it several detrimental consequences for the basin in general but especially for irrigated agriculture. In the irrigation systems the water allocated was greatly reduced causing a reduced agricultural production, an accelerated and alarming decrease in groundwater levels and the transition for a lot of people from a rural agricultural life to an urban life.

Homer-Dixon (1999) identifies three different types of water scarcity which are supply induced through the decline of a key resource, demand-induced through an increase in the demand and structural scarcities through a change in the relative access of different groups to the resource. Since the construction of the Chadegan Dam in the Zayandeh Rud, as basin, there has been a slowly increasing demand induced water scarcity as the agricultural frontier in the basin has kept on expanding and the other water use sectors extended their water demands.

Since 1999 this scarcity was accentuated by a very extreme supply induced scarcity as was analyzed above. Here the developments within the agricultural sector are described. In 1986, when the first two tunnels were finished the water availability in the basin was augmented with 540 MCM a year to cope with the increasing water demands. This augmentation increased the allocation to the existing Nekoabad and Abshar systems in the beginning. Nevertheless, this augmentation has slowly decreased through new water allocations to the new irrigation systems and to other water use sectors (Salemi *et al.*, 2000) (see fig. 3.2 and 3.3).

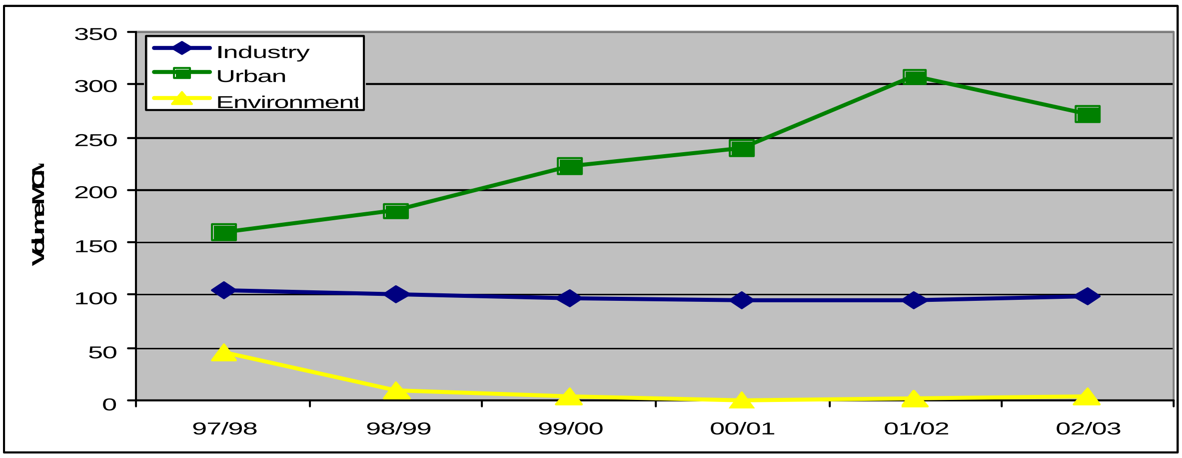

Figure 3.2 Water allocations at basin level to other water use sectors (EWA, 2004)

Unfortunately for the water use sectors other than agriculture the available data only covers the past six years. In these six years the industrial sector has not increased its water use while the urban/domestic water demand/consumption has been constantly increasing the past five years despite the severe scarcity that prevailed and, as in most basins, the environment and agriculture have been the great losers in the last few years of drought. Agriculture has seen its share of the total water volume released from the dam reduced since the drought despite the fact that dam releases have recovered. In the years 2002 and 2003 dam releases have greatly recovered yet agriculture has had less water than before the drought. This is because the percentage of water diverted to agriculture has been greatly reduced as can be seen in table 3.1.

Table 3.1 Dam releases and diverted volumes to agriculture from 1990-2003

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Diverted	837	738	1138	1153	1170	1057	1074	1104	1136	709	328	15	533	652
Released	1463	1308	1891	2433	1405	1437	1679	1418	1460	1284	987	613	1187	1549
%diverted	57	56	60	47	83	74	64	78	78	55	33	3	45	42

Within the agricultural sector in 1996 water started to flow to the newly installed Borkhar system, followed in 1997 with the first allocations to the Mayhar and Garguye systems and in 2000 the first water deliveries started to flow to the Rudasht system. These new systems have, since their first water allocation, slowly increased the amount of water flowing into the system at the expense of the older Nekuoabad and Abshar systems (See Fig. 3.3). This higher water allocation to the new systems is especially notable after 2001. In these years, even with a much reduced water allocation for irrigation in the basin, these new systems got water which historically would have flowed to the older systems. In this way the existing systems have lost a lot of their water allocation to the newer ones. These reallocations have taken place to alleviate areas where groundwater supplies have dwindled. These water allocations to new irrigation systems is clearly a reallocation strategy followed by the government to ease water scarcity in areas where groundwater has been over-exploited for a long time.

The competition for water is a clear sign of a closed basin in which the government is trying to "make do with what it has" by squeezing agriculture and spreading scarcity to an ever increasing number of users in order to keep the largest number of people content and to prevent social unrest. In the paragraphs below the dynamics that allowed the new irrigation systems to gain more irrigation water in a closed basin that faces great scarcity problems is described.

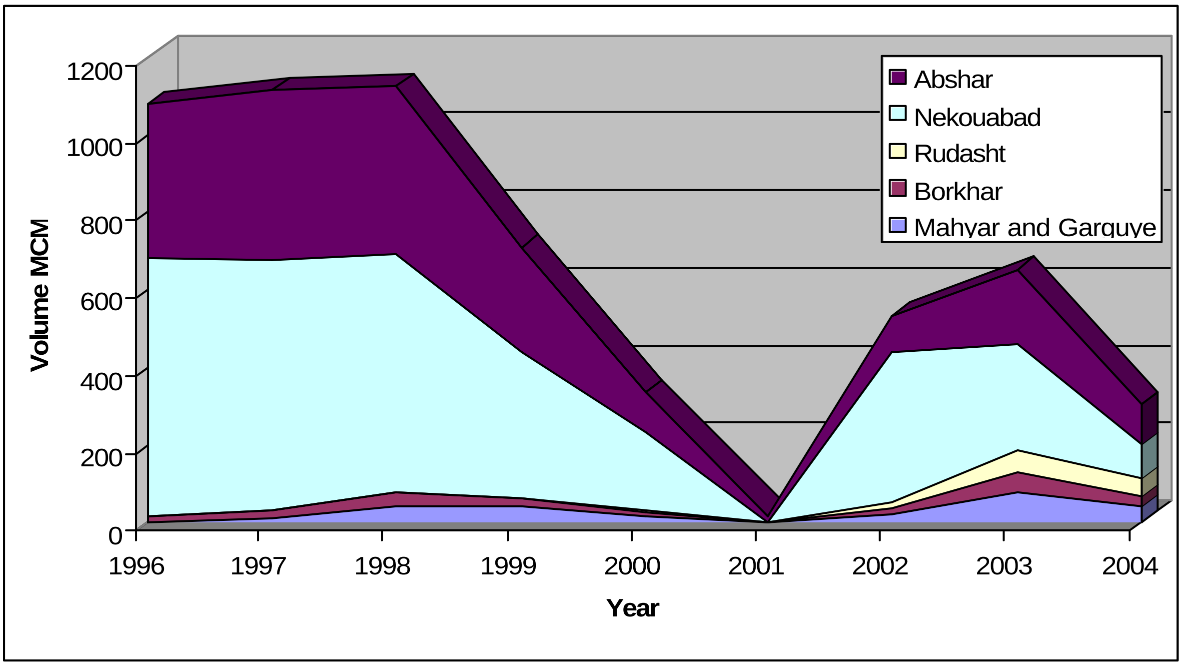

Figure 3.3 Water allocation to the different irrigation systems in the Zayandeh Rub basin[14] (EWA, 2004)

The Mayhar and Garguye as well as the Borkhar systems were originally developed using only groundwater through the use of private tube wells. As water withdrawal in these areas exceeds long-term recharge it results(ed) in rapidly declining groundwater levels with the consequence that some aquifers have dried up or made water exploitation uneconomical because of low yields or because of salinity problems. This problem was exacerbated during the drought as recharge of the aquifers almost disappeared and the decline of groundwater levels exacerbated. The farmers, who slowly lost their water, have put a lot of pressure on the

[14] In this table the Lenjanat irrigation system is not included as this system has still old mahdi rights and its water is not controlled by the EWA. Furthermore the data for 2004 is not complete as it only includes the water delivery of the spring season of this year.

government to grant them surface water for irrigation to compensate for the drying aquifers.

The systems are designed to operate as conjunctive water use systems. The Rudasht IS was originally irrigated by the traditional canal system (madhi's), and groundwater exploitation.

At the moment the IS is still under construction to replace the old *mahdis* that supplied most of the irrigation water in the area. The replacement of the old systems is clearly an efficiency issue in which it is believed that by reducing conveyance losses and increasing the control over water flows, water use efficiency will increase. Because in the madhis water flows were not measured, it is not clear if this system has increased its water use or not. Nevertheless what is sure is that the new system is being built with the intention to expand the area irrigated with surface water in the system. Nevertheless a lot of the newly constructed canals have never seen a drop of water flow through them. This fact raises great questions regarding the further construction of the network.

Because of the political power of the groups of farmers in the new irrigation systems, the revenues that irrigation construction bring (pork barrel politics) and a fear of great migration flows to the cities the government has expanded the irrigation systems to these new areas as a strategy for 'establishing political stability and human settlements'. The political discourse used to validate the expansion of irrigation systems in a closed basin is that water supply will be augmented in 2006 with the diversions from the new Khurang tunnels. The astonishing fact is that even though water availability has only decreased the past five years these new systems have gotten more and more water allocated.

3.4 Reallocation of water during the drought

To manage the above mentioned reallocations of water, and the overall scarcity in the basin, since 2000, EWA has decided to divide the basin into the upper basin and the lower basin with as division point the city of Esfahan. The upper part of the basin with the irrigation system of Lenjanat, Nekuoabad, Mayhar and Grarguye has water priority in the summer. This means that the priority of production in this region is concentrated around the cultivation of rice with high water supplies during the summer months.

The lower parts of the basin, which include Abshar and Rudasht, are now considered as mainly for the production of wheat and barley. This means that these systems have priority of water allocation during the autumn and spring irrigation season. Priority in the allocation of water means that the EWA tries to keep water flows as "normal[15]" as possible, for the specified season, to ensure that users can cultivate at least one basic crop per year. Under this water division structure, all the water received out of the priority season is considered as "extra" water because the EWA can not guarantee farmers that with the allocated water (which falls out of the priority season) they will be able to produce a crop.

In the Abshar System, in the years 2002, 2003 and 2004, in the summer season, a rotation was established in which each bank of the system would alternately get the allocated flow for one full week. With this allocation supplemented by groundwater a lot of farmers were still able to produce rice and vegetables in the summer season. Before the drought there was a constant supply of water to all the irrigation system during nine months of a year.

3.5 Groundwater resources

On basin level, 72% of total water use is groundwater with a total estimated use of 3500 MCM per year. At basin level there is little data available on groundwater, the different

[15] I refer to "normal" to the situation of irrigation water delivery which prevailed before the drought of 1999 started.

aquifers and the dynamics of them. The only data available in English is the data produced in the IAERI-IWMI reports. EWA does have more data on groundwater by all is in Farsi and not published. The staff of EWA empirically know in great lines how groundwater resources function and have 700 control wells that are measured on a monthly basis in the basin. Nevertheless there were no maps, models or any other information available during the field study period on where and how different shallow or deep aquifers function; where their boundaries are; how the groudwater flows are; or how the shallow and deep aquifers interact.

The bulk of this water is used for agricultural production. In the irrigation districts groundwater use is high. In Nekoabad and the areas of the Abshar and Rudasht irrigation districts that are near the Zayandeh Rud River have shallow aquifers of between 10-50 m. that are intensively exploited for agriculture. In these shallow aquifers there is a direct link between river flows, surface water irrigation in the systems and the level of the groundwater table (pers. com. Saberi). In general it is observed that the further form the River bed, the deeper the aquifers (See Fig. 3.4). These deeper aquifers respond much less to the fluctuations of surface water flows and can be considered mainly as fossil water reserves (*idem*). The deep aquifer water reserves are used mostly in the Brokhar and Mahyar irrigation systems as well as the northern most edges of the Abshar Left Bank.

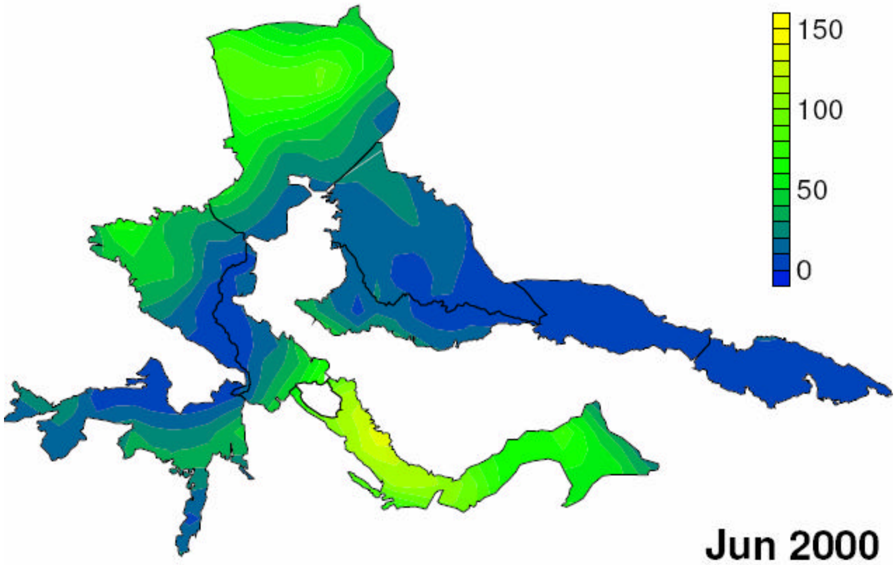

Figure 3.4 Groundwater levels in the main irrigation systems of the Zayandeh Rud basin in June 2000 (Droogers and Miranzadeh, 2000)

During the years of drought the shallow aquifers in the irrigation systems had a severe drop in groundwater levels as groundwater use increased while recharge was almost absent. Several farmers responded by deepening the existing wells. According to Saberi (pers. comm. and confirmed by farmers' interviews) the drop of groundwater levels in the deep aquifers also increased during the drought although in these deeper aquifers the drop of water level was less severe than in the shallow ones.

Although the EWA has a constant monitoring program in which the static groundwater level of around 700 wells in the basin is monitored on a monthly basis this information is not available to me but it was used by Droogers and Miranzadeh (2000) to calculate groundwater levels as shown in figure 3.4. An important aspect of this information is that it is based on static groundwater levels, which implies that the dynamic groundwater levels that are relevant for farmers are not included in this data set.

The above presented information on groundwater is the little information that is available to me for this study. The remainder of the information on groundwater used in this thesis is based on interviews with farmers and EWA staff and is not based on actual measurements or models. Because of this the descriptions made only describe the stories of the farmers and EWA staff without pretending to describe or understand how aquifer systems work or evolve. The information given on the evolution of groundwater levels in different areas is therefore also based only on farmers accounts and their descriptions; for this reason the terms deep and shallow aquifers are used in the way farmers use them and not based on any other data or understanding of the systems.

Finally, if we consider that average surface water releases from the Chadegan Dam are around 1500 MCM/year and groundwater use in the basin is calculated at 3500 MCM, it not hard to conclude that groundwater resources are being overexploited in several areas of the basin with the associated water quality degradation. This is a common problem especially in the north, south and the east parts of the basin (Salemi, 2003). This means that on the long run the exploitation of deep aquifers that have little direct recharge form surface water resources will exhaust the groundwater reserves. As control over groundwater, especially on the use of shallow aquifers, is very hard due to the fact that installing a shallow well is very easy, the EWA is limited in its management of groundwater to monitoring groundwater levels and limiting the construction of new deep wells in the basin.

3.6 Managing water scarcity at basin level revisited

As the Zayandeh Rud basin developed several strategies have been used by the EWA to deal with water scarcity. The first responses where mostly supply responses such as the construction of dams and hydraulic infrastructure in the basin followed by basin transfers and the massive development of groundwater based agricultural production. The last project within this supply response is the construction of a third trans-basin tunnel. A lot of these responses went along with conservation responses such as the modernization of most of the old *mahdi* irrigation systems, the reuse of treated urban water and an increased attention on management of the existing systems. In the past years, due to the drought, allocation responses have appeared as a necessity. These allocations have created some conflicts and prevented others from increasing and the EWA tries to keep as many parties as possible on its side. This political strategy has led to a “sharing of the cake” among sectors by squeezing agriculture (especially the old Abshar and Nekoabad IS) and spreading the water to as many beneficiaries as possible to prevent social unrest and massive migration flows from rural areas to the cities which are not able to absorb these population flows.

3.7 Wrapping up

This chapter described the evolution of the basin in the last years and the most important changes that have taken place in this period. The most notable changes are the reallocation of water to new irrigation systems despite extreme drought; the division of the basin in two priority areas for irrigation and the creation of a council to decide on water distribution at basin level since 2000. This chapter shows that as basins close and water resources become more contested changes to adapt to new situations emerge. Reallocation of water within sectors and among sectors is one of the most important responses used. The loser is mostly the long established irrigated agricultural sector.

This chapter also shows that within a basin the interdependence of users increases and is augmented by situations of scarcity. This is very easy to conceptualize by acknowledging that “what is stored, conserved or depleted at point A dictates what is available at point B further downstream” (Molle, 2003; 8) be it surface and/or groundwater resources and thus if water use for urban water supply is increased it inevitably gets reduced from the water supply for other uses unless it is reused as is often the case with urban wastewater.

Another interesting aspect is that the tensions and discussions on water allocation and distribution revolve around surface water, while groundwater keeps on being an open access resource in most of the shallow aquifers of the basin. This same phenomenon I observed in Mexico (Hoogesteger, 2004) and the tentative explanation is that the state can control surface water flows but groundwater flows and individual boreholes are very hard to control.

Chapter 4 Managing water scarcity at Irrigation System level

This chapter explores how water scarcity is managed at the domain level of the IS and in this context special attention is given to the arena of the Mirhab which is the company responsible for the O&M of the irrigation systems since 1993. The domain at the IS level is studied by looking at the institutional practices and context. After the analysis of this company, the chapter focuses on the AIS and how in this system water is managed by looking at technologies, and the organization of human activities. The end of the chapter presents the outlets used as case study areas.

4.1 Managing water at system level; the Mirhab

Irrigation reform, participation, decentralization and privatization of state operated irrigated systems has characterized interventions and changes in irrigation management for the past two decades around the world. The literature abounds with examples of failures and successes but in general the World Bank and other big international organizations have pushed for decentralization, volumetric pricing and reducing the role of the state under the neoliberal banner which has dominated world politics since the beginning of the 1980’s (Moore, 1989; Repetto, 1986). Iran has not lagged behind in these developments.

Institutional change or a new facade

Before 1993 all the O&M down to the outlet level was done by EWA. The Mirhab, as an independent semi-governmental institution created and contracted for the O&M of the irrigation networks in the basin, was established in 1993. This was done in a move of the central government to reduce the size of the institution through the decentralization of several responsibilities, especially the ones concerned with the execution of works. This move of the government opened the doors to private initiatives that compete against each other for the execution of public works and services. These changes were aimed at “improving the performance of the systems and increasing efficiency[16]”. The establishment of the Mirhab evolved through the branching-off of a part of the governmental (EWA) responsibilities and staff. The Mirhab was established as a parastatal enterprise in which 49% of the stocks are owned by the Water Authority and 51% by private investors. These private investors are nevertheless, for its majority, staff and personnel of the EWA.

The creation of the Mirhab brought little real change in the management of water resources at IS level. When the Mirhab branched off as a parastatal enterprise almost all the staff retained their jobs within the new organization and the institution changed little in its organizational structure. For the staff the working contracts changed from government employees to private employees yet most positions and responsibilities remained unchanged. The only difference was that the workers lost a lot of their privileges which they had had as government employees. The working hours have become longer and the responsibilities of the staff have increased, in the words of a staff member “the creation of the Mirhab was a political move on paper and the reduction of costs for the government has come on the shoulders of the workers”.

The EWA is still the major shareholder with the faculties to appoint and fire the Director General (DG) of the Mirhab and also to dictate policies and strategic changes in the institution. At the time of the field work the DG that has now fulfilled two terms finished his second term yet was not appointed for another term. There existed a lot of uncertainty about the future appointment of the DG of the Mirhab as there were speculations that he might be

[16] “Government officials by law work less than 8hrs a day and for the execution of operation and maintenance works such working hours are not efficient; therefore an independently contracted company was created” (Keiwanpour, 05-09-04).

changed because of political reasons. The decision lay at the EWA that seemed to play a political game by creating uncertainty and unrest within the Mirhab.

That the EWA keeps on holding almost all decision making power in its hands is not a strange phenomenon. Mollinga and Bolding (2004) show that in several countries such as Mexico, the Philippines and Indonesia the irrigation bureaucracies have been very good in maintaining their power and technical orientation despite reforms and changes which on paper seem very drastic. They call such a strategy a defensive strategy which entails that bureaucracies mould things in such a way as to continue with what they have done in the past despite "reforms" imposed from outside agencies such as the IMF and the World Bank.

The Mirhab and its responsibilities

The Mirhab as organization is responsible for the O&M of all the main irrigation systems in the basin reaching from Chamaseman (95 km west of Esfahan) all the way to the Gawkhuni swamp. Its responsibilities are the O&M of all primary, secondary and tertiary canals up the level of the outlet. From this point on it becomes the responsibility of the groups of farmers.

The Mirhab has in total 40 regular workers and added to these there are about 60 workers on a contract basis. The contracts vary a lot with some personnel being hired for only a couple of days or for a certain season and others having a fixed contract. The Mirhab is structured with one DG that is controlled by the DG of the EWA. Under him the DG of the Mirhab has three engineers responsible for operation, one responsible accountant and an engineer responsible for maintenance. For operation the basin is divided in three units. One unit compromises all the irrigation networks above the city of Esfahan, the other unit consists of all the irrigation systems below the city of Esfahan and the third, which is much smaller, consists of the irrigation network supplied by the dam of Karvan.

The Mirhab is contracted on an annual basis to execute all the O&M of all the irrigation systems in the Basin. As there is no competition from other companies the contract gets renewed every year. In this contract the contractor gets the responsibility for: operation and water delivery to the outlets (a fixed budget per year); small maintenance works, and; emergency maintenance of the system. For the bigger works of maintenance and construction tenders are set out on which different competitors (mostly construction firms) can submit proposals. This is for instance the case for the expansion of the networks or for the lining of great parts of canals. It seems that the EWA at the moment is pleased with the Mirhab and they claim that services have improved while the overall costs have dropped by between 15-20%.

Financing

The Mirhab gets financed by the EWA. Of all the funds on which the Mirhab operates around 20-25% come from the collection of water fees and the rest comes from the funds of the central government, which makes irrigated agriculture a highly subsidized sector despite a constant rise in the prices of water for agriculture. The collection of these fees is done by the EWA through a joint bank account of the Mirhab and the EWA. The bank account is controlled by EWA but the Mirhab has access to its information to control payment by the farmers and to keep its accounting for water delivery. The accounts of the farmers are paid per outlet. How farmers organize after the outlet is outside of the responsibilities of the Mirhab which only controls if the payments are made or not. The costs of operation of the Mirhab are pre-established by the EWA every year. The Mirhab must do with the budget they get with a 20% legal excess margin. In this budget O&M of the irrigation systems is included as well as all the other costs needed for making the irrigation systems function. Emergency works are not included in this budget, but the Mirhab has a financial 'carte blanche' for executing them.

Water fees are calculated volumetrically per cubic meter. This is possible through the accurate accounting and measuring of water deliveries through the use of 'modules a masque' and NEYRPIC modules that allow for a high level of accuracy in discharges, and control of flows in canals (Salemi *et al.,* 2000).

The 1983 water law empowered the Ministry of Energy to fix the average cost of water per cubic meter in regions where development plans or water nationalization had been put into force and to gradually incorporate all water users in each district or river basin into a water rate system based upon current expenses for management, maintenance, repairs, operations and capital interest (Ghazi, 2004). Before 1990 the prices of water were determined centrally from Tehran, but since then this faculty was decentralized to the provincial government. At present the prices of water vary between the different irrigation systems because the water fees are based on a collection fee based on the main produced crop. Therefore water is more expensive in areas where the main crops are more remunerative; at present the prices are 32 Rials/m^3 (€0.0032) in Nekuoabad (based on rice) and 26 Rials/m^3 (€0.0026) in Abshar (based on wheat and barley).

The EWA has a lot of checks and balances to control the operation of the Mirhab; for this reason "it is almost impossible to get more money than is really needed for the execution of the works" (Keiwanpour, per. comm.). The checks and balances are on all levels of accounting, field controls and constant monitoring of all the work. The EWA is pleased with the Mirhab, which is not strange if we acknowledge that the EWA and its personnel are still the ones that dictate and fully control the enterprise by holding all the stock and all the decision-making power.

Regardless of the political arrangements and power positions that dictate how the Mirhab operates it is a well functioning organization. The entire infrastructure of the IS is very well maintained; water delivery is controlled very strictly and with good management. I was amazed at how well maintained all the systems in the Abshar left and right bank were.

4.2 The Abshar Irrigation Network

The Abshar irrigation network originates just downstream of the city of Esfahan where the Abshar diversion weir feeds one right and one left bank (See Fig. 1.2 and Annex 2). Both the left and the right bank have a maximum design capacity of 15 m^3/s and a designed command area of 15,000 ha per bank. Nevertheless the left bank irrigates a cropped area of 23,000 ha while the right bank only irrigates 12,570 ha. The main canals are regulated using 'NEYRPIC' hydro-mechanical gates, while diversions to most secondary canals use NEYRPIC modules to deliver desired discharges (Murray-Rust *et al*., 2000). In the irrigated area conjunctive water use is common with some areas using exclusively groundwater and other relying solely on surface water.

The modern irrigation system was installed in 1970 to replace the old *mahdi* systems that existed. The modernization of the systems permitted the expansion of the agricultural frontier by making more water available and by extending the land suitable for the production of agricultural crops. Both the left and the right bank had a lot of swampy areas in the lower lying parts of the systems. These were not suited for agricultural production before the installation of drainage which went along with the construction of the irrigation canals in 1970 (field notes, 08-2005).

The groundwater conditions within the command area vary greatly. While in the areas that are close to the river groundwater at shallow depths provides a constant and good supply of water, there are other areas in the command area that can only access water from deep aquifers at depths of 120-200 m often with problems of water quality due to the high concentration of salts in the water. Accounts from farmers and researchers claim that thirty years ago when the system was installed in almost all of the area the depth of economically exploitable water lay between 6-20 m. At present some areas have dried up[17]. This is the case in the left bank canal in the areas that are very near to the mountain that lies in the middle of the irrigated area which corresponds to more or less the first half of the main canal. After this the main canal flows through the lower lying parts of the valley which have much deeper aquifers. On the right bank there is also an area where the shallow aquifers have dried up and this is at more or less the same height as on the left bank, where the mountain lies. On the right bank it is above all in the areas near to the canal as towards the river groundwater becomes economically exploitable (See Annex 2).

The farming conditions in the command area show great variation. As mentioned before there is great variation in groundwater availability. Some areas have 'abundant' groundwater and are able to produce a vegetable crop in the winter and rice in the summer. Other areas where groundwater supplies are non-existent or dwindling farmers are only able to produce wheat or barley in the winter and fodder corn in the summer on only a restricted area with surface water supplied by the canal.

Another variable that shows great diversity is the type of farmer and the size of the landholding. There are a couple or very large landowners that own and cultivate between 150 and 300 ha with some extremes in which one family owns around 1000 ha. On the other hand there are areas where the average landholding is 0.2 ha, and between these two extremes the ranges of variation are great. Although there is no clear pattern in this variation in general the areas that have an old irrigation history based on the use of old *mahdis* and qanats have small landholdings while the areas that were developed through the exploitation of groundwater with tubewells and later the use of the new irrigation network have a large degree of land accumulation.

The areas with large landholdings are areas were the land was acquired mostly by rich individuals that had access to cheap, at that time, unproductive land and had the resources to invest in tube well technology for the exploitation of groundwater and the start of cultivation of these lands (See Box 4.1). In several areas farmers started farming in this way based solely on groundwater, a process that took place since the advent of tube well technology in the first decades of the twentieth century. In the 1970's with the construction of the new irrigation network these farmers were able to buy surface water rights and thus increase their water supply making a shift to conjunctive water use. The same process is taking place at the moment in the Borkhar, Mahyar and Garguye irrigation systems in which farmers that depended only on groundwater are now slowly acquiring surface water rights. This increase in the use of surface water for irrigation implied in the case of the Abshar system that the environment (the Gawkhuni swamp[18]) saw its water allocation reduced. At present, the increase in surface water of the new irrigation systems goes directly at the cost of the water allocation to the old irrigation systems.

The areas that used to be irrigated with *mahdis* and qanats have an agricultural history that dates back hundreds of years. Through the passage of time the land has been inherited from generation to generation to an ever increasing number of farmers. Through this process the size of the landholdings has been reduced and the ownership of land fragmented. In some areas farmers with old *mahd*i rights were able to increase their land and water rights by buying land that was brought into cultivation by the drainage of the areas and the introduction

[17] This occurs where the alluvial material that stores water has little depth and lies on impermeable bedrock.

[18] The Gawkhuni swamp is the receiving body of the basin which holds great ecological values especially for migrating birds. In the recent past it has been declared a protected natural area and the tensions around its water supply have raised a lot of unrest in the water management processes.

of the new canal network. At present the very small landholdings (0.2 ha) are not able to support a family anymore and are cultivated for household consumption as an extra source of income beside other economic activities.

An extended family of 4 brothers (the Noubarsh family) work together on several farms controlling in total an area of 1000 ha around the Goh Ab (place with a lot of water) settlement which is situated near the Esfahan Airport. They have 500 workers and produce mostly wheat, corn, melons and some similar crops. In 2004 alone, a relative dry year, they produced 3000 tons of wheat on their farm. Together they own 13 wells, some are dug up to 300m. Before the drought the groundwater table in the area where they farm was at 30-40 m with very good yields. This water came from a shallow aquifer which dried up during the years of drought. The shallow layer has at the moment, at a depth of 50-60 m, groundwater but the water is salty and very little of it is available for exploitation. Now most of the water is pumped from a deep aquifer at a depth of 150 m. During the drought period they were pumping at depths of up to 250 m because water tables dropped to those extreme depths. When the brothers started to farm on a small landholding of their father, 55 years ago they used qanat water. At that time the groundwater table of economically exploitable water was at 6-7 meters depth. During the past 55 years groundwater tables have been dropping continually having as first consequence the drying up of the qanat. Beside the use of groundwater, the brothers also have a concession of 250 l/s from the Abshar Left Bank outlet P-5-12. This canal water right they bought in 1971 when the new system was put into operation. The surface water was administered to supplement groundwater resources on the farm. During the years of drought their water concession was reduced to 50 l/s so they relied almost entirely on their groundwater resources. The brothers are well educated and boasted about their trips to Europe of which they had some good memories and pictures. Besides they were well informed about the developments of the water plans and hope that with Kourang 3rd diversion there will be more water, both surface and groundwater… but we shall see what happens.

Box 4.1 An example of a big landholding within the Abshar irrigation network

Beside the variation in water access and size of the landholding, there also exists a great variation in the production patterns and crops. In the Abshar area the most important crops are rice, silage corn and vegetables in the summer and wheat and barley in the winter. Beside this there are some farmers that are specialized in the production of dairy products with Dutch Fresian-Holstein cows for which fodder crops such as maize and alfalfa are produced. Lastly in most areas sheep production also forms an important activity which is done in conjunction with the production of other agricultural crops feeding the sheep the left overs of after harvesting.

4.3 Defining the undefined rules of water rights

According to the law, since 1983, for assessing agricultural water rights, the Ministry of Agriculture determines the water needs of farmers based on the local tempo-spatial conditions of the farms and the public requirements of water. In practice only the area under cultivation and agricultural patterns are considered. This method is still applied for any allocation of water for irrigation by the regional water authority in Esfahan (Ghazi, 2004).

In the last few years no new water allocations have been made in the AIS, on the contrary water scarcity has forced the Mirhab and EWA to reduce water allocated to the different outlets. During the field work it became a great challenge to identify how water rights are defined and how the Mirhab reduced water flows to the different outlets. After the first interviews with the staff it seemed that all outlets shared scarcity equitably yet when controlling water volumes allocated to the different outlets and interviewing different farmers this seemed not match reality.

After several interviews and discussions with the staff of the Mirhab and farmers some interesting points came up. One is that water rights are not volumetrically defined and are left mostly to the discretion of the Mirhab. The Mirhab takes decisions on water allocations to the outlets for a certain season depending on the amount of water allocated by EWA to the different IS, the amount of water every outlet applies for at the beginning of the season and the kind of water rights different outlets have. The Mirhab considers three different kinds of water rights (Moslehi pers. comm.) and all water rights are coupled to land:

- *Mahdi rights*: These water rights are water rights that stem from the time when the *mahdis* and qanats were still in use. With the construction of the new irrigation network these water rights were kept by the original users/land. These water rights are coupled to the land that was originally irrigated with the old systems and based on that land the volume corresponding to these kind of rights is determined.
- *Branch rights*: These rights are surface water rights that were entitled to users once the irrigation network was completed. These water rights were given at the time to users that got new land for irrigation with the new network. The allocation of these rights was based on the then 'new area' to be irrigated.
- *Share rights*: After the construction of the network and the allocation of all *Mahdi* and *Branch rights*, the EWA kept on selling water titles to users that were willing to buy a water use permit. These permits were sold until the drought started in 1999. The permits originated form outlets that stopped using water because of urban sprawl or other reasons.

These individual rights of the users and the outlets of canal water are not clearly defined in terms of volumes or shares of the total amount of water, neither in the law nor at the office of the Mirhab. Water volumes of the use rights of outlets and individual users are thus subject to the decisions taken by the Mirhab and the outlet management. In 'regular years' the volumes are determined based on the historical water consumption which is based on the irrigated area and the kind of water rights the outlets have. In normal years there is no difference between the different water rights; nevertheless, this distinction in water rights plays a key role in the management of scarcity as will be explained later.

Farmers can not only acquire but also lose their water rights. This happens if a user or group of users does not use his/their water rights or do/does not pay for them in three consecutive years (Morshed and Moslehi pers. com). As surface water rights are directly coupled to land, users also lose their surface water rights when the land use changes to, for instance urban or industrial use. Some outlets near Labzon have lost a lot of water rights because of the expanding urban sprawl (Morshed, pers. com.).

With regards to groundwater, the Law for Fair Distribution of Water, ratified in parliament on the 2nd of March, 1983 establishes that the use of groundwater through digging wells, qanats or through the expansion of these systems must have a permit of consent from the Ministry of Energy, except wells with a discharge under 25m^3 per 24 hrs in non-restricted areas. For wells installed and functioning before the ratification of this law, the owners are compelled to register them. If the Ministry of Energy establishes a well to be functioning against the law it has the right to cancel the utilization of it. Besides, the Ministry of Energy has the faculty to prohibit and/or stop the digging, deepening and or expansion of wells and qanats that want to increase their water discharge for a specific period of time when: a) water extractions surpass sustainable yields and aquifers are in overdraft; and b) when the water resources are destined for a specific use as determined by the government.

The law also establishes that if the owner of a groundwater resource does not fully use all his resources he is able to sell the unused amounts of water to other users, unless the Ministry prohibits these water transactions. Besides, if the Ministry finds it necessary, users have to install a flow meter and a water depth level meter.

Despite the extensive regulations and sanctions established in the law a large number of wells are established illegally (Saberi, pers. com.). The number of shallow illegal wells increased in the past few years as farmers were forced to take greater risks in order to access water (several field notes, 09-2005). The EWA softened its hand on illegal shallow wells as a poverty alleviation and political strategy to keep farmers involved in agricultural production. Deep tubewells, which require large machinery to be dug are much more difficult to install illegally because EWA has a strict control over the enterprises that own such well digging machines and because to make it economically viable electricity is needed.

4.4 Water Scarcity in the Abshar Irrigation System

Based on the water scarcity and the decisions taken at basin level, AIS has suffered from a severe reduction of the water flows in the system. Figure 4.1 shows the evolution of the water allocated to AIS since 1981. This figure shows a significant increase in allocated water since 1986 which was the year the Kournag diversion tunnels started to function. The high water allocation of around 500 MCM was maintained until 1993. After this year the volume decreased to values just above 400 MCM. Water allocation started to drop drastically in 1999 reaching a historical low of 15 MCM in 2001 after which allocations have remained low. The Mirhab has developed strategies to deal with this water scarcity; these are analyzed in the section below.

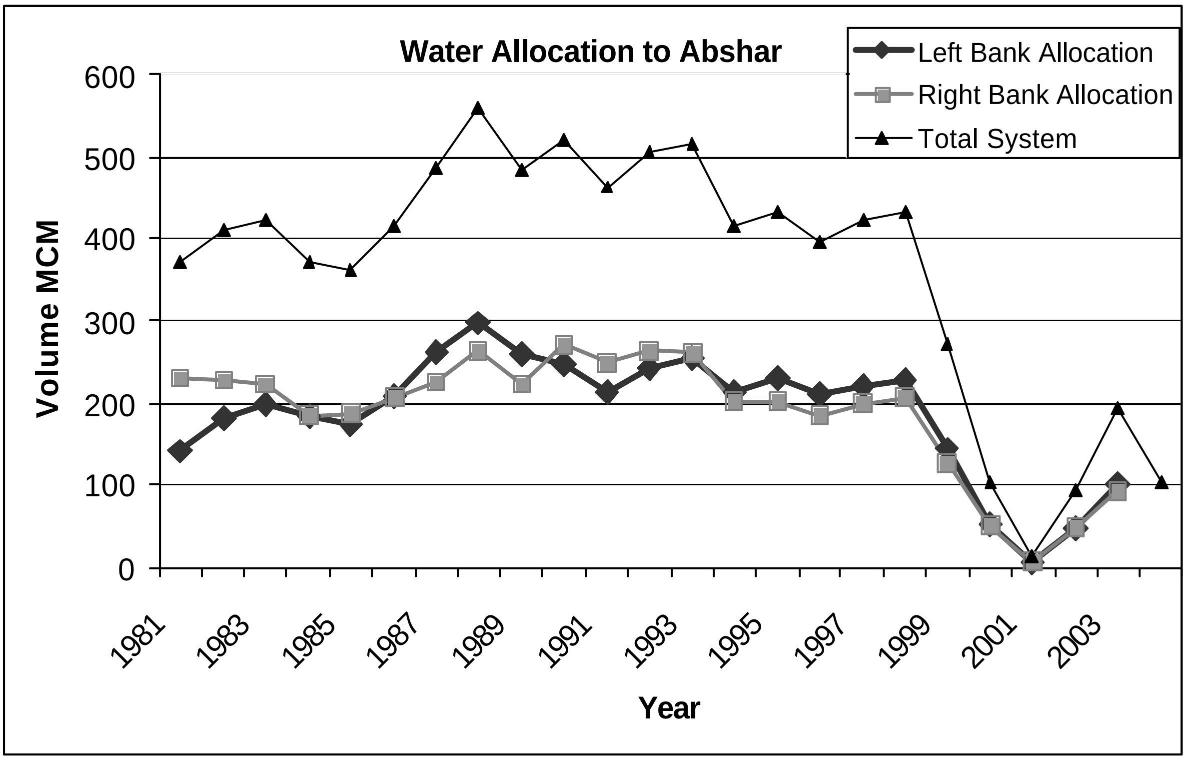

Figure 4.1 Historical water allocation to the Abshar Irrigation network (Source EWA)

4.5 Water allocations and reductions based on water rights

Since 1999 the inflows to the canals have been greatly reduced. This reduction in main canal allocations, are above all during the summer season because AIS has a priority of allocation for the winter-spring (wheat/barley) season. In the summer, water flows in a rotation in which one week water flows to the Right Bank and one week to the Left Bank with a reduced canal flow. In this way outlets get a reduced discharge of water for a week and then one week no water during the whole season.

Beside the above described measure to manage scarcity at system level, the Mirhab also makes water adjustments per outlet. The adjustments made depend on a couple of factors (Moslehi, farmer interviews, Morshed):

- *Availability of groundwater*: Farmers that have abundant groundwater supplies are reduced in their water allocation first, except if the water rights attached to the land are *Mahdi rights.*
- *Kind of water rights*: The different water rights have a different status when water allocations are reduced. If land with *share or branch rights* has good access to groundwater, its water supply gets reduced or even nullified, reducing first the *share rights* and secondly the *branch rights.* Several farmers in the RB P10 outlet, which is mostly *branch rights,* have not gotten surface water since 1999 because they own a well in an area with good groundwater resources. The Mirhab follows the *principle of prior appropriation* in which sustained historic access to irrigation water confers property rights enforceable by either law or custom and tradition (O'Mara, 1988). Once these have been reduced or nullified, the remaining water rights get reduced proportionally based on the water availability in the main canal.

Although officially not acknowledged, sometimes exceptions are made especially for the resource poor. One example is an outlet in Rudasht where wells have dried up and a whole community depends on the water of one outlet. In this case the manager of the IS gave the outlet proportionally much more water than other outlets. In the last years the Mirhab has also become much stricter in closing gates to outlets that do not pay their water fees on time, and some farmers without access to groundwater have gone bankrupt and leave agricultural activities. These two strategies have freed some water that gets distributed within the system.

As the above section shows, the Mirhab shares the cake as best as it can. An important aspect of this strategy is to keep farmers informed about the amount of water they will receive so that farmers can design strategies to maximize returns to available resources. The theoretical assumption underlying such a strategy is that farmers will focus on increasing water productivity instead of land productivity (Perry and Narayanamurthy, 1998).

4.6 Three different realities within one system

Within one irrigation system, in most cases, there prevails heterogeneity of realities, conditions and people. In the literature there has been a lot of attention to the differences that prevail between head and tail enders within a system (Wahaj, 2001; Kloezen, 2002; Oorthuizen, 2003). Because this study focuses on conjunctive water use the case study areas were chosen based on the degree of groundwater use. After a general survey of AIS, I chose three outlets[19] as case study areas; these are described in the section below.

It is here important to note that the information of the outlets is gathered from interviews with the farmers. This information was often contradictory and I tried to verify as much as possible at the Mirhab. Nevertheless this was very difficult. Information on the size of the different command areas of an outlet was non-existent or not available at the EWA and Mirhab. The only information that was available at these institutions are the old maps used for the construction of the irrigation system. These maps of 1968 are the most updated information available and in these only the layout of the main canals and gates is registered.

[19] An outlet is the command area that is supplemented with canal water from a gate controlled by a "*module a masque*" that is operated by the staff of the Mirhab. These gates are the transition point in which water management shifts from the Mirhab to the farmer(s).

Because of this, the command areas of the outlets are estimated by field walks and the interviews with farmers but these estimates are far from accurate.

The P5-1 Abshar LB outlet

The P5-1 Abshar LB outlet is situated very close to the city of Esfahan and belongs to the Labzon village. It has a command area of more or less 20 ha which is cultivated by around 180 farmers. The land holdings are very small with an average size of one to two jerib[20] which are often scattered within the command area in smaller sized plots. This land fragmentation can be attributed to the long history of agriculture of the site, which dates back hundreds of years, to the times when a *mahdi* and qanat supplemented the area with irrigation water. The qanat that supplemented that area was directly fed by the seepage 'losses' of the mahdi, so when in 1970 the mahdi was taken out of use and the new irrigation system got installed the qanat dried up and farmers became dependent on the present day irrigation network.

According to accounts of elderly farmers, the new irrigation system provided a higher and more regulated flow of water than the old systems did. This increase in water availability enabled a lot of farmers to change from crops like cantaloupe, cucumber and other vegetables to the production of rice in the summer. Nevertheless this outlet remained producing vegetables on about 40-50% of the land in the summer before the drought. The rest of the area was sown with rice. In the winter the crop production is mainly barley and onions and on some fields potatoes.

In the area there are two wells dug to a depth of 110 m and with a reliable discharge of 5" (which is an equivalent of 25 l/s) of water. Both wells are legal and operate with electricity. One of these wells was installed the year after the drought but at the moment is not working because the owner of it died and the inheritors can not get on good terms to operate the well. The other well in the command area is owned by one owner. This well is situated at the other side of the secondary channel and was installed 25 years ago. It has been functioning since then. Nevertheless it worked at a depth of 30 m before the drought and dried up during it. After the drought it was deepened to the present 110 m depth where it has a reliable discharge.

The P-4 Abshar LB outlet

The P-4 gate has two different outlets for two different groups of farmers and also belongs to the Labzon village. This gate is used to irrigate an area of ten hectares with farmers having holdings up to 10 jerib and most of the area belongs to one extended family. This area had *mahdi* rights before the construction of the irrigation system.

Before the drought this area had both surface and groundwater to irrigate the crops. The crops that were produced were mainly wheat and rice and to some extent cantaloupe. At present conditions of drought the outlet gets water two days a week every other week. The farmers can choose which days they want their water. They have to communicate it to the Mirhab and then the gatekeeper will open and close the gates according to their requests. During the winter- spring season the outlet gets its 30 l/s for as long as the season lasts or as much water as the water authority allows the outlet.

The area was supplemented with two 5" (50 l/s) wells that were installed already more than 40 years ago. The wells were dug to a depth of 40 m and during the drought these wells dried up and were deepened to a depth of 50 m where they hit on bedrock. One of the wells was dug 30 m into the bedrock but still no water was found and so all the attempts to continue to dig further where stopped.

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[20] A jerib is a Farsi land measuring unit and it compromises 1000 m^2.

At present the only water they have is a reduced amount of surface water and as a result the only summer crop that is grown is corn on only around 20% of the total area. Most of the owners of these lands have searched for other jobs outside of agriculture and now several of these lands are rented out with their supply of water. The agreements on which these lands are rented out vary greatly; some are on a fixed rate whether a crop is harvested or not. Other agreements are based on a sharecropping agreement which depends on the final yields that are obtained. In the winter-spring season surface water is more abundant and it enables farmers to produce up to 80% of the area with surface water alone.

Esfahanak and the outlets P-9 and P-10 Abshar RB

This area is also a place of old irrigation practices. Before the construction of the irrigation system there was an old mahdi called Esfahanak (at present the mahdi is still working but only serves a very small area near the village which is close to the river) which delivered water to some of the fields. The rest of the fields were, before the construction of the irrigation systems, swamps not fit for cultivation. The installation of drainage systems paired with the irrigation canals opened the irrigated frontier to 2-5 times its original cultivated area depending on the outlet.

The new areas that were put under cultivation were sold to the villagers nearby and some to outsiders. Most of the land became the property of the local people, for the outlets P-9 and P-10 most of the owners belong to the village of Esfahanak. The fact that such a great amount of land got distributed made the land holdings approximately 20-25 jerib per farmer with some extremes where farmers own up to 100 to 200 jerib. Most farmers have their holdings spread in different outlets and different areas within the outlet. This makes water management for the farmers more laborious and for this same reason some farmers have shares of several tubewells to irrigate the different plots they own.

P9 has a command area of around 400 jerib. The area has good groundwater supplies at depths of around 40 m with a maximum of 60 m, at which depth an impermeable layer of bedrock is found. Before the drought the groundwater depth was at around 23 m while when the network was constructed it could be found at 2-5 m.

The drought years saw an explosion of the number of wells in the area as farmers dug new shallow wells in an attempt to guarantee an abundant water supply for their crops. In the area the main crops for the summer are rice, silage corn and vegetables such as cucumbers, celery and others. In the winter the cropping pattern is dominated by the cultivation of wheat and barley.

The command area of P10 is a little less than 550 jerib and in it there are 24 landholders with all more less the same amount of water. Originally it was designed for 1000 jerib but after the Revolution the government expropriated 450 jerib for the establishment of a dairy production farm.

4.7 Conclusion

This chapter has described how water is managed within the Abshar IS domain by the Mirhab. In this system water allocations have been greatly reduced since the onset of drought. The Mirhab has responded by reducing its allocations to the different outlets by taking into account how much groundwater is used within the outlets and by the kind of water rights these have following the *principle of prior appropriation* in which sustained historic access to irrigation water confers property rights.

Chapter 5 Water scarcity management at field level

This chapter deals with the coping strategies farmers have developed at field level to manage a reduced surface water supply. The first section of the chapter deals with water control in its three dimensions which are technical water control, organizational water control and socio-economic and political water control. The analysis of water control bridges the domains of the irrigation system level and the outlet level and helps the reader understand the strategies farmers have developed to deal with water scarcity as the different dimensions of water control determine the 'room to maneuver' of farmers. Special attention is given to the shift from surface to groundwater. The chapter ends with a revision of the theoretical conceptualization on conjunctive water use.

5.1 Technical water control

Technical water control of canal water in AIS, which entails the physical control of water flow by means of irrigation technology, is basically controlled up to the outlet by the Mirhab. The ditch tenders of this institution have locks on all the gates to control the water flows to the outlets and patrol the main canals every day a couple of times to ensure that no farmers or others 'steal' water or tamper with the infrastructure. After the outlet, technical water control becomes the responsibility of the groups and/or individual farmers. These control the water flows within the outlet through earthen canals and simple 'self-made' sluices and earthen ditches; in some cases farmers have invested in lining their canals but this is rare. Through these ditches water is conducted to the fields within the outlet where irrigation is mostly flood irrigation for the production of rice, vegetables, wheat and barley; for silage corn, furrow irrigation is more common. At field level technical water control is the responsibility of the individual farmers.

Technical groundwater control is determined by the technology to extract groundwater and the presence of economically exploitable groundwater. Tubewell technology for shallow tubewells up to 50 m is easily accessible for most farmers as several dealers in drilling machines; diesel and electric pumps exist in the area. The access to diesel is very simple as it is a common fuel for trucks and other agricultural machinery. Access to electricity is more difficult as it implies a contract with the electricity company and the extension of the electrical network to the place where the well has been drilled. Once the water is pumped up the water flows are regulated through earthen canals and sometimes pipelines but there is no interference from the Mirhab or EWA personnel.

5.2 Organizational water control

In AIS, organizational water control, which encompasses regulation and control of human behavior in which processes of conflict management, communication, resource mobilization and decision making are needed, is guided mainly by old rules and traditions of water distribution and social conflict resolution.

Organizational water control is guided by the principles established in the traditions that stem from the Toomar edict. These are generally referred to as 'the Sheikh Bahai rules' which ensure a fair distribution of water within the outlet. According to these rules, an outlet is divided in six equal parts which are named *joughs*. Every jough has its own canal system, gates and sluices and is generally delimited by one 'main' canal within the outlet. These *joughs* rotate the full discharge of the water running though the canals by periods of one day. Every *jough* has one full day (24 hrs) of water to its disposition. The rotation works in such a way that the *jough* that in the first rotation gets the water first, gets, in the second rotation, the water the last as seen in Figure 5.1. Such a system is also still in operation in the management of qanat rights (Molle *et al.*, 2004). At *jough* level the same rotation system works among the different users.

The water users that operate within the domain of an outlet are responsible for O&M of their distribution canals. O&M of canals is organized by the users who usually establish one day on which all the users have to help with cleaning and repairing the canals. The *jough* and outlet tenders are responsible for the organization of these days. Depending on the outlet the maintenance works are done either once, twice and in some cases three times a year. Usually the work is done just before the summer season starts and at the beginning of the winter-spring season. Every *jough* has a responsible ditch tender that has the responsibility of controlling water distribution and fee collection within the *jough*. These *jough* tenders in turn have to pay to the outlet tender which is responsible for distributing water to the different *joughs*, collecting the fees from the *joughs* and paying the water fees for the whole outlet to the EWA. *Jough* and outlet tenders pay the water fees for their management area in advance and collect the water fees from individual farmers at the end of the growing season. The outlet tender is the person that directly deals with the EWA and its staff regarding all the water related affairs.

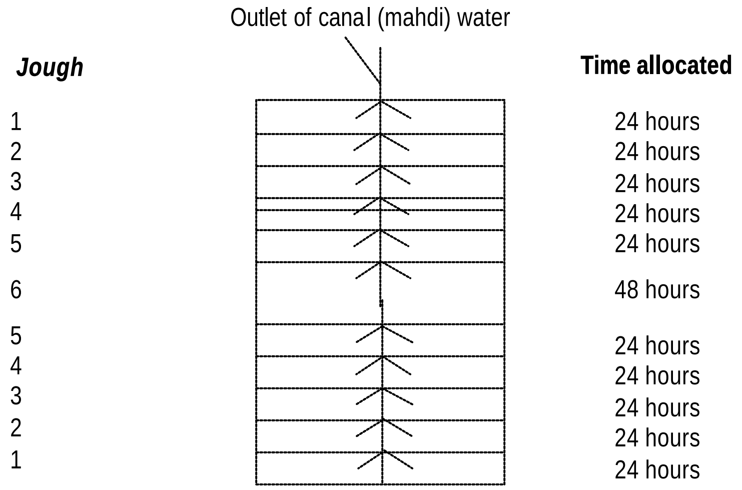


Figure 5.1 Water distribution system among joughs

The position of 'tender' for either an outlet or a jough is a position which is entitled through elections among the users. It is an honor position (no pay) and is usually granted to individuals that are respected in the community. The outlet tenders have to pay the water fees in advance to the Mirhab and later they collect the fees from the *jough* tenders, and they in turn, from the users. In most cases the outlet tenders are the people that have a good economic position and political influence in the community (See Box 5.1). Despite the fact that there exist different kinds of water rights, every season these are renegotiated amongst users as there are no volumetric concessions or water rights based on a fixed percentage of the total volume delivered to the outlet. The renegotiations of water rights are determined by factors such as the individual land area, crops produced, the history of the water use of individual farmers and the kind of water rights. In general, in these (re)negotiations of water rights within the outlet, small holdings get priority over larger holdings and people having rights that stem from *mahdi* or qanat rights have preference over more recent water rights[21].

All management and conflict resolution within the outlet is the responsibility of the users. Conflict resolution is done mostly in the field among users. If two users cannot resolve the conflict, more users are called upon and the decision is set to discussion in the group and eventually to voting. If this mechanism does not offer a solution, the community elder is consulted. In case a conflict cannot be solved in this manner, it is taken to court. Nevertheless

[21] See Chapter 4 on the different kinds of water rights there are within the irrigation system.

this only happens in extreme cases and not a single farmer remembered a case in which a conflict had risen above the community elders.

In the outlet P-5-1 Abshar Left Bank, the outlet tender is Mr. Yatafity who beside his job as ditch tender works as a taxi driver. In his younger years he had worked for the government in different positions starting as a worker in a government industry and working himself up though several positions until he became one of the leaders of the workers. Within the outlet he is the person that has the biggest landholding and two of his brothers are among the other 'larger' landholders of the outlet. Mr. Yatafity is the only user of the outlet that owns a functioning well. As a result he has a groundwater monopoly within the outlet. I never got the opportunity to speak to him even though I made several attempts to speak to him or make an appointment. Nevertheless, he never took an interview as he claimed to be always very busy. My feeling was always that he did not want to speak about his position within the outlet.

Within the P-9 Abshar Right Bank the outlet tender is Mr. Hussein Sarei whom I found one day inspecting the outlet. This man is also a respected man in Esfanak. On a second visit we met at his house which was one of the biggest houses in the village, towering with 3 floors way above the surrounding houses. His sons are studying in Esfahan or help him to manage the land. Mr. Sarei owns 10ha in the P-9 outlet and in outlet P-11 he owns another 20 ha. He also owns 3 wells to supplement his surface water supply and he mostly concerned himself with managing the people that worked the land for him. Beside this he seemed to be involved in other business in the town. When the irrigation network was built in 1970 he was one of the workers with a relative high position as land surveyor. Probably because of his position then he was able to accumulate so much land, which he bought once the irrigation network was finished and much land came into production through drainage of swamps and an increased surface water supply.

Box 5.1 Examples of the outlet tenders within the Abshar Irrigation Network

The farmers of outlet P-5-1 have a small tea house (office building) as their place of meeting, discussion and negotiation. During my visits to this outlet I always found the farmers and the ditch tenders having tea and water pipe there. During these encounters I always found them discussing when and where the water would flow during that week.

This place of meeting seems to be the oil that greases the irrigation practices at this outlet. During my visits to this place I noticed that all users participated in the discussions and the interviews which indicate that these farmers communicate openly with each other and thus find ways to solve the conflicts that might arise within the outlet. During and after the drought these encounters at the "office" have become more common as farmers look for strategies to manage their most limiting and at this moment scarce resource. During these encounters farmers not only discussed water management but all the different elements involved in agricultural production and would often organize to, for instance, rent a combine to harvest the rice, buy fertilizers in bulk, etc. What is evident is that the agricultural production planning, and water distribution process is a cyclic process is which decisions have to be readjusted all the time depending on the specific circumstances, the place where this takes place is in the tea house and in the fields.

Box 5.2 The tea house; the enabling medium for water management within the outlet

Oorthuizen (2003) shows how relations of friendship, kinship and personal contacts are of utmost importance in water management and conflict resolution within irrigation systems. In AIS it is also mostly family, friend, and community bonds that smear the negotiations within the outlets. All farmers know each other and through different bonds they manage to make agreements on how to share and distribute water (See box 5.2). A very important element in all these negotiations are the Sheikh Bahai rules that set the framework for negotiation and conflict resolution. Although these rules are not written on paper or imposed by the government, they live in the culture and traditions of the users, guiding their values and personal frameworks of negotiation. These rules determine for a great part what are found to be 'fair and correct' manners of handling negotiations over water and water distribution. Because of these rules water owners have a clear sense of their ownership of water and know when they are allowed to make use of the water.

During the field work it was very common to find several farmers in the field sitting under a tree or at a water division point discussing day to day matters of water management, the market price of different products or the difficulties they had, but also family and community issues. These encounters account for most of the negotiation and interaction about water management and water distribution within the outlet (See Box 5.3). Therefore, they commonly take care of the irrigation of their neighbor's plots, either because this has been agreed upon, or because the latter did not show up at the required time.

In contrast to the strong family, kinship and community ties that exist and guide negotiations and encounters at outlet level, ditch tenders of EWA are seen as outsiders from the city of Esfahan that do their job for the institution. Therefore they do not get involved in negotiations at outlet level. They know the outlet tenders and deal with them as contact persons but their domain does not reach further into the social structure of the outlet.

Groundwater management knows different forms of management but generally these are confined to a limited group of users in the field. The most common modes of groundwater management are:

- *Private well for private use*: This mode implies little organizational control as it is one user that has control over the water flows. In some cases the users use the surface water canals for transporting the water. In these cases it is only necessary to ensure that the use of these does not affect other users.
- *Private well for private use, selling excess water:* In some cases when farmers have a well which exceeds their personal needs they sell water to other users. In this case farmers have to organize to manage the water. In P-5-1 LB, as there is only one well, all its water is sold to all the users of the outlet. In this case, because of the high number of users, the groundwater gets managed under the same rules as surface water. The only difference there is that the fees for the use of the water go to the owner of the well instead of the Mirhab. The fact that the well owner is also the outlet tender makes the management and regulation easy.
- *Private well owned by several users:* Often farmers do not have enough resources to invest in a well by themselves. In these cases, farmers often organize in groups of two to five users, mostly friends and family and jointly invest in the drilling and installation of a well. The most common arrangement for these wells is that farmers pay for the O&M of the well according to the amount of hours they make use of it. As in most cases it is friends and family that jointly invest in a well, little conflicts arise in the use of them.

5.3 Socio-economic and political water control

This aspect of water control addresses the conditions of possibility for technical and organizational control. This type of control is about the domination of people's labor and the regulation of social processes (Mollinga, 1998). Although it is very hard to understand what elements are determining in the regulation of social processes, some important ones are explained below.

The strict control of the Mirhab over surface water within the irrigation system greatly determines how farmers operate within the system. The strict control of the Mirhab is possible by the enabling legal and political situation which gives the Mirhab a lot of faculties. In the last years and especially because of the water shortage in the systems the Mirhab has become a virtual water police (see Box 5.3).

At outlet level culture, traditions and history play a very important role in the regulation of water control as they determine how people relate to each other to achieve organizational water control; they shape the social structure that prevails within an outlet, within the system and in society in general. Besides, traditions determine for a great extent what crops people cultivate, how they cultivate them and what priorities they have in their negotiations.

During the field work several trips were made with the staff of the Mirhab to explore the AIS. During these field trips twice we found people pumping water directly from the canal into a water truck. On both ocasions the ditch tender immediately drove over to the truck, stopped the pumping and wrote down the licence plate of it. These trucks where reported to the police which would fine these. In case of repeated illegal water pumping the trucks can be confiscated. This strict control the Mirhab also has over farmers stealing water from the main canal. Farmers are usually also reported to the police but the real punishment is that the water deliveries to the outlet are cut for a couple of days.

At the moment of the research there was a legal process in the courts which would enable the Mirhab to become a virtual water police. If the process was succesful the Mirhab would acquire the direct faculties to take people to court and confiscate pumps, trucks and other technologies without the interference of the police. This move was aimed at reducing the bureaucratic procedures that make it hard for the Mirhab to file "water crimes". With this ammendment in the law, the Mirhab might get a lot of faculties that now still lie in the hands of police and different courts.

Box 5.3 The Mirhab's strong control over water resources in the irrigation systems

International, national and local markets are decisive elements that determine the cost of agricultural products, inputs and labor which greatly influence the decisions water users make with regards to the crops they produce. Other important factors are the decisions taken on higher level at the Mirhab, the EWA and the Ministry of Energy. These decisions directly affect the water availability of farmers; their organizational structures; their possibilities to take action and their ways of dealing with the authorities. For instance that fact that the Mirhab only deals with one outlet tender forces farmers to organize amongst themselves and to deal with their conflicts and water scarcity in their own fashion. If, for instance, a user of an outlet tampers with the gates in order to increase his water supply or commits another illegal act of water stealing, the Mirhab in first instance sets a punishment on the whole outlet. In this way the Mirhab ensures that through social control and pressure users behave according to the rules.

Of course these different elements of water control do not stand on themselves but are interrelated and affect each other across different domains, but for the analysis of water management it is very useful to differentiate these as each one gives another insight into the complex issue of water management. This section on water control has sketched the 'room to maneuver' farmers have within the outlets and as is seen, organizational water control plays a very important role in water management at outlet level.

Now that the situation of water control at outlet level has been described, in the following section the strategies developed to cope with drought and water scarcity at personal level are described in the paragraphs below.

5.4 Water Scarcity at outlet level

Since 1999, when the drought started in the Zayandeh Rud, the amount of surface water allocated to AIS and its outlets drastically decreased (See Fig. 4.4 and Fig. 5.2). Historically surface water allocations per studied outlet have been high. Figure 5.2 shows the evolution of allocated water volumes to the studied outlets. Because there is a lack of data on the area irrigated per outlet it is not possible to calculate irrigation depths for these outlets. Based on interviews with farmers and their accounts on the size of the outlet command areas would give annual (summer (rice) and winter (wheat) season) irrigation depths of between 3-5 m. depending on the studied outlet. Annex 4 shows monthly water allocations to the different studied outlets from 1991-2003.Unfortunately the command area of the studied outlets was not available at the EWA nor at the Mirhab so I have to "make do with what I have".

When considering the outlet area as described by the farmers, P-9 RB has a 'low' water allocation which is due to the fact that the outlet has excellent groundwater supplies and a more recent settling history in which groundwater supplies for irrigation were taken into account when the EWA extended water rights.

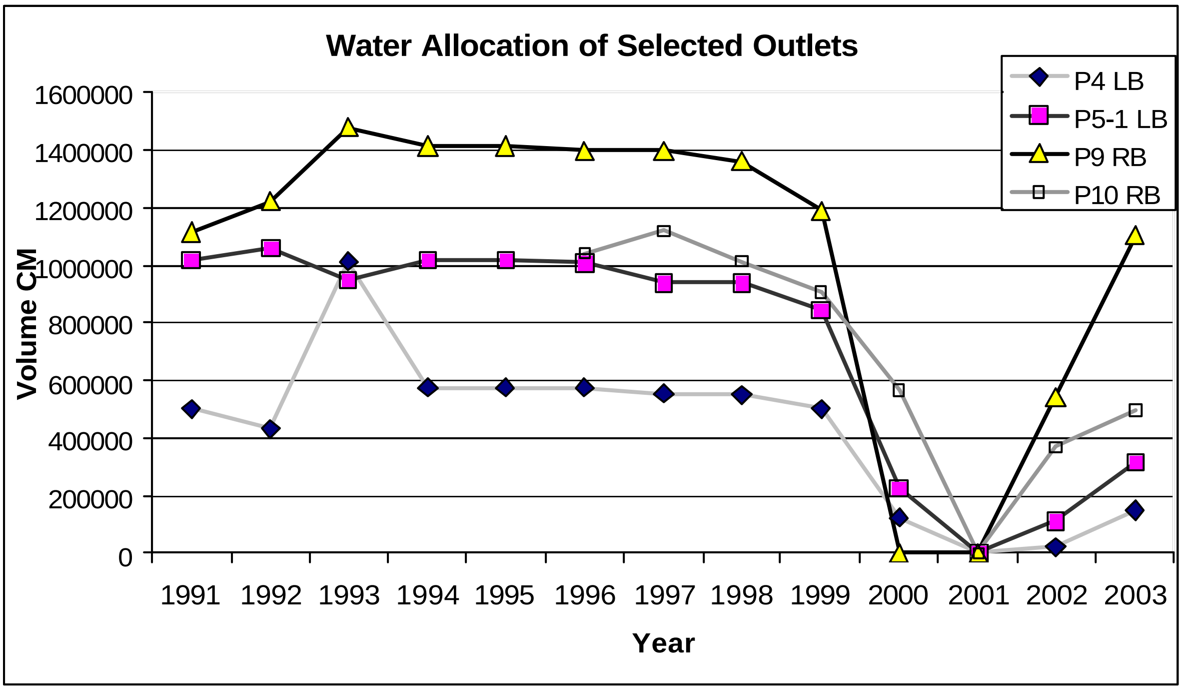


Figure 5.2 Water Allocation to selected outlet within the Abshar Irrigation Network (Mirhab, 2004)

In order to manage water scarcity in the different outlets farmers increased their groundwater use considerably. Farmers that owned wells started pumping around the clock while other farmers that had the possibility to do so, started digging wells in a frantic search for water. In the study areas P-9 the number of shallow wells increased from 5 wells before the drought to 18 operating wells[22] in the period between 1999 and 2004. P-10 has almost the same record. This was possible because a shallow aquifer, with a bedrock layer at between 50-60 m and with good direct recharge from the Zayandeh Rud River, underlies the area. Before the drought most wells could pump from 20 m while during the field study in 2004 most were dug to a depth above 50 m. According to farmers the groundwater level has a direct

[22] In the P-9 RB area there where 18 wells in operation at the time of the field work, yet there were also a lot of perforated wells that had dried up or collapsed.

correlation with the level of the Zayandeh Rud River and the surface water supplies. Thus, the aquifers have recovered to around 35-40 m since water flows have returned to the river and the irrigation canals.

In P-4 LB the two existing wells dried up and were deepened down to bedrock at 60 m without finding water. As a result this outlet has had to do without groundwater since 2000. At the time of the study one of the wells yielded water for 2 hours every 24 hours. New wells could not be dug because of a lack of groundwater in the outlet area.

In P-5 LB during the drought the existing well was deepened from 30 to 120 m and a new deep well (110 m) was dug. During the field work and since 2002 the second well was not functioning because of family disputes. Farmers in the area had already applied a couple of times for a permit to drill a new deep well but EWA has not granted it. In this area since the drought the existing well runs almost 24 hrs a day in the summer and occasionally in the winter season while before the drought it was used only to supplement surface water in the summer.

The increased use of groundwater on the one hand and a decreased recharge of the aquifers (due to low surface water use), led to a decrease in groundwater levels in the studied outlets and other aquifers of AIS[23]. The case study areas show that some wells dried up (P-4 LB) while others could be dug deeper (P-9, P10 RB and P-5 LB). Control wells of the EWA show a decrease in groundwater levels in the whole basin (Saberi, pers. comm.).

Molle & Mamanpoush (2004) found, based on an analysis of crop production and surface water flows in irrigation canals in the Zayandeh Rud Basin, "that drastic reduction of water supply in irrigation canals has been largely offset by a reduction in cropping area and an increase use of groundwater, with a limited loss in yields (p.10)." Figure 5.3 shows the evolution of cropped area from 1991-2003 for the Abshar LB. What is interesting is that although the cropped area got greatly reduced with the drought agricultural production remained relatively high, which can be attributed to the overall increase in groundwater use to compensate surface water scarcity. In 2001, the lowest water supply year still 9,975 ha out of the average 26,000 ha was cultivated exclusively with ground-water!

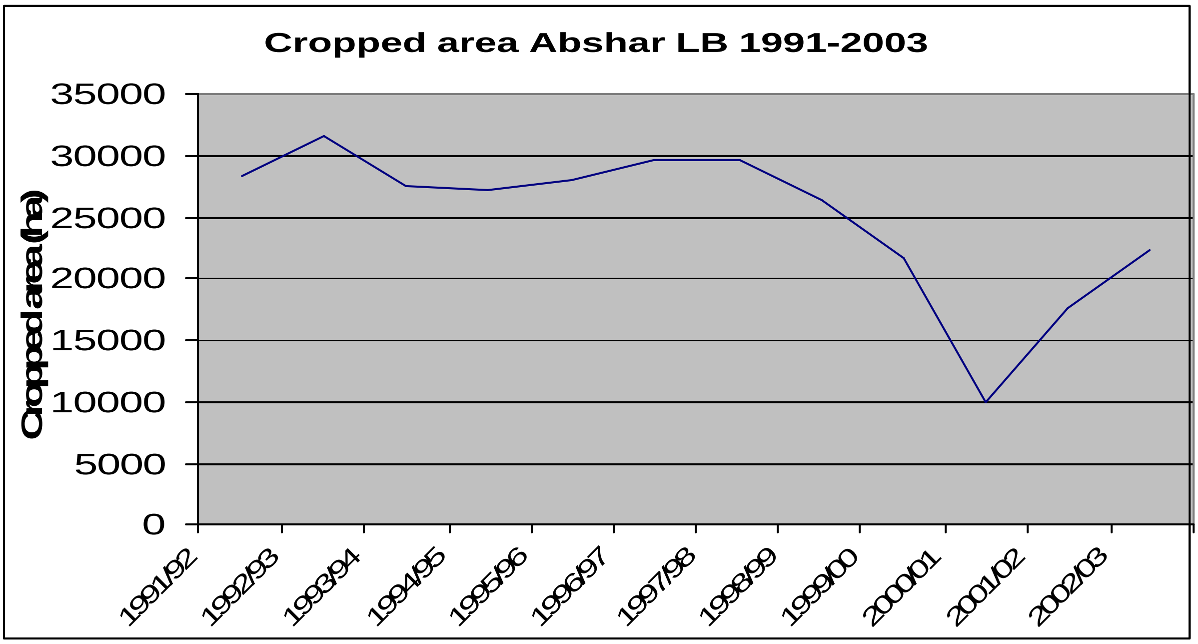


Figure 5.3 Cropped area of Abshar LB 1991-2003

[23] This information is from several interviews that were held outside of the case study outlets.

Thus, while before the drought groundwater was used merely to supplement surface water supply, at the moment because of the drop in surface water supply groundwater has become, for some farmers, the primary source of water, especially in the summer. During this season, for farmers without access to groundwater it becomes impossible to produce crops with the allocated surface water. In the P-4 LB outlet, where the well dried up for good, in the 2004 summer only 15% of the command area was planted to silage corn. This was possible because the water allotted to the whole outlet was concentrated on one field.

When the water shortage in the Basin started, the water supply was rationed and the Mirhab now decides when farmers get water. These decisions are well communicated to farmers and so farmers do know when they will get water. Water is allocated to the different systems before every irrigation season. Once the Mirhab knows how much water it has for every main canal, it computes the amount of water every outlet will get. This computation is based on the kind of water rights each outlet has and the amount of surface water available[24]. Once these computations are made the water allocation and schedules are given to the outlet tenders. Within the outlets, there exist well defined rotation strategies which enable farmers to know when they will get their water share.

5.5 Managing scarcity at field level

If the farmer has insufficient access to water from one source of water, as described above, then he will be forced to resort to other water sources or to other coping strategies. In this section, I describe how within the described conditions of water control people act to cope with water scarcity at field level. People are knowledgeable and capable actors that interact with their environment and other people; their behavior is shaped by the interaction of intrinsic personal values and extrinsic motivations. Thus, when the context changes, people respond by searching and implementing strategies, resources and intermediaries that enable them to manage a new situation in which they will keenly act to meet their objectives. Hence, when farmers are confronted with a short surface water supply they mobilize their resources and adapt their strategies so that they can achieve their personal objectives as best as possible. The responses are varied and can not be taken for granted as they are determined mostly by the context and the enabling conditions of possibility. Here the most common strategies used by farmers to manage surface water shortage during the drought period that started in 1999 in AIS are described.

- *Selling land*: Some farmers faced with water shortage have opted for selling part or all of their land. On the Abshar Right Bank P-8 secondary canal, several farmers sold part of their land, in most cases their orchards, to wealthy people from the city of Esfahan. These pieces of land have become large weekend villas with swimming pools and large gardens. Most of these villas have installed a small well to meet their water needs. Farmers that sold a part of their land mostly used that money to invest in the digging and replacement of wells. Around the head of the Abshar LB, several farmers have sold their land to meet the land demands of the expanding urban sprawl of Esfahan. Scarcity exacerbated this trend as several farmers where not able to remain in production. Most of these farmers have been absorbed by the urban economy.
- *Investing in the installation, replacement and expansion of wells*: To increase their water supply and sustain agricultural production as high as possible farmers with the possibility to do so made great investments to acquire groundwater.
- *Water stealing*: Although, as described above, the Mirhab is very strict in controlling surface water, since the drought the amount of cases in which farmers tamper with the

[24] See also Chapters 3 and 4 on how the EWA and Mirhab share water scarcity.

gates or use other strategies to augment their surface water supply has greatly increased. The Mirhab has had a hard time trying to control this water stealing with harsh measures such as closing the gate for a couple of days. Nevertheless it keeps on occurring and farmers have discovered the use of plastic pipes to make siphons. These siphons are installed at night when there is no supervision by the Mirhab and are removed before the ditch tender makes his round.

- *Legal surface water supply augmentation*: Some of the outlets can increase their surface water supply by pumping and or utilizing the water that remains in the main canal after its intake has been closed. The outlets that are able to do this are above all the ones placed at the head of the canal because the NEYPRIC systems installed control water levels upstream. The Mirhab allows this water use and in some cases also regulates it. Often this water supply consists of a very low discharge for two to four days after the main gate of the canal has been closed.

  Also to augment water availability, the P-5-1 LB outlet has installed, with the authorization of the Mirhab, a small ditch in the canal to increase the discharge of the outlet through a higher water level at the height of the outlet.
- *Sharing water within the outlet*: Kloezen (2002) shows how in central Mexico different water modules help each other to share scarcity and manage water. In the AIS, I witnessed the same phenomenon within outlets. Within the studied outlets users had devised strategies to manage the scarce surface water supply. The strategies mainly imply sharing water between the different *joughs* and between users. In P-5-1 LB, several farmers leave their land fallow during the summer season because of a lack of water; their water is then shared among the users that produce a summer crop. Farmers with less water consuming crops also give part of their water allotment to farmers that produce high water consuming crops such as rice. When farmers share their water the agreement is that the farmers that use the water pay for it. Amongst *joughs* farmers organize the management of water in such a way that the different fields get irrigation water when they need it. For instance rice fields that need water every day or every other day, depending on the season, will get the needed irrigation by sharing the water amongst *joughs*. Such sharing mechanisms involve a lot of encounters, a lot of negotiation and are only possible because of the high degree of organizational water control present in the outlet. In P-9 and P-10 RB water sharing in the outlet is less common because of the abundant groundwater supplies which make farmers more flexible. Nevertheless, as the cropped area is larger than can be sustained with surface water all farmers are very keen on using all the surface water allotted to them.
- *Reducing the area cropped*: A logical response to a reduced water supply would be to restrict the area under cultivation. This is a strategy which several farmers are forced to take in the areas where groundwater resources are not abundant enough to compensate for the surface water supply deficit.
- *Changing the crop pattern*: In AIS, traditionally most of the summer crops produced are high water consuming crops such as alfalfa, vegetables and rice. In the last years the production of fodder corn has increased considerably because it is less water demanding and can support some water stress without serious crop losses. In places where groundwater is scarce or absent, fodder corn has become the main crop while for farmers that can exploit groundwater resources without much restrictions rice and vegetables keep on being the main crops. Nevertheless most farmers are still focused on increasing land productivity instead of water productivity, for this reason most farmers keep on producing traditional crops on the land they have instead of changing to less water consuming crops.

Of course the kind of farmer and his personal objectives greatly influence the choices. For instance small farmers are very keen on producing rice because it is for selfconsumption and their monetary income mostly comes from other sources. Dairy farmers mostly produce fodder crops such as alfalfa and silage corn, while commercial basic grain and vegetable producers try to till the crops that will give them the highest economic returns.

- *Renting land elsewhere*: Some farmers have decided to move their agricultural practices to places where they can rent land with good water resources. These farmers become virtual agricultural gypsies following the best growing conditions for their specialized crops per season. Others just locally rent land that has good groundwater supplies. In some cases, farmers with little land but a good well will rent land from neighbors that have no access to groundwater.
- *Moving to other activities outside of agriculture:* The most extreme adaptation strategy is to leave agriculture altogether temporarily or in other cases permanently.

The responses to water shortage in the basin differ greatly because every user has a different set of intrinsic and extrinsic motivations to act in a specific way and adopt a specific strategy. In general farmers with access to abundant groundwater resources are inclined to increase land productivity instead of water productivity, in which case the production will be mostly vegetables and rice. On the other hand, farmers with access to little or restricted water are inclined to search for strategies that increase water productivity such as changing to less water consuming crops. Full time farmers of large holdings are very keen and careful in the management of land and water trying to get the highest profit out of their land and water while part time of absentee farmers with other sources of income will, in case of reduced water supply, more easily rent out their lands or sell their share of allotted water.

The degree of involvement in farming generally varies significantly. Full-time farmers living near their farm make decisions that differ from part-time or absentee farmers who live in the city. Also the economic situation of farmers greatly affects how they respond to changes in water supply. For instance rich farmers easily invest in well digging and deepening to increase their water supply, while resource poor farmers will be forced to "make do with what they have" or move to other activities. The returns from agriculture are usually low for people with little land, and to supplement their incomes a lot of smaller farmers have other sources of income; thus the shift to other activities and leaving agriculture becomes an easy escape for this group. Farmers with more capital invested in agricultural implements and land are more willing to make great investments to increase their water supply as the returns from the investments also bear more fruits.

5.6 The evolution of conjunctive water use revisited

The development and evolution of conjunctive water use under conditions of drought, which was studied in the section above shows that the conceptualization presented in figure 2.5 is a valid generalization of the responses that take place as a result of the reduced supply of surface water supply. Nevertheless, this conceptualization only holds if; the supply of groundwater resources is constant; the drought does not persist and/or affects the aquifers; and the irrigated area cannot be further expanded when surface water resources return. If land is not the constraining factor, there exists the risk that with the return of 'normal' surface water flows the area under cultivation gets expanded or a shift towards more water consuming crops takes place, instead of the groundwater use being reduced to original levels (See figure 5.4), creating an overall increase in groundwater use and eventually a long term non-sustainable situation which exhausts groundwater resources.

As this case shows, during drought groundwater supplies get greatly affected as farmers increase their groundwater use to compensate for the surface water they 'lost'. And as land is not the limiting factor, probably with the return of ‘normal’ surface water flows through the system, farmers will increase the irrigated land or change to other crops if groundwater supplies allow for it. In this way groundwater use will be higher than before the drought, a situation which will, over the long run, increase the exploitation levels of aquifers if no measures are taken to control groundwater exploitation.

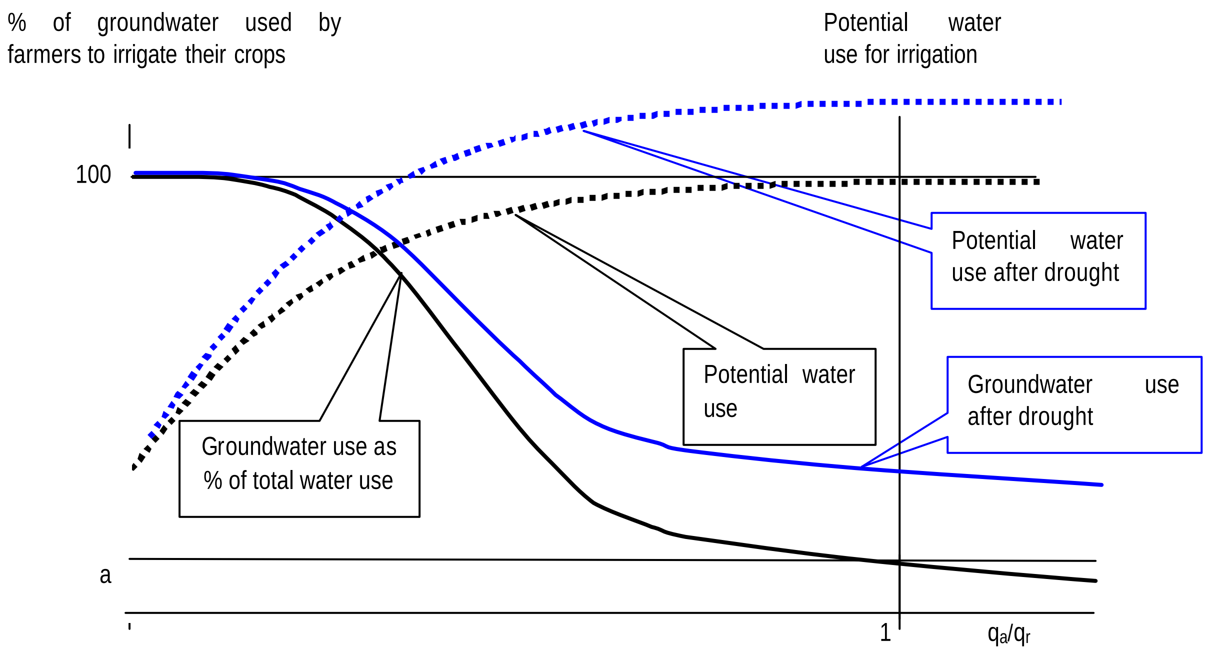
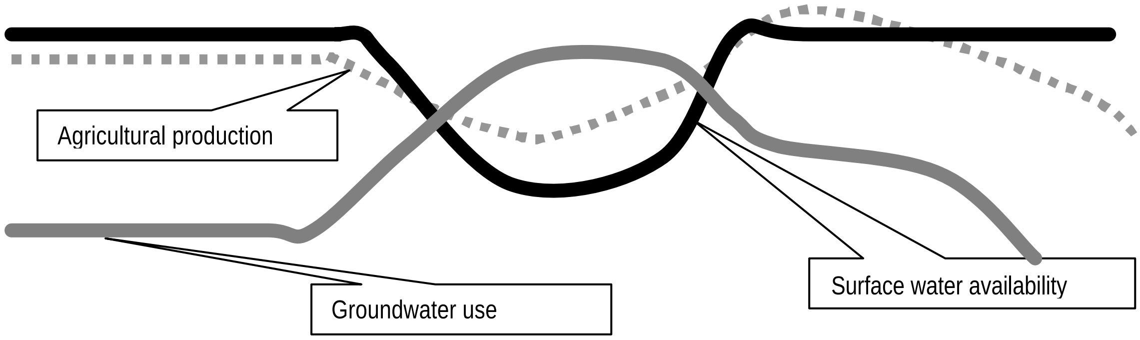


Figure 5.4 Conceptualization of the shift form canal water to groundwater and cultivated area related to relative water supply after a severe drought

My previous work in Mexico (Hoogesteger, 2004) shows that wells installed in irrigation systems for drought alleviation have become permanent sources of water even if normal water flow conditions return to the irrigation network. This process I also expect in the Zayandeh Rud Basin once the drought has passed because there is no strict control on pumping levels of the wells. As the number of farmers with access to groundwater through the installation of new wells has increased, so will their use of groundwater also increase once normal surface water flows return. This process of groundwater development and the increase of its use would lead to ever increasing levels of over-exploitation which on the long turn collapses as groundwater resources get exhausted. In this process, within a conjunctive water use setting drought can greatly trigger the increase in the number of tubewells and groundwater use within the IS. This process of groundwater development before, during and after a drought is shown in figure 5.5. In this process of water use, with the return of normal water flows first there will be an increase in groundwater use compared to the situation before the drought if aquifer yields have enough water (be it fossil water or recharge). In this period there is a slight increase in agricultural production, nevertheless this bubble of high production fades away little by little as groundwater resources get exhausted and farmers come to rely again on only surface water. Such a system, which might eventually find a stable point, will be much less resistant to another drought event if it reappears because groundwater resources will have less resilience due to over-exploitation.

In such situation of groundwater use, even in a conjunctive water use setting, a problem which will often be encountered, where there is a lack of control over groundwater use, is the over-exploitation of groundwater in great parts of the system, because often farmers mine groundwater reserves to irrigate their crops. As these reserves gradually disappear, even under normal conditions of canal water flows, the loss of this source of water is inevitable.



Normal surface water availability	Drought period with low canal flows	Normal surface water availability after drought

Figure 5.5 Rise and fall of groundwater use as a response to drought in a conjunctive water use setting

The evidence of this study and the consequences of the increased use of groundwater after a drought event brings us back to the importance of groundwater control and management for ensuring the sustainability of the exploitation of this resource. The problem with groundwater resource management is that it does not involve great infrastructure which can be controlled by an irrigation agency, but its control implies controlling and restricting the groundwater use of thousands of individual users. As such measures are very expensive and unpopular the governments usually leave groundwater use to ‘laisse faire’ regulations and control until it is too late to ‘close the door after the horse has bolted’.

5.7 Scarcity management revisited

This Chapter clearly shows that in a conjunctive water use setting groundwater use is directly linked to surface water availability. The recent years which presented an extreme case of surface water scarcity triggered an explosive increase in the number of wells and the use of groundwater for irrigation. In AIS only a few farmers have shifted to an exclusive use of groundwater as farmers have shown an increased interest in their surface water supplies. This interest can be attributed to the high quality and low cost[25] of it and the awareness of most farmers that surface and groundwater are intrinsically linked.

This chapter shows that farmers have responded to a reduced surface water supply through a mixture of supply, conservation and allocation responses to scarcity according to the specific ‘rooms to maneuver’ different farmers have in a conjunctive water use setting. Supply responses are the most common and imply increasing groundwater use; nevertheless not all farmers are able to augment their supply. Farmers with a reduced water supply have been forced to use conservation responses at field level such as a change in cropping patterns and reducing the irrigated area. At outlet level several allocation responses have also evolved among users.

[25] See Chapter six for an analysis of the costs of water.

Chapter 6 Is there room to maneuver?

This chapter focuses on possible changes in water management in the basin. For water management agencies it becomes a challenge to design policies of shortage management that stimulates society to optimalize the use of the little water there is. This chapter looks at two issues of water management that could create some “room to maneuver” for farmers and the Mirhab.

6.1 Conjunctive water management in AIS.

As seen in Chapter 2 there are several voices in the literature that advocate for conjunctive water management as a way to increase water use efficiency in irrigation systems with surface and groundwater. Yet most of the studies and empirical material come from systems where water management institutions have a high degree of control over surface and groundwater as well as the users. These conditions are mostly found in the United States and some European countries. O’Mara (1988) recognizes that, in most of the rest of the world, there are several constraining factors that make conjunctive water management difficult or impossible to implement.

Advocates of conjunctive water management often ignore the fact that control over groundwater extractions is, in most developing countries, an almost impossible task (Burke and Moench, 2000; Hoogesteger, 2004). In AIS there is also little control over groundwater exploitation with the result the water tables have drastically dropped in the past few decades. In a case such as this, conjunctive water management will probably imply reducing the exploitation of aquifers to sustainable levels, a process that will meet a lot of resistance from the side of the farmers because it means reducing water consumption and thus production.

Coming back to the more general management issues discussed in Chapter 2, in AIS, conjunctive water management is at the moment and idea that is far from becoming reality. The institutional setting is not ready for such an approach towards water management. Some of the most important constraining factors are:

- ❖ A lack of knowledge about groundwater flows and the relationship these have with surface water flows.
- ❖ A lack of control over groundwater exploitation within the system.
- ❖ A disjoint management of surface and groundwater. These two sources of water are managed by different institutions and there is a lack of interaction between the two.

On the other hand, there are also factors that would enhance a shift towards conjunctive water management:

- ❖ The high degree of surface water control in the irrigation network enabled by the technology used (NEYRPIC systems and “modules a masque”) and effective management by the Mirhab.
- ❖ Accurate volumetric surface water pricing.
- ❖ Political pressure to manage water resources as efficiently as possible.
- ❖ A legal system that theoretically enables the government to control both surface and groundwater resources.

Hence, a move towards conjunctive water management would need an institutionalized change of water management practices in the IS and at field level. Institutionalized change is almost always shaped by new arrangements such as new norms, bylaws, rules, roles, procedures and regulations which emerge within institutions or come from outside pressures. These reforms create new forms or patterns of interactions and relationships between all actors involved (Kloezen, 2002). The established practices at different levels, which always involve social, political, physical, economic or human relationships, will also have to change to adapt.

The implementation of conjunctive water management in AIS would require first of all better control over groundwater exploitation and more studies on how aquifer systems and their flows work. For these studies and a careful planning of conjunctive water management expertise is necessary which could best come from the joint work of the Ministry of Agriculture and the Mirhab. Secondly groundwater control and monitoring should be decentralized and become the responsibility of the Mirhab which, in such a case, should closely work together with the Ministry of Agriculture at field level. It would require careful planning of water delivery schedules that take into account groundwater availability per outlet, irrigation efficiencies, surface water availability, crops and area that are being produced per season, and so on. Such changes, or lets call them adaptations, of the management of water resources in the Zayandeh Rud basin would require extra financial resources but could very well fit within the present day structure of water management.

6.2 Water markets for seasonal water reallocation

Worldwide, many countries have introduced new water acts, or modified existing water laws in order to provide market incentives for establishing secure water rights in such a way that should stimulate the reallocation of water through water marketing, instead of the more common administrative decision making process (Kloezen, 2002). The idea behind it is that "water allocation through markets in tradable water rights offers a viable approach to improving the efficiency of water allocation" (Kloezen, 2002 p. 17). According to Kloezen (2002), the most common assumptions and arguments used by advocates of water markets are:

- water markets encourage users to allocate and use water more efficiently;
- water stimulates buyers and sellers to treat water as an economic good and consequently will induce economic efficiency by shifting water from low to high value uses;
- water markets encourage crop diversification by increasing the flexibility of farmers in response to changing prices.

On the other hand it is also widely recognized that water markets are far more limited and static than is often assumed in policy papers. Water pricing and water transactions are already part of the day to day practices in AIS. In the section below the prices of water and the dynamics of the transactions are analyzed, and later the possibilities for seasonal water reallocation are discussed.

Cost of surface- and groundwater

Perry (2001) suggests that charging for water in the Zayandeh Rud Basin has had little or no effect on the efficiency of use of water. Since 1979 charging for water has taken place in AIS. At the moment of the research the cost of surface water in AIS was 2.6[26] toeman/m^3. As in many countries throughout the world, the Iranian government keeps the use costs of water for agriculture low. The reasons are mainly political in nature and include: subsidizing low food prices, stimulating self-sufficiency in the production of staple foods; controlling political unrest and poverty alleviation.

The costs of groundwater vary greatly depending on the circumstances. Farmers that buy groundwater from other users usually pay the highest price for groundwater which is three to over four times the price of surface water. In the P-5-1 LB outlet the cost of groundwater was 11 toeman/m^3 (calculated based on the discharge and the time the water was used) making groundwater more than 4.25 times more expensive than surface water.

[26] One toeman is the equivalent of ten rials and represents € 0.001

For users that own or co-own a well, the price of water is determined by the kind of energy they use (diesel or electricity) and the depth of the groundwater table. For an average diesel pump that extracts water at a depth of between 40-60m, the costs of groundwater O&M, is some 6-7.5 Toeman/m^3. For a same well, operating on electricity the price drops to 3-4 Toeman/m^3. Wells deeper than 100 m operate almost exclusively on electricity. For these wells the price of water is 5-6 Toeman/m^3. Of course the O&M costs of different kinds of engines vary a lot an depend on the type of engine, how well it works, at what depth groundwater is, how good the water supply is, and the efficiency of the pump.

Beside O&M costs, the investment costs of installing a groundwater well have to be added. The drilling costs vary greatly depending on the contractor that digs the well, the kind of material into which the well is dug, and the depth of the perforation. A perforation of 40-50 m, 4’ discharge well in ‘soft’ alluvial material costs between 3 and 3.5 Million Toeman (Mt) (€3,000 – 3,500) to which 2-3 Mt have to be added for the installation of a diesel pump or 5-6 Mt for an electric pump. If the perforations are deeper and on harder material such as compacted impermeable layers perforation costs of a 120 m well can account for up to 25 Mt.

Summing up groundwater is always more expensive than surface water and depending on the case the costs can be one and a half to up to 4.25 the cost of surface water. Although the costs of groundwater are higher, in the last years the use of groundwater has increased considerably with a lot of farmers investing in installing new wells in the whole AIS area. At present the expenses of groundwater irrigated crops, on average, represent according to farmers one quarter to one third of the total input costs for crop production. Because the price of water, even if it is expensive groundwater, is the most limiting factor for crop production, farmers do not hesitate to use the groundwater they need. Most interviewed farmers were willing to buy more surface water at prices they now pay for groundwater. This willingness to buy surface water and the many transaction that already take place with groundwater trading offer scope for creating water reallocation mechanisms at outlet level.

Is seasonal reallocation through market mechanisms feasible?

Within AIS water markets could become a way of seasonal water reallocation between outlets within the system. For this to happen some outlets would sell part or all of their water rights per season to other outlets within the system. Under such an arrangement water rights would not be lost but the water only transferred to another outlet during part of- or a whole season. Outlets with good groundwater supplies or outlets that leave a season fallow could sell their surface water to other outlets that are willing to buy the water at a higher cost. The highest bidder would then buy the water though a process of negotiation in which the Mirhab would play a crucial role as mediator. There are two possibilities to establish arrangements:

- Trade water before the start of the season: once water availability per outlet is calculated by the Mirhab farmers would have the chance to, based on their allocation, decide whether they are willing to buy or sell surface water for the whole season. The Mirhab would play a role as intermediary in the negotiations as it is the institution that would also execute the actual water deliveries.
- Trade water during the season: this would be a more *ad hoc* strategy in which farmers would buy and/or sell water as the season and their water requirements go.

The introduction of a legal and institutional structure to implement such changes could be easily achieved in the present day structure of the Mirhab.

One point of attention which would need a revision is the establishment of volumetric of proportional water rights per outlet. As at the moment the water rights are not clearly established, these would need to be specified more accurately than at present. The framework already exists but the water rights would have to be defined better. Boelens (2002), based on work in the Andes, stresses that clear water rights are the first step towards water trades and markets as they give farmers ownership over water.

Although it was a very strange idea for the staff of the Mirhab that water could be marketed and traded, several individuals within the institution believed that it would not be very hard to introduce a structure in which the transactions take place. Among the farmers there was more skepticism and not a single farmer wanted to sell part of his water right, even for a season. On the other side, in practice farmers are already sharing, buying and selling water within the outlet all the time, which indicates that water trading is already a part of the water management practices of farmers.

In interviews most farmers showed great interest in buying more surface water if the possibilities for it would exist. The past drought and its aftermath have made farmers aware of the 'real price of water' so they are not willing to do with less water than they get and are thus not willing to sell it. Nevertheless, if we consider this drought as an exceptional case of water scarcity in which farmers are in a frantic search for water, probably, if surface water availability increases, aquifers stabilize and conditions return to a more 'normal' situation, farmers will ease their grip on water and become more flexible in its trade if the enabling framework for it exists.

It is important to acknowledge that people are motivated by complex intrinsic and extrinsic values which guide their behavior. Therefore it is not realistic to believe that all farmers will react in an 'economic rational manner' when dealing with water which is a resource that has many cultural values. If the price of surface water is kept low by the EWA, for most farmers, regardless of the crop or the size of the land, irrigated agriculture keeps on being financially interesting so there will be little willingness to sell the precious resource even for a season if the financial compensation for the water is not close to the outputs they would get from using the water themselves. The advantage of having the possibilities to sell and or buy surface water would give farmers much more flexibility in their use of water.

Water 'markets' for seasonal water reallocation between outlets is a new concept and like any change it needs time to settle in the minds of the farmers and to prove if it is an effective strategy to reallocate water among outlets within the AIS. For the Mirhab it would be possible to establish a framework that facilitates seasonal water reallocation. The effectiveness of such a strategy of reallocation can only be tested by implementing it. I expect that a strategy in which water can be traded among outlets will make water more mobile and give framers more 'room to maneuver' with regards to their water use practices and income generating strategies. I don't believe such a strategy will have much effect on water productivity. The most it does is increase the possibilities farmers have with regards tot their livelihoods strategies and the mobility of their economic activities.

6.3 Conclusions

In conclusion farmers have at present little 'room to maneuver' beyond the outlet domain. The most plausible option to create some space to negotiate under present day circumstances is the implementation of mechanisms that enable the exchange of water among outlets. Such a possibility would widen the range of strategies that land owners have for pursuing their livelihood strategies.

EWA and the Mirhab are also limited in their possibilities to design strategies that enable them to 'optimalize' the management of water by social pressure, a lack of knowledge and control over groundwater resources, and a growing pressure on water.

Chapter 7 Water scarcity and coping strategies

7.1 Wrapping up scarcity and drought management

There are a lot of theoretical approaches towards how societies and individuals react to drought, water scarcity and an increasing pressure on water resources within a basin. This study has focused on the real life situations and empirical responses that have evolved in the Zayandeh Rud basin as a result of drought and increasing water pressure. Special attention was given to situations of conjunctive water use because it is very common for irrigation systems to have both surface and groundwater use along side each other.

In the Zayandeh Rud Basin, partly as a response to the drought, which is a climatological phenomenon, several institutional changes have taken place and new allocation policies have emerged. These policies have tried to spread the overall water scarcity of the basin among all the users by squeezing water allocations to agriculture; by reallocating water from older irrigation systems to new ones and by sharing the remaining water between the existing systems. In this manner scarcity is accentuated in already existing irrigation systems.

Drought has allowed and in other cases forced politicians to impose policies that enable them to deal with the water shortage even if they are unpopular. These policies are not only a result of political decisions; they are embedded in a very specific context which creates the conditions of possibility that enable and form these policies. The context is created by the natural environment, the perceptions of society, the different lobby groups, and international discourses on water management, the economy, personal interests and culture. The adaptation strategies developed at political and governmental level emerge as a response to a felt need for change created by extreme events that appear by the exhaustion of a resource. Change is not always welcome as it brings both positive and negative effects; as a logical outcome several actors will offer resistance to change but this is part of the adaptation strategies chosen.

While politicians and managers of water resources in the basin try to spread the resources amongst all users, individuals develop strategies to deal with a reduced water supply. These coping strategies are in first instance all aimed at maintaining their water supply level high, mostly by the use of groundwater. Only when this possibility is exhausted, do farmers search other solutions to 'make do with what they have'.

The increased use of groundwater and the absence of aquifer recharge through return flows from surface water irrigation have accentuated the overexploitation[27] of groundwater resources with as a result declining water tables and in some cases aquifers that have run dry. The government has kept a blind eye on groundwater exploitation of shallow aquifers as its use temporarily alleviates the tensions that have emerged because of the drought. On the long run, however, groundwater overexploitation is a virtual "time bomb" which is already exploding in some areas.

As the sealing potential of water augmentation in the basin will probably be reached with the third Kurang tunnel and the present high use of groundwater, no new sources of water will be available to further increase the supply of water. As pressure on water will keep on increasing society will have to find strategies to optimalize the use of its precious water. This will probably imply reducing the allocations to agriculture and using the water for other economically interesting uses. In such a proces compensation mechanisms have to be devised to give the present water users in the agricultural sector other livelihood alternatives by some kind of compensation mechanism. The options are varied but special attention should be

[27] The increase in groundwater is not quantified nor studied by EWA of any other institution so the only indication we have of this increase is the decline of aquifer levels and qualitative field data.

given to the implementation of them. In the proces of change that would be required with such a shift in water use it is important that users become active participants in the proces and not mere recievers. This implies a longer road in which a lot of negotiation will be needed, nevertheless it will probably create a wider basis of support for such reforms.

7.2 Methodological discussion

The character of this thesis is above all empirical and descriptive by which it comes in the region which is usually attributed to the social sciences. I attribute this to the fact that in the Zayandeh Rud there are almost no studies of this kind except the recently published work of Molle *et al.,* (2004). All other studies conducted by earlier research of the IWMI-AERO collaboration are, what I would call, technical studies which are good for describing environmental changes and natural phenomena or making projection over future resource utilization. Nevertheless these studies ignore the interactional domain created in the political, social and economic arenas that shape the decisions taken at basin, system and field level. In these studies politics and social phenomena are usually taken as a black box. As in a great part of the irrigation literature, in these studies a lot of attention is paid to technical and policy challenges which are, most of the time, approached from a theoretical point of view. The use of mathematical, hydrological, economic and political models is often the basis for the studies as they present a 'rational' base for analysis. At the same time such models are also 'safe' in that they produce rational and usually relatively simple results to complex problems by taking only a couple of variables into account. By manipulating these variables researchers often work out scenarios that might develop in the future under different assumptions and validate these with their models and theories.

Nevertheless the fact is that more often than not reality is more complex than the models that are used to describe it. This is especially true for models that take into account social phenomena. With this critique I do not want to discard such studies and models; they are very valuable tools which should keep on developing, but want to focus the attention on the need for empirical 'down to earth studies' which take into account the day to day struggles of individuals in the irrigation domain.

The need for such empirical studies appears form the necessity to understand how institutions and individuals work, operate and react to changing environments. These studies require a broad understanding of the complex social processes that take place in a specific context and how these relate to the natural environment and the changes that take place within it. The information for such studies can only be gathered by entering, as researcher, into the interactional domain of the involved actors and study their day to day practices. Entering this domain can only be done through field observations, long semi-structured yet open interviews and the collection of above all empirical qualitative data. From this point of view it might appear that such studies become almost anthropological studies. To a certain degree this is true, yet the great difference is that in studies of irrigation, it is also necessary to deal with the natural environment which is determining in shaping social structures and responses. This creates the need for reliable quantitative data on the technologies and environmental phenomena present. These can then be related to the social processes of change and adaptation that are observed in the field. In this way both technical and social sciences are integrated to describe, explain and understand a specific situation.

7.3 Theoretical implications

This thesis shows that irrigation entails the management of water, information and people. Hence, for researchers of irrigation it is necessary to understand the arena of irrigation and the broad context in which it takes place. The concept of practice has shown to be a good tool to study the people and their strategies that interact in the irrigation domain in which water transforms livelihoods.

During the field work of this thesis it became clear that when analyzing responses to drought it was not possible to understand what was happening at field level by just looking at that domain. Thus I had to extend the analysis to the domains of water management at irrigation system and basin level. For this I studied the practices of the people of the institutions that manage water at these levels. I am convinced that only by studying the people and their practices we are able to understand why certain decissions and actions are taken within a certain domain.

In the Zayandeh Rud basin there is a general lack of qualitative data that describes the processes that take place within water management institutions and at field level. This thesis is to a certain degree a pioneer in its kind. It is a first attempt to try to understand how the practices that guide water management at different levels are shaped.

With regards to scarcity and drought-management this study shows that the practices of the water management institutions within the government developed strategies that spread scarcity among society by squeezing agriculture. From within the institutions it is a very rational decision that acknowledges that agriculture is the largest water consumer with proportionally the lowest economic returns per water unit. From a societal point of view it is well justified that agriculture gets reduced in its water allocations as it is the sector where with the least economic and societal damage the largest volumes of water can be liberated.

At field level in the agricultural sector there is no understanding for such strategies and farmers do their best to acquire as much water as possible. Their main concern is their own sustenance and production. Farmers are concerned with water management on their plots but what happens at basin or even irrigation system level is not "their direct business" so there is little understanding of the processes that take place at those higher levels. The only results they see are a reduced water flow and a reduced production.

This brings us to the fact that in the study of irrigation and the different levels that compose water management it has to be clear what the purposes and aims are of each person and institution involved. In this sense we should see farmers mainly as producers trying to maximize production and water managers as people trying to manage water in such a way that their social, institutional and political goals are met

Because of the above mentioned rationalization I strongly believe that in policy discourses an active role of the government in natural resource management should be advocated. Governments have to deal with political pressure, social unrest and society in general which makes them responsible and accountable to society. This responsibility is, in one way or another always one of the most important factors that determine political decisions. Private investments do not have the social pressure as motivating factor in decision making. Private companies are most of the time inclined to only look at the economics of their investments but far less to the social results of their work and thus they should not be involved in the creation of policy. The role of private investments in natural resource management should be limited to execution work under the strict supervision of the government. Decentralization can, as with the Mirhab, be a good option as long as the institution keeps on being accountable to the government and its users. Thus, I believe that interventions for inducing change in public administration should shift towards strategies that change inefficient governments instead of the present trend that seems to make markets, private investments and economic rationality 'untouchable and unquestionable' strategies needed to improve natural resource management around the world.

7.4 Wrapping up

Now that I am almost closing this chapter and this thesis I come back to the research question that gave form to this thesis in order to concisely present the answers to it:

Which strategies have the water authorities and farmers developed to cope with drought induced water scarcity in a conjunctive water use setting in the Abshar Irrigation System?

The answer to this question was found for this thesis through the study of institutional practices and irrigation practices which gave a deeper understanding of the mechanisms that have surged for designing measures aimed at coping with drought in a closing basin.

The first level that was studied was the basin level; at this level the most important strategy that has evolved is spreading the scarce water among as many users as possible by squeezing agriculture in the basin. The second level is the Irrigation System Level at which the Mirhab also distributes water to all the outlets following the status of the different kinds of water rights, the amount of groundwater present in the area, and several subtle social and political motivations. At this level scarcity is also divided among all the users.

At field level farmers have developed several strategies aimed at increasing the availability of water at field level which is possible in most areas by increasing groundwater use either by longer pumping hours, deeper wells or new ones. Other strategies developed to deal with water scarcity at field and outlet level are: selling land, water stealing, sharing water within the outlets, reducing the area cropped, changing the crop pattern, renting land elsewhere or moving to other activities outside of agriculture. These strategies are guided and shaped by the context in which the farmers operate and by the personal rationale every individual follows.

The context and existing practices at outlet level enable the introduction of seasonal water reallocation mechanisms at outlet level through water exchange mechanisms. In such a situation water could be traded (bought/sold) between outlets and farmers. These trades with surface water already take place informally between farmers but only within outlets. Groundwater buying and selling is in most outlets common practice. For the regulation of these water transactions between outlets the Mirhab would play a central role in the negotiation between outlets and would also be responsible for the actual execution of these water trades. These water trades would increase the communication between the different outlets and might even create new situations and organizations in the irrigation system.

Conjunctive water management could also work to alleviate the pressure on surface water resources and help to get a more equitable water distribution which takes into account the total water availability and not only surface water of the farmers. Nevertheless there are great institutional and knowledge hurdles that would need to be overwon before any serious attempt towards conjunctive water management is made. Another risk with conjunctive water management is that it will only create a more intensive use of water resources if, for instance both surface and groundwater are exploited to their sealing potential.

7.5 Further research

As mentioned before this research is mainly qualitative in nature. In this it is almost an exception to most other studies on the Basin; most existing studies are technical and quantitative in nature. Hence there is a great need for qualitative empirical studies on the social processes related to resource management and its development at different levels in the Basin and Iran in general. Little is known about how institutions, society and irrigated agriculture develop in qualitative terms. Thus there is a need to better understand which factors shape the dynamics of change taking place in the basin.

On the other hand, there are also great gaps of information on groundwater flows, recharge and the relation between surface and groundwater. Other basic data on the irrigation network are present but not updated; especially maps. At the EWA there is also a lot of information on water flows within the basin yet little is done with this data and it is very hard to access it from outside. Hence it is another point which could be analyzed in the near future to see the development of water distribution within the basin and within irrigation networks.

Another point of great interest to study is the role of women in the communities that are dependent on agricultural production and how this role is changing as society moves toward a more urban lifestyle within a strict Islamitic regime.

This thesis has studied how society manages scarcity through different strategies; as shock events such as this drought usually trigger processes of change it would be very interesting to study what the effects of the drought are on policy, water management strategies and conjunctive water use in the long run. Such a study would analyze what lasting changes were triggered by the present drought (I expect that the drought will have long lasting effects on society and the manner in which it uses and manages its water resources). For such a study this thesis gives a very good starting point.

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List of pictures

All pictures taken by Jaime Hoogesteger. The pictures used for the cover of the chapters are modified with the aid of Photoshop.

Annex 1 List of people interviewed

The following list contains the names and position of the people interviewed during the field work in Iran. Of the people listed on this list some where interviewed one, others twice and others several times.

Dr. Iran Ghazi	Department of Geography at Esfahan University
Dr. Asad Qureshi	Head of IWMI-Iran
Dr. Husseini	Department of History at Esfahan University
Alireza Mamanpoush	Esfahan Agricultural Research Centre
Mr. Reza Shariati	Tenders and external relations of the Esfahan Water Authority
Mr. Saberi	Department of groundwater research EWA
Mr. Karamalian	Head of the department of studies of the EWA
Mr. Rajabi	Information manager of surface water flows EWA
Mr. Heidarpur	Manager Director of the EWA
Mr. Keiwanpur	MD of the Mirhab
Mrs. Jameli	Head accountant of the Mirhab
Mr. Moslehi	Responsible of operation of the Abshar and Rudasht irrigation systems
Mr. Hajian	Responsible of operation Nekoabad irrigation system
Mr. Mahmodih	Responsible for O&M Rudasht Irrigation System
Mr. Jafari	Responsible for O&M Abshar Left Bank
Mr. Seidi	Responsible for O&M Abshar Right Bank
Mr. Malek Zadeh	Ditch tender Abshar Right Bank
Mr. Anvar Morshed	Ditch tender Abshar Left Bank

Beside the abovementioned interviews an additional 65 interviews where held with farmers. These interviews took place in the fields in the form of structured yet open interviews. Of the interviews with farmers about two thirds where taken in the case study outlets and the rest took place on exploratory field trips aimed at understanding the Abshar Irrigation System better. Coupled to the interviews I did extensive qualitative field observations through long walks in the fields of the different outlets and drives along the canals.

During the field work I also attended an IWMI workshop in Karaj (22-24 of september 2005) on water management and its challenges in Iran.

Annex 2 Map of the Abshar Irrigation System in the Zayandeh Rud Basin

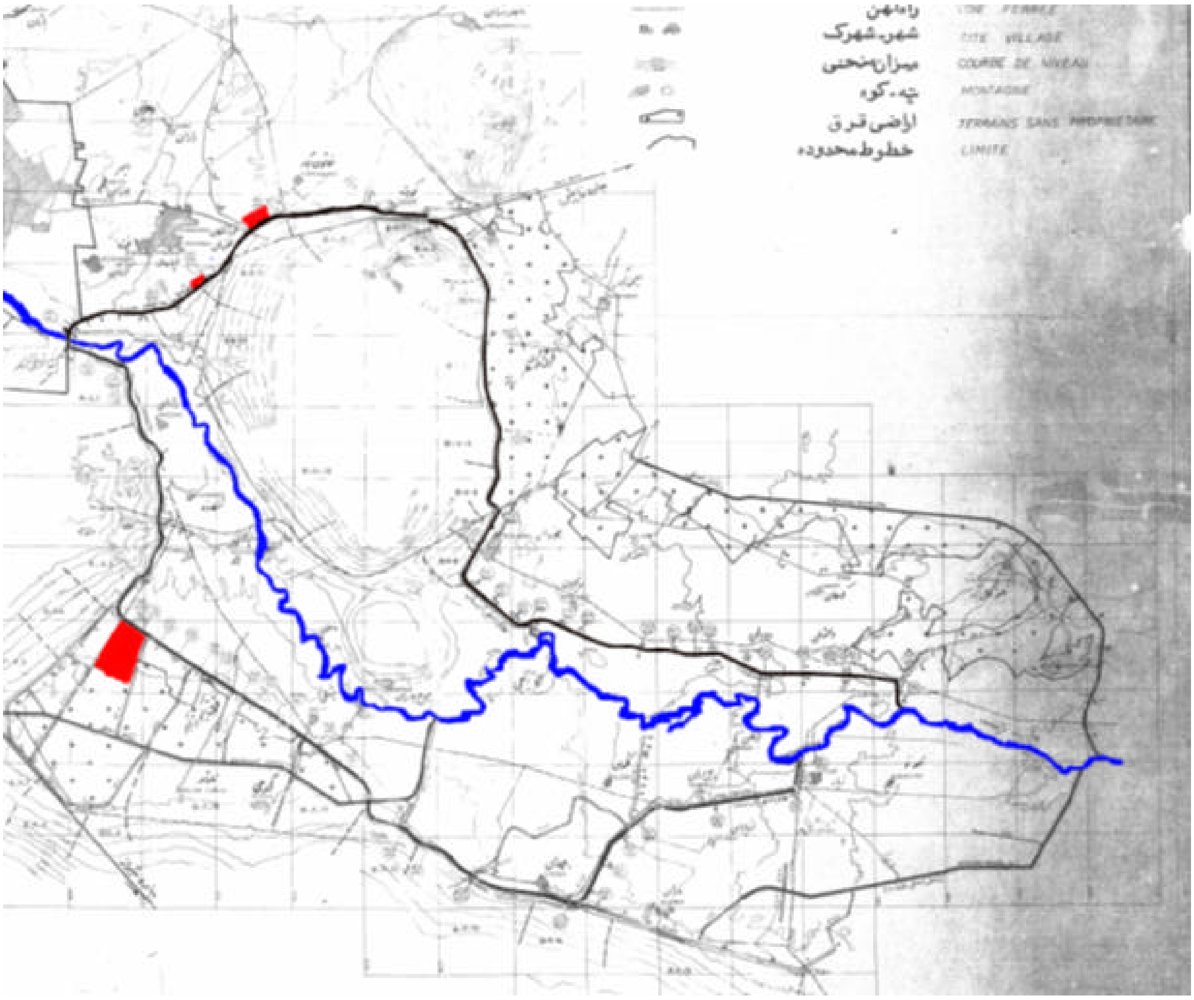

Figure 1 The Abshar Irrigation System (SOEGRA, 1968)

The basis of the map is the original map of SOEGRA (1968) which is the French company that built the irrigation infrastructure. For clarity the Zayandeh River is painted blue, the main canals are repainted in black and the outlets used as case study areas are marked in red.

Annex 3 Conversion of persian months to western dates

Farwardin	march 21st – april 20th
Ordibehesht	april 21st – may 21st
Chordad	may 22nd – june 21st
Thir	june 22nd – july 22nd
Mordad	july 23rd – august 22nd
Shahrivar	august 23rd – september 22nd
Mehr	septemberr 23rd – october 22nd
Aban	october 23rd –november 21st
Azar	november 22nd – december 21st
Day	december 22nd – january 20th
Bahamand	january 21st – february 19th
Esfahand	february 20th – march 20th

Annex 4 Historical water allocations to the different case study outlets

The tables presented below show the water allocations for the outlets that were used as case study areas. The water allocations are followed for the period 1991-2003. Here also some explanation is given on the tables. The variations of water allocation in the first months of the irrigation season, especailly in Farwardin are due to rainfall and the start of the irrigation season. The start of the irrigation season in the system depends on the rainfall (100 mm on average) that falls during the winter season in the AIS area. If rains are abundant and soil moisture is maintained by rains or low temperatures, the irrigation season starts later. If, on the other hand water is depleted before the actual start of the season, the irrigation season starts earlier. The same holds true for the end of the irrigation season and the beginning of the winter rain season in the months of Aban and Azar (See Annex 3 for the equivalent of the persian months).

During the drought year of 2000, 2002 and 2003 the surface water received by the outlets is concentrated in the winter season because the AIS is, during drought periods, a prority area for the production of wheat and barley which are tipically winter crops.

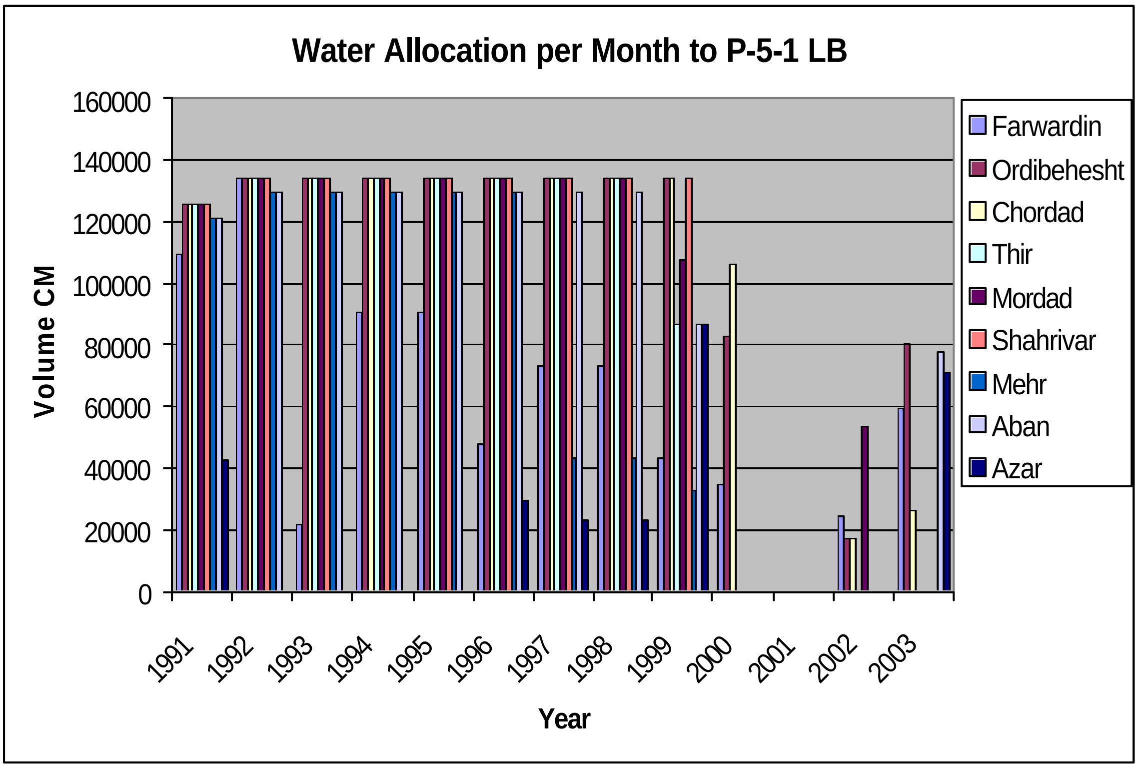

Figure A4.1 Water Allocation per month to outlet P-5-1 LB (Source Mirhab, 2004)

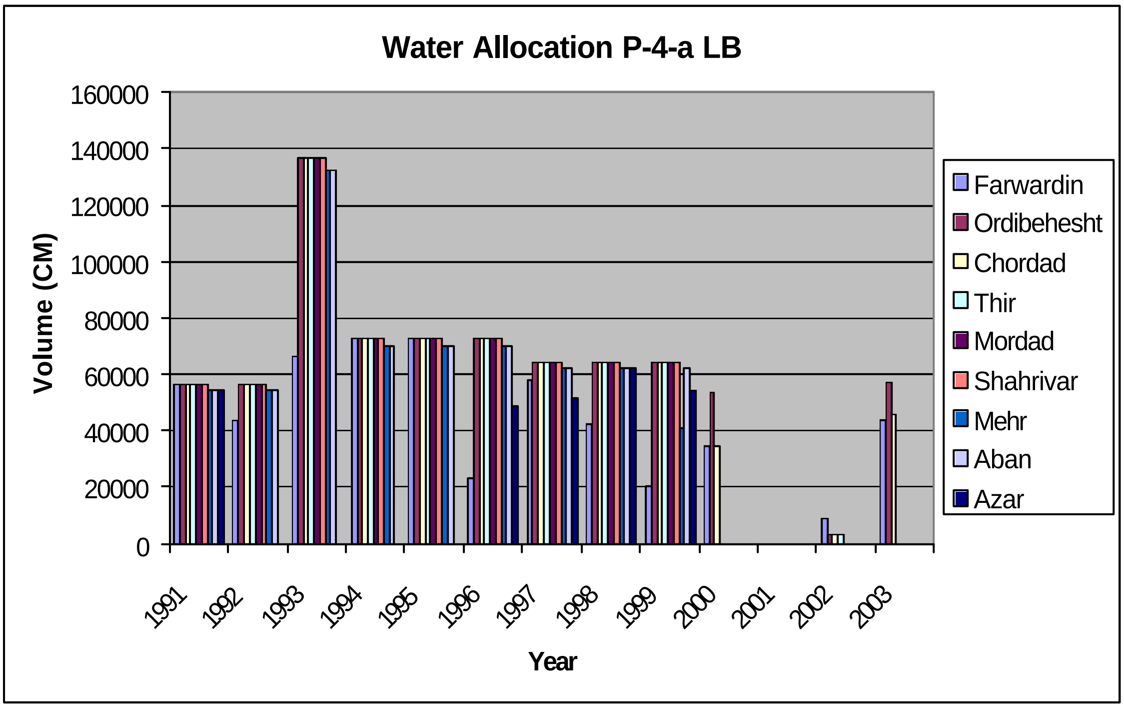

Figure A4.2 Water Allocation per month to outlet P-4-a LB (Source Mirhab, 2004)

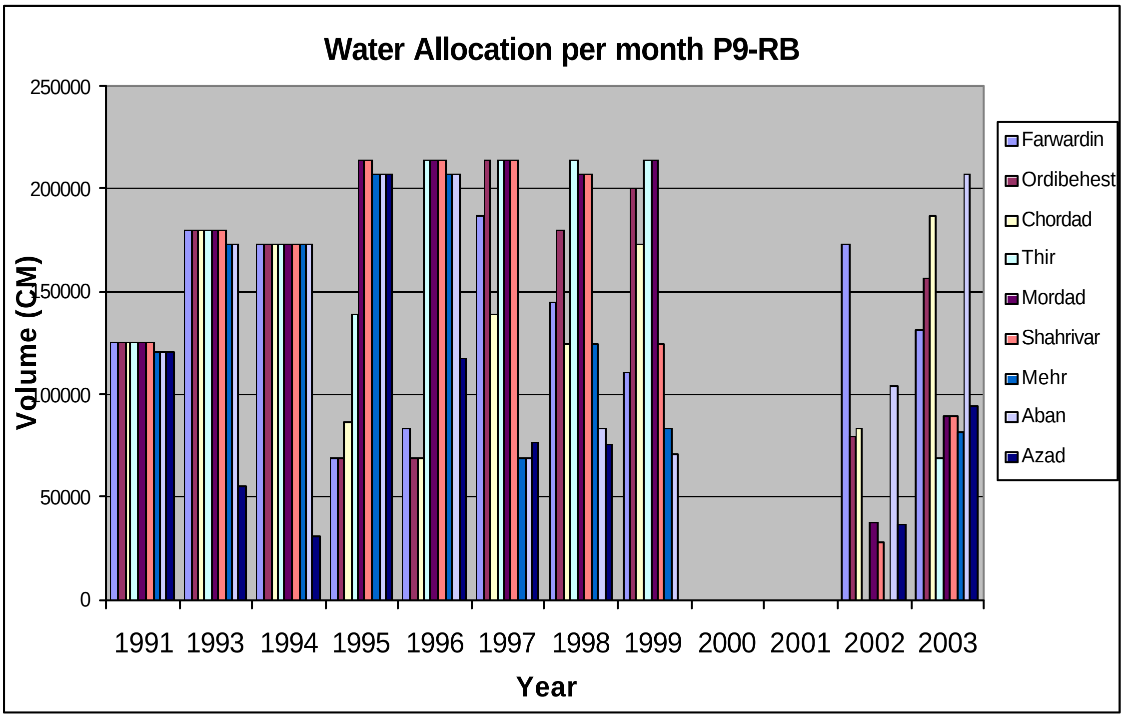

Figure A4.3 Water Allocation per month to outlet P-9 RB (Source Mirhab, 2004)

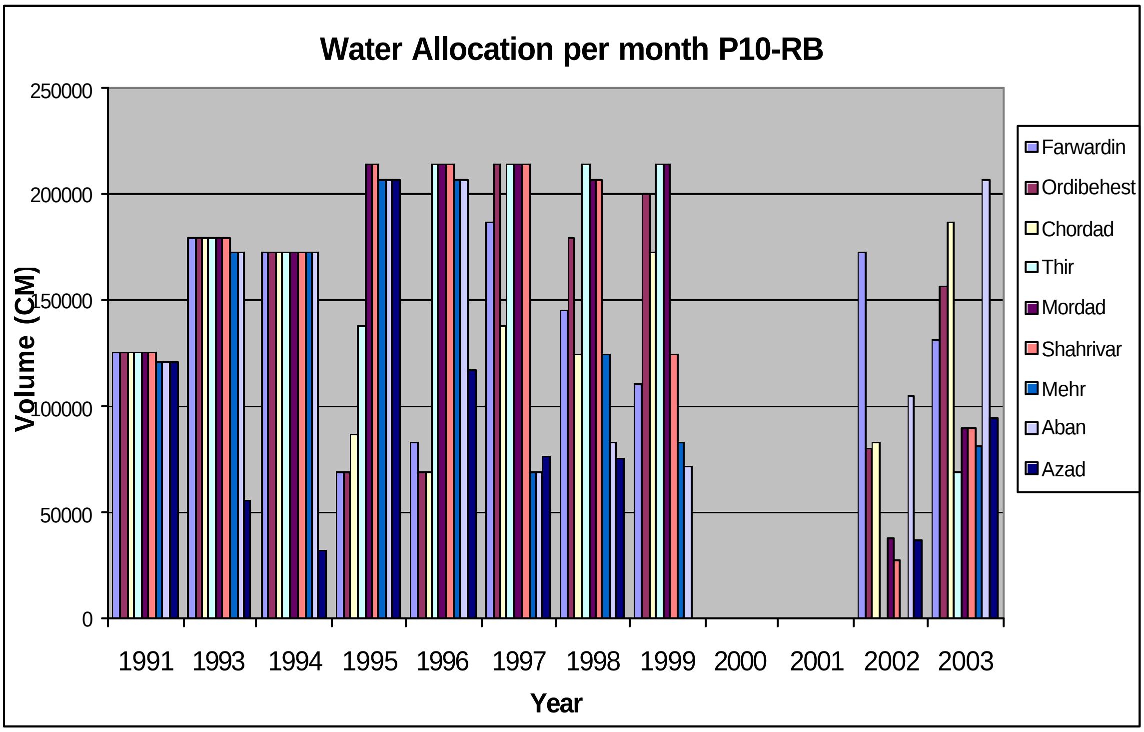

Figure A4.4 Water Allocation per month to outlet P-10 RB (Source Mirhab, 2004)