“The Underground”

Understanding the failure of institutional responses to reduce groundwater exploitation in Guanajuato

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

May 2004

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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

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Man…….

Man; the most intriguing creature on this planet
A mystery to a question:
Who are we?
Where do we come from?
Where are we going?
How do we know what we believe to know?
How come we believe anything at all?

…open questions waiting for an answer….

An answer that will lead us again to another question…..
and that answer again to a new question and again an answer…
and so on and so on……
Nevertheless, at the end we will not always find the same questions…
and……. not always the same answers…….

-Anonymous

"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

…….dedicated to Pedro Vargas and all Mexican farmers that depend on groundwater resources…..

Abstract

Groundwater in the State of Guanajuato, Mexico is being overexploited. Since the advent of tube well technology in the early 50's groundwater irrigation has bloomed in the State and presently consumes between 75-85% of extracted groundwater. At the base of the problem of overexploitation lies a lack of water control by the government. Farmers are basically semi-subsistence producers of basic grains and commercial farmers that supply national and international markets with vegetables. Contract farming has developed as one of the most important production systems for both kinds of producers. Several governmental responses to reduce overexploitation have emerged. This thesis explores irrigation practices and the institutional responses that have emerged and shows that irrigation practices and institutional practices have to be studied when analyzing and designing measures aimed at reducing groundwater exploitation.

Summary

The Lerma-Chapala Basin is one of the most important socio-economic areas in Mexico and is undergoing rapid economic and social change. A dynamic agricultural sector and a rapidly growing industrial sector characterize the basin in which, since at least the mid 1980's, water resources have been over-committed. As a result water scarcity has raised a lot of interest for water management in the last decade.

Guanajuato occupies 44% of the Lerma-Chapala Basin and contains most of the agricultural production of the basin. Exploitation of groundwater mainly by the agricultural sector has reached unsustainable levels. This MSc thesis studies the development of groundwater irrigated agriculture in the past 50 years and the present day situation of groundwater irrigation in Guanajuato.

The thesis comprises six chapters. After the background and methodological introduction in Chapter one is given, Chapter two follows with a historical analysis of groundwater dynamics, *water control* in the past 50 years and the theoretical framework and concepts used for this thesis. Chapter three analyzes the present day situation of the aquifers and water use distribution in the State. Chapter four is an empirical analysis of present day *irrigation practices* and is followed by a study of the institutional interventions aimed at reducing groundwater exploitation in the agricultural sector in Chapter five. Chapter six wraps up this thesis with a search for proposals aimed at reaching more sustainable groundwater use levels based on the forgoing chapters.

Chapter one sets Guanajuato within the context of the Lerma Chapala River Basin as one of the most interesting states to study groundwater *irrigation practices* and the responses these have had to institutional interventions. It presents the research question and followed methodology.

In Chapter two the history of the politics on groundwater and the developments hereof are studied. The history of the irrigation sector in Guanajuato goes back as far as the first Spanish settlements. Groundwater exploitation began with the coming of tube well technology in the early 50's giving way to the groundwater agricultural boom. The politics on groundwater that have allowed such expansion have had an inconsistent development passing from a total *laisse faire* situation to an official promotion of its exploitation and finally to a pretended control which characterizes the present day situation. To understand this situation *water control* is a useful term that is used as part of the analysis of the present day situation of irrigated agriculture.

For making the assessment of the present day situation a theoretical framework based on Mollinga (1997-1998) was developed in which groundwater use, development and exploitation are seen as a socio-technical phenomenon that is part of a broad interrelated

network. In this broad network the different social, institutional and economic domains are recognized as essential elements needed for understanding *irrigation practices* which ultimately determine groundwater use. This framework was useful and helped get a broader understanding of the groundwater irrigation sector in Guanajuato analyzed in Chapter four.

Chapter three analyzes the present day situation of groundwater in Guanajuato. The *Comisión Estatal de Agua de Guanajuato* (Guanajuato State Water Commission, CEAG) and the *Comisión Nacional del Agua* (National Water Commission, CNA) have done different studies of the aquifers. Although the studies are conducted on the base of several assumptions and can be considered as estimates, all studies indicate that there is an increase in groundwater exploitation. The degree of overexploitation is around 1200-1300 MCM/year. This overexploitation is most visible in the annual drop of static levels in all aquifers (2 m/year average), subsidence and a deterioration of the quality of the extracted groundwater.

Agriculture as the largest user has come under great pressure to reduce its water use. Chapter four gives an analysis of the agricultural sector of Guanajuato through an analysis of *irrigation practice.* Based on field work the different production modes present in Guanajuato are classified. Farmers are divided in two groups; *semi-subsistence farmers* and *commercial farmers. Contract farming* is analyzed as a special mode of production which has gained great importance in the last decade.

Semi-subsistence farmers have had a hard time competing with the international basic grain markets since the opening of the international markets. Migration to urban areas and/or the United States of America has been one of the utilized strategies to cope with low economic agricultural productivity.

Commercial farmers have suffered an increasing competition of international markets during a little more than a decade; nevertheless new markets have surged in a lot of the developed countries, especially the United States of America. These markets are mainly for fresh vegetables.

Contract farming has emerged for a lot of producers as a good alternative to the uncertainties of free markets. Farmers produce under contracts for a specific producer which gives guarantee prices and ensures that the production is sold. *Contract farming* has become of great importance in the production of export vegetables and in the production of barley for the Mexican beer Industry.

Access to groundwater, ‘the liquid gold of the Bajío’, is organized in three different ways, which are: individually owned private wells, communally owned private wells and ‘official’ (public) wells. *Commercial farmers* have almost exclusively access to water through individually owned private wells while *semi-subsistence farmers* are mostly bound to either one of the other modalities of access to groundwater. Besides groundwater, in the DR 011 and 085 there exists the possibility for farmers to access surface water.

Although the liquid gold of the state fairs in a critical situation of overexploitation and most producers are aware of this problem no significant grass roots initiatives have appeared to tackle the problem. For producers outputs and remunerability of the production are more pressing factors than water scarcity. For most producers ‘facts and/or money speak’, this is evident when looking at the types of crops that are produced and the dynamics hereof. For example *contractors* and *contract farming* have increased the vegetable production in Guanajuato during the last years and produced a shift form wheat to barley by economic market mechanisms.

The state government of Guanajuato has invested a lot of resources in water since 1995 through CEAG and the *Secretaría de Desarrollo Agropecuario* (Secretary of Agro-pecuary Development of Guanajuato, SDA). These and other institutional responses are analyzed in Chapter five. SDA operates mainly through five programs aimed at stimulating more efficient water use within the irrigation sector. The programs aimed at groundwater irrigation entail the installation of low pressure conduction systems, drip and sprinkler irrigation and soil leveling. *Commercial farmers* making use of these programs use water in the most productive way (in economic terms) through modern high pressure irrigation systems. These farmers have capital to make investments and access to markets that make these investments profitable.

The programs aimed at surface water savings are aimed at reducing conduction losses and increasing efficiency of water delivery. A question that remains unanswered is what effect these programs have on groundwater levels. Scott & Garcés-Restrepo (2001) fear that modernisation programs of surface water irrigation will have detrimental effects on groundwater levels.

In total around US$120 million have been invested by SDA, CNA, the *Secretaría de Agricultura, Ganadería, Desarollo Rural, Pesca y Alimentación* (Federal Secretary of Agriculture, Livestock, Rural Development, Fisheries and Food, SAGARPA) and users in increasing irrigation efficiency since 1996. This represents a governmental investment of around US$180 per irrigated hectare over a period of seven years (around US$25-30 a year per irrigated hectare). The results hereof are the improvement of irrigation systems that benefit 251.602 ha and 54,600 users. If compared to subsidies farmers get in the US and Europe these investments can be considered minimal and yet very effective in increasing water use efficiency. The programs aimed at reducing groundwater use are well structured, and should be evaluated on the effect they have had on increasing water productivity. It is not clear if these programs have had results on total groundwater extractions. The problem of quantitative groundwater control is a problem that has to be solved by CNA, which has been ineffective in doing so. One of the main constraints that have impeded this is *rent-seeking*, lack of capacity within the institution and the role of groundwater in society. An alternative to solve this problem is to decentralize water control to CEAG and the *Comités Técnicos de Aguas Subterráneas* (Aquifer Management Councils, COTAS).

A key approach for controlling groundwater extractions that 'speaks' to farmers, beside more efficient water use is energy pricing. At present some adaptive conservationist behavior on the part of groundwater users is visible. Proposals to make energy pricing more efficient in controlling groundwater use are in the paper phase and give hope for controlling groundwater exploitation. Of the established proposals, gradual increment of energy costs coupled to the amount of energy used seems a very good option.

Since 1995 COTAS have been established in Guanajuato. COTAS are defined as full-fledged user organizations, whose membership consists of all the water users of an aquifer. They are to serve as mechanisms for reaching agreement on aquifer management by the various sectors using groundwater. The impacts COTAS have had on groundwater use are insignificant if one compares them with the impact the other programs have had. Little response has been received from the agricultural water users; this can be attributed to three elements: the water users, the institution and the context. The reluctance of the government to impose strict pumping limits and the continued race to the pump house by farmers bode ill for the functioning of COTAS. Their role in groundwater management should go beyond mere consultation; bundling extraction rights in an aquifer and concessioning this to a COTAS is feasible under the Mexican water law and should be seriously considered. Now that extension of the grant that expires at the end of 2004 for the COTAS is being evaluated, a strategic choice has to be made with regards to the future of COTAS. There are two options:

- COTAS will be established as effective governmentally subsidized institutions in which more resources and responsibilities will be delegated.
- COTAS are left to their own with the result that most will probably disappear.

Chapter six is the last chapter and wraps up the thesis with proposals for improving groundwater management in Guanajuato. One of the proposals is based on institutional reform which consists of the decentralization of the responsibilities of the CNA to stakeholder platforms and user organizations. The other options explored are aimed at changing present day *irrigation practices* toward more conservative water use through energy pricing and market mechanisms. The government is to play a central role in these interventions through the implementation of subsidies and regulations that enable these changes to take place.

Integrated Watershed Management in the Lerma Chapala River Basin surges as a “must” when searching for new approaches to manage water (surface and groundwater) in a more efficient and integrated manner at River Basin level. Here the River Basin Council is to play a key role in coordination of agreements on integrated management between the different stakeholders in the Basin.

Theoretically this thesis shows how important it is to study irrigation practices and institutional practices in their context. The analysis of these is a very good tool to analyze and design measures aimed at reducing groundwater exploitation. In the case of Guanajuato it has shown that measures implemented to reduce groundwater extractions have to work on the production rational of farmers as they see themselves primarily as producers and not aquifer managers. The role of managing aquifers is of the state; nevertheless it is the institutional practices of this state bureaucracy that has impeded efficient regulation of groundwater resources. Another issue that has become clear through the analysis of *practices* is that the state and civil society are intrinsically linked and that they are not independent of each other. The interaction between civil society and the state ensure that these reproduce each other and in the process shape society as a whole.

Resumen Ejecutivo

El agua subterránea del Estado de Guanajuato, México, está siendo sobreexplotada. Desde el desarrollo de la tecnología de pozo a principios de los anos 50's la agricultura bajo riego ha florecido en el Estado y en el presente consume entre 75-85% del agua subterránea extraída. Los productores son básicamente *agricultores de semi-subsistencia* que producen granos básicos y *agricultores comerciales* que proveen a los mercados nacionales e internacionales con verduras. *La agricultura por contrato* ha surgido como uno de los modos de producción más importantes. En el estado han surgido varias respuestas gubernamentales dirigidas sobre todo a incrementar la eficiencia del riego y a la creación de "la cultura del agua". Para inducir medidas de ahorro de agua entre los agricultores el cobro de energía eléctrica ha surgido como una herramienta eficaz, ya que los productores determinan sus *practicas de riego* sobre todo sobre la base de factores económicos. El problema de la sobre-explotación se origina por la falta de control sobre las extracciones. Esta tesis explora los elementos mencionados através del estudio de prácticas de riego y prácticas institucionales y señala algunas posibilidades que deben ser consideradas si se quiere llegar a niveles de explotación más sustentables en Guanajuato.

Resumen

La Cuenca Lerma Chapala es una de las áreas socioeconómicas más importantes de México y actualmente está sufriendo grandes cambios sociales y económicos. Un sector agrícola dinámico y un creciente sector industrial caracterizan la cuenca en dónde desde mediados de los años 80's se han sobre-concesionado los recursos hidráulicos. Por lo tanto, la escasez del agua ha creado un gran interés por el manejo del agua, durante la última década.

Guanajuato ocupa 44% del territorio de la Cuenca Lerma-Chapala y contiene la mayor parte del sector agrícola de la cuenca. La explotación de agua subterránea por el sector agrícola ha sobrepasado los niveles de explotación sustentable. Esta tesis de maestría estudia el desarrollo del sector agrícola bajo riego con agua subterránea en los pasados 50 años en el estado de Guanajuato.

Este documento consta de seis capítulos. El primer capítulo posiciona al estado de Guanajuato en el contexto de la Cuenca Lerma Chapala como el estado más interesante para estudiar *prácticas de riego* con agua subterránea y las respuestas institucionales que han surgido. Este capítulo también presenta la pregunta del estudio y la metodología seguida.

El segundo capítulo trata la historia de las políticas del agua subterránea en México. Describe cómo las políticas que han permitido la expansión del sector de riego con agua subterránea han pasado por varias fases, iniciando con un *laisse faire* total, seguido de una activa promoción de su explotación y finalmente un pretendido control. Desde 1989 la Comisión Nacional del Agua (CNA) administra la concesión de títulos de derechos de uso del agua, tanto de agua superficial como de agua subterránea que están inscritos en el Registro Público de Derechos de Uso de Agua.

Enseguida se expone el marco teórico que se desarrolló para analizar la presente situación, basado en Mollinga (1997-1998), en el cual el uso y el desarrollo del agua subterránea se consideran como un desarrollo socio-técnico y parte integrada de un contexto interrelacionado. Dentro de este contexto, las *prácticas de riego* y el *control sobre el agua* se reconocen como elementos fundamentales para entender las dinámicas del uso del recurso dentro de los diferentes dominios sociales, institucionales y económicos.

El tercer capítulo presenta la actual situación del uso del agua subterránea. La Comisión Estatal del Agua de Guanajuato (CEAG) y la CNA han efectuado diferentes estudios de los acuíferos. Aunque estos estudios están basados en supuestos, pueden ser considerados como buenos acercamientos a la realidad. Todos los estudios, desde 1998, muestran un gradual

incremento en el nivel de explotación de los acuíferos, a pesar de las intervenciones institucionales que han tratado de revertir este desarrollo. Los efectos de sobre-explotación son visibles en un constante descenso de los niveles de los acuíferos y un deterioro de la calidad del agua extraída. La producción agrícola con riego ha caído bajo gran presión para reducir su consumo, por su baja eficiencia y productividad en el consumo de agua. Este sector se analiza en detalle en el capítulo cuarto.

Los sistemas de producción en Guanajuato se caracterizan por una gran heterogeneidad. Para efectos de este estudio se han considerado dos categorías de productores y una modalidad de producción: los *productores de semi-subsistencia*, los *productores comerciales* y la *agricultura por contrato*.

Los *productores de semi-subsistencia* han tenido tiempos difíciles tratando de competir con el mercado internacional de granos básicos. La estrategia de supervivencia más usual para este grupo ha sido la migración a centros urbanos y a los Estados Unidos de Norteamérica. Una segunda opción ha sido la venta de sus tierras, que ha tenido como resultado la acumulación de terrenos en menos propietarios.

Los *productores comerciales* también han sufrido, por más de una década, una creciente competencia de los mercados internacionales; sin embargo, para ellos, al mismo tiempo, se han abierto muchas alternativas en los mercados internacionales de verduras, sobre todo en Europa y los Estados Unidos.

La *agricultura por contrato* ha surgido como una creciente alternativa para los productores pues garantiza precios y la venta de la producción. Esto elimina los riesgos del libre mercado que se ha desarrollado. Esta modalidad de producción existe sobre todo para verduras de exportación y para la cebada.

El acceso a agua subterránea “el oro líquido” está organizado en tres modalidades: pozos privados con un propietario, pozos privados comunales y pozos oficiales. Los *productores comerciales* tienen acceso casi exclusivo a pozos privados de un propietario, mientras que los *productores de semi-subsistencia* tienen acceso a agua por medio de las otras dos modalidades. Además, existe la posibilidad de tener acceso al agua superficial en los Distritos de Riego 011 y 085.

A pesar de que la situación del agua subterránea es crítica, y de que la mayoría de los usuarios tiene conciencia de esto, los productores no han tomado la iniciativa para solucionar el problema. Para los productores la remunerabilidad de la producción es un problema más grande que el agua; un hecho que se refleja en los cultivos y las dinámicas de producción. Por ejemplo, la agricultura por contrato ha incrementado la producción de verduras en los últimos años y ha provocado la sustitución del cultivo de trigo por el de cebada en la producción de granos básicos.

El Gobierno del Estado de Guanajuato ha invertido muchos recursos en agua desde 1995 a través de CEAG y la Secretaría de Desarrollo Agropecuario del Estado de Guanajuato (SDA). Estas intervenciones institucionales son estudiadas en el capítulo quinto.

La SDA opera sobre todo a través de programas que estimulan el uso eficiente del agua en el sector agrícola. Los programas para usuarios de agua subterránea apoyan con financiamiento la instalación de sistemas de riego presurizado, como son el riego por compuertas, riego por aspersión y riego por goteo; además de estimular la nivelación de tierras. Los programas implementados para el agua superficial promueven la reducción de las pérdidas en los sistemas de distribución. Al analizar estos programas hay una pregunta que sigue abierta: ¿Qué efecto tendrán estas inversiones sobre los niveles de los acuíferos? Según Scott y Garcés-Restrepo, (2001) existe el riesgo de que la modernización de sistemas de agua superficial tendrán efectos negativos sobre los acuíferos.

En total SDA, CNA y la Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación (SAGARPA) y los usuarios han invertido alrededor de 120 millones US$ en el riego desde 1996. Estas inversiones representan, en un periodo de siete años, 180 US$ por hectárea de riego (tanto con agua superficial como subterránea), lo que asciende a una inversión de 25-30 US$ por año por hectárea. El resultado es la mejora de sistemas de riego que benefician a 251,600 hectáreas y 54,600 usuarios. Si esta inversión se compara con subsidios que reciben los agricultores en Europa ó Estados Unidos, las inversiones se pueden evaluar como mínimas y han tenido un gran impacto sobre la productividad del agua en la agricultura.

Los programas muestran significativos ahorros de agua, sin embargo, éstos no se reflejan en los estudios de los acuíferos y no existen datos al respecto. El problema cuantitativo del control sobre el agua es un problema de la CNA, la cual no ha sido efectiva. Las razones para la baja efectividad de esta institución son: la falta de capacidad dentro de la institución, los problemas en torno a la corrupción y el importante papel que el recurso agua juega dentro de la sociedad. Una de las alternativas para este problema es la descentralización de las facultades de la CNA al Consejo de Cuenca, la CEAG y a los Comités Técnicos de Aguas Subterráneas (COTAS).

El cobro de energía eléctrica es una herramienta eficaz para regular la extracción del agua subterránea, al lado de estimular la eficiencia en el riego. Actualmente algunas respuestas a los últimos cambios en el cobro de la energía han mostrado efectos positivos. Las propuestas para usar el cobro de energía eléctrica para controlar extracciones dan esperanza para llegar a niveles de explotación más sustentables. De las propuestas actuales, el cobro gradual de energía eléctrica parece la más viable y efectiva.

El impacto que los diferentes COTAS han tenido sobre la extracción del agua subterránea es insignificante, si se compara con los demás programas. El trabajo de COTAS ha sido mucho más en el ámbito de la "*cultura del agua*". La respuesta de los agricultores ha sido muy baja, lo cual se puede atribuir a tres factores: los usuarios, las instituciones y el contexto. La falta de implementación de sanciones por sobre-explotación a escala individual por parte del gobierno y la *carrera al pozo* (race to the pumphouse) por parte de los usuarios, dificultan el trabajo de los COTAS. El papel de los COTAS tendría que trascender la simple consulta. Legalmente es posible, agrupar los títulos de concesión en un acuífero y delegarlos a los COTAS. Esta opción debería de ser considerada seriamente como parte del proceso de descentralización de la CNA.

El fondo de los COTAS termina a finales del 2004 y se tendrán que tomar decisiones estratégicas con respecto al futuro de estas instituciones, con base a las evaluaciones de sus resultados. Existen dos opciones:

- COTAS se establecen como instituciones gubernamentales subsidiadas con más recursos y responsabilidades y con la capacidad real de controlar y regular la extracción y uso del agua.
- Se dejan de subsidiar, y el resultado será que la mayoría desaparecerán.

El sexto y último capítulo de esta tesis cierra con una exploración de recomendaciones que pueden llevar a un manejo del agua más sustentable que el presente. Entre las opciones exploradas se considera como esencial descentralizar las facultades de la CNA a los órganos de manejo del agua descentralizados tales como el Consejo de Cuenca, la CEAG y los COTAS. El cobro gradual de energía eléctrica y el uso de subsidios y mercados son opciones que también reciben atención en este capítulo. Como último se presenta el Manejo Integral del Agua al nivel de Cuencas como una necesidad para llegar a un mejor manejo de los recursos hídricos en la Cuenca Lerma Chapala.

Es evidente que el presente nivel de explotación del agua subterránea no es sustentable y que la bonanza de oro líquido pronto se terminará. Si los recursos hídricos de Guanajuato y la Cuenca Lerma-Chapala se quieren manejar de manera sustentable los presentes esfuerzos para incrementar la productividad del agua y para controlar su extracción se tienen que continuar e intensificar los siguientes años. En este proceso se tienen que tomar decisiones estratégicas muy importantes dentro de la CNA y otras organizaciones gubernamentales en los diferentes niveles de la administración pública.

Dentro del marco teórico para el estudio de los problemas de sobreexplotación y posibles soluciones, esta tesis muestra la importancia que tiene el estudio de *prácticas de riego* y *prácticas institucionales*. El estudio de éstas ha mostrado ser una buena herramienta para estudiar y diseñar medidas e intervanciones que buscan reducir el consumo del agua subterránea dentro del sector agrícola. Además ha mostrado que el estado y la sociedad civil están intrínsacamente ligados. La interacción entre el estado y la sociedad civil es un proceso en el cual el estado y la sociedad civil se reproducen y recrean dando forma a la sociedad en el término más amplio de la palabra.

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Glossary

Article 27	Important land tenure article of the Constitution of 1917, which provides the basis for federal legislation on land property matters.
calculus	A specific socially determined set of aims and devices, which are found legitimate and valid for farmers.
CEAG	*Comisión Estatal de Agua de Guanajuato* (Guanajuato State Water Commission). Since the creation of the CNA in 1989 the federal government has encouraged the modification of the federal laws to promote the participation of state governments in water management through the creation of State Water Commissions. CEAG was created in 1991.
CFE	*Comisión Federal de Electricidad* (Federal Electricity Commission)
CNA	*Comisión Nacional del Agua* (National Water Commission) created in 1989 as an independent institution within the SARH. In 1994 it became an administratively independent body.
Commercial farmers	Large farmers with access to international markets, great flexibility in production and capital to invest. Mainly producing vegetables for the export.
contractors	Enterprises that contract farmers to produce specific crops under strict arrangements which often include quality norms of products and financing.
COTAS	*Comités Técnicos de Aguas Subterráneas* (Aquifer Management Councils) At national level COTAS are defined as full-fledged user organizations, whose membership consists of all the water users of an aquifer. They are to serve as mechanisms for reaching agreement on aquifer management by the various sectors using groundwater.Through the establishment of COTAS, CNA is seeking to stimulate the organized interaction of aquifer users with the aim to establish mutual agreements for controlling groundwater depletion.
CPR	Common pool resources
DOF	*Diario Oficial de la Federación*. The federal newspaper which publishes new acts and amendments to existing acts.
DR	*Distrito de Riego* (Irrigation District) compromising the 'large irrigation' surface water schemes in Mexico.
ejidatarios	Members of *ejidos.*
ejidos	Land Reform communities, created after 1917 as a result of the Mexican Revolution. *Ejido* lands belong to the State but are worked by *ejidatarios*. The *ejido* system was changed with the 1992 revision of Article 27 of the Constitution of 1917.
FAO	Food and Agricultural Organization of the United Nations.
GATT	General Agreements on Trades and Tariffs which was signed by Mexico in 1987.
hacendado	Owner of a large ranch, mainly before the land reform program that started in 1917.
INEGI	*Instituto Nacional de Estadística, Geografía e Informática* (National Institute for Statistics, Geography and Information in Mexico)
INIFAP	*Instituto Nacional de Investigación Forestal, Agrícola y Pecuaria* (National Institute for Forestry, Agricultural and Livestock Research).
IMT	Irrigation Management Transfer
IMTA	*Instituto Mexicano de Tecnología del Agua* (Mexican Institute of Water Technology) which used to be the research institute of CNA. Although still

	closely related to CNA, it has now become a financially independent research institute.
irrigation practices	What people do in a structured and structuring fashion with regards to irrigation for crop production, always set and defined by the context in which they take place.
IWMI	International Water Management Institute, one of the sixteen centers supported by the Consultative Group on International Agricultural Research (CGIAR).
LAN	*Ley de Aguas Nacionales* (National Water Law) enacted in 1992.
MCM	Million Cubic Meters, equivalent to 811 acre feet.
módulo	*Módulo de Riego or módulo, s*trictly spoken the area administered by a WUA. In this thesis mainly used to refer to the user association itself (See WUA).
NAFTA	North American Free Trade Agreement (*Tratado de libre comercio, TLC)*; a trade agreement between Canada, United States and Mexico. Implemented since January 1994.
O-I cycle	*Ciclo Otoño-Invierno* (Autumn-Winter cycle) that compromises the months of November-May. Characterized by usually four irrigation turns in DR 011 but not in scarcity years. Wheat and barley are the most common grains produced.
O&M	Operation and Maintenance of irrigation infrastructure at all levels.
P-V cycle	*Ciclo Primavera-Verano* (Spring-Summer crop production cycle) compromising the months May-November characterized by one or two supplementary irrigation turns in the DR 011 and 085. Maize and sorghum are the most commonly produced grains.
REPDA	*Registro Público de Derechos de Agua* (Public Register of Water Rights) created in 1992 after the National Water Law was enacted.
SAGARPA	*Secretaría de Agricultura, Ganadería, Desarollo Rural , Pesca y Alimentación* (Federal Secretary of Agriculture, Livestock, Rural Development, Fisheries and Food).
SDA	*Secretaría de Desarrollo Agropecuario* (Secretary of Agro-pecuary Development) of Guanajuato, formerly SDAyR.
SDAyR	See SDA
semi-subsistence farmers	Small decapitalized producers (mainly but not necessarily *ejidatarios*) that basically produce basic grains and alfalfa and often depend on external sources of income to complement agricultural activities. Abbreviated as SSF.
SRH	*Secretaría de Recursos Hidráulicos* (Secretary of Hydraulic Resources)
SSF	See *semi-subsistence farmers*
tarifa	Electricity fee. For agricultural production there exists a special subsidized *Tarifa 9 and 9a*.
URDERAL	*Unidad de Riego para el Desarrollo Rural* (Irrigation Units for Rural Development), refers to the 'small' surface water irrigation schemes that do not have the status of DR (See DR).
UNAM	*Universidad Nacional Autónoma de México* (National Autonomous University of Mexico).
water control	"politically contested resource use" see chapter 2.5.
WUA	Water User Association. In the context of the Mexican Irrigation Districts often referred to as Civil Associations of Agricultural Producers (*Asociasiones de Productores Agrícolas).* In Mexican Spanish referred to as *módulo.*

Preface and acknowledgements

First of all I want to let you, as reader, know that I have thoroughly enjoyed working on this research during its different phases. Of course there were moments of doubt and difficulties but these do not weigh off against the joy I have had with this work.

This thesis started long ago in the first years of my study late at night in a Droevendaal room when Hans Paters (study and house mate at that moment) and I planted the seeds of a joint research project in Mexico. It was then a dream; a nice idea which came true. While I was on my practical in Brazil I got an e-mail from Hans inviting me to do research with him in Mexico under the guidance of Flip Wester. That e-mail started the snowball that triggered this work.

My work on my research proposal started in March 2003 with a speed course in the irrigation world and the socio-technical approach developed by the Irrigation and Water Engineering Group of Wageningen University. This I did through a thorough review of irrigation literature and key papers (I had originally planned to do a thesis on forest ecology).

The field work in Mexico was just incredible; so many nice people, so many nice experiences, so much help form different people and such a beautiful country. Here, I first of all want to thank my parents with whom I lived during my field research period. They kindly offered me love, moral support, a home and a car for conducting my research. I would also like to thank all individuals in Mexico for their time and for enabling this research. Special thanks go to Gaby Monsalvo and Citlally Torres for their long hours of discussions, support and insights, hospitality and above all their friendship. Ricardo Sandoval for opening the doors of the *Comisión Estatal del Agua del Estado de Guanajuato* (CEAG, Guanajuato State Water Commission). I thank all of the staff at CEAG that kindly took time for long interviews and discussions with me and provided me with essential information and insights. Miguel Angel Solis Montemayor for opening the doors of the Sub-Secretaría del Riego (Irrigation Sub-Secretary) at the Secretaría de Desarrollo Agropecuario (SDA). I enjoyed the times I visited the CEAG in Guanajuato and the SDA in Celaya; I felt at home in these institutions with their people who treated us with great patience and a great dedication to make us understand the different aspects of the Guanajuato water world. I would also like to thank all the people at the different Comités Técnicos de Aguas Subterráneas (COTAS), *Módulos de Riego* and the Distrito de Riego 011 (DR 011) which took time for our research through field trips, parties and their insights on water management. I would especially like to thank Ing. Rubén of the Módulo Cortazar for sharing his ideas, tequila and time and his unflinching determination to improve the situation of the farmers of the DR 011. Erik Mollard and Sergio Vargas of the Instituto Mexicano de Tecnología del Agua (IMTA) for their support in the research and for the workshop in Valle de Santiago. It was a great workshop full of wonderful people! Paula Silva for her friendship and a big smile. Jonathan Martinez of the *Secretaría de Agricultura, Ganadería, Desarollo Rural, Pesca y Alimentación* (Federal Secretary of Agriculture, Livestock, Rural Development, Fisheries and Food, SAGARPA) in Mexico City for his valuable information and insights.

I would also like to thank all my friends in Mexico that made my stay a pleasant journey and would like to dedicate this thesis to Pedro Vargas a primary school friend. His future as a farmer depended on the groundwater resources that are vanishing just as he did. Nevertheless

he left behind his big smile, his unending enthusiasm and dreams of constructing a better future. The time I spent with him during my thesis will always remain with me.

I want also to thank Hans Paters for all the good company, wine, discussions, Mamma Mia nights and all the help you have given me for completing this thesis. It was great to work together on a thesis!!!!!

Flip, you are a great supervisor!!!!! I could not have thought of a better teacher to guide me through this Thesis. Your critique and clear ideas, thoughts and vision helped me a lot. I really enjoyed hopping into your room every now and then to get things clear to come again on a good working path. I also want to thank you for your friendship, it has been great working with you. I have learned a lot of your way of working and looking at research, science and life in general.

Lastly, this thesis has been one of the greatest teachers I have had; I have learned a lot and done it with great joy. I hope this is reflected in the thesis work and hope you enjoy reading it!

Jaime Hoogesteger
May 2004

Chapter 1

Guanajuato in context; an introduction

The objective of this chapter is to provide the introduction and background of the study of groundwater irrigation practices in Guanajuato. This MSc thesis deals with the management challenges of groundwater in the socio-ecology of the state of Guanajuato and stresses the importance of understanding irrigation practices, water control and the context in which groundwater exploitation takes place when designing and analyzing measures aimed at reducing over-abstraction of groundwater.

The research is part of the Basin Synthesis Study of the Lerma-Chapala River Basin, Mexico, supported by the International Water Management Institute (IWMI) as part of the Comprehensive Assessment of Water Management in Agriculture Program (CA). The study is being executed by the Irrigation and Water Engineering Group (IWE) of Wageningen University in collaboration with the Instituto Mexicano de Tecnología del Agua (IMTA, Mexican Institute for Water Technology) and the Institut de Recherche pour le Développement (IRD, French Institute for Development Research).

The present chapter describes the background situation of (ground) water in the Lerma-Chapala Basin, and narrows down to the State of Guanajuato. It also presents the research question and methodology of the study, and wraps up with an outline of the structure of this thesis.

1.1 The groundwater management challenge

Groundwater is a contested, life sustaining natural resource which poses great management challenges. Its management requires special attention as groundwater overexploitation, in many parts of the world, raises serious threats to the sustainability of groundwater dependent socio-ecologies.

Groundwater is the most reliable source of supply for potable water and supports a wide array of economic and environmental services. As a result groundwater has become a cornerstone in the foundation of regional socio-economic and environmental systems. In many cases, the productive status of large groundwater bodies has been lost because of over-abstraction and pollution which, under present recharge regimes and pollution intensity, will not be regained. Because the link between users and the resource are often not apparent and the resource itself is often considered a public good, it becomes, in most cases, a common pool resource, which leads to competition between individuals, sectors and regions (Burke & Moench, 2000).

Competition for this resource and the notion of unsustainable groundwater exploitation levels have triggered an increasing realization that this resource has to be managed in a more sustainable way, while at the same time conserving its social and economic benefits (Shah *et al*., 2003; Young, 1992). Some form of regulatory management is essential to maintain the manifest public interest. However, as this thesis shows, the role regulation can play is specifically conditioned by socio-economic and cultural circumstances. Furthermore regulation can not be achieved by simple one ended measures but compromises a complex web of socio-technical interlinked measures. Aquifer management, which deals with a complex interaction between human society and the physical environment, presents an extremely difficult problem of policy design, especially because control and restrictions on its use imply adverse effects for a social group in the present and near future (Young 1992). A choice has to be made as to whether these adverse effects will be carried in the present or if they are thrown into the future. Decisions with regards to groundwater use in the present are decisions over people’s lives, society, its economy and the environment.

In the context of the present day situation of groundwater in Guanajuato, this thesis deals with groundwater use in the agricultural sector and analyses how groundwater control and irrigation practices are affected by different socio-economic and cultural conditioning factors. At the same time, it analyzes the measures that have been implemented by the state to reduce over-abstraction of groundwater. The lessons learned in the struggle of the state to manage agricultural groundwater use in Guanajuato show how complex groundwater control is, and why, for analyzing, designing and coordinating regulatory measures for groundwater management, irrigation practices and water control have to be studied.

1.2 The situation of water in the Lerma Chapala basin

In central and north Mexico water scarcity has raised a lot of interest for water management in the last decade. The spatial and temporal distribution of water in the country is very unfavourable to cover the requirements of the different water demands. The arid and semiarid regions account for 76% of the population, 90% of irrigated agriculture and 70% of all industries while it only receives 20% of the total precipitation (Baker *et al.*, 2000). To cover the gap of water demand and surface water availability groundwater is being mined.

The Lerma-Chapala Basin (Fig. 1.1), which covers some 54,300 km^2, is undergoing rapid economic and social change and is one of the most important socio-economic areas in Mexico. A dynamic agricultural sector and a rapidly growing industrial sector characterize the basin (Scott & Garcés-Restrepo, 2001). It contains 12.5% of the population, and has

13% of irrigated agriculture, 13% of the total livestock production and 35% of the industrial production of the country (Marañon-Pimentel & Wester, 2000). The annual water availability per capita is low: 1000m^3 against 4,067m^3 at the national level (Marañon-Pimentel & Wester, 2000; CEAG, 2001).

Since at least the mid 1980s, water resources in the basin have been over-committed (Scott & Garcés-Restrepo, 2001), and the basin has evolved from an open basin to a closed basin (Seckler, 1992). Surface water depletion exceeds supply in all but the wettest years; as a result Lake Chapala, the receiving body of the basin, is drying up (Wester *et al.*, 2003). A lot of pressure has been put on water resources as demand keeps increasing in the basin. This demand surges from within and from outside the basin. Mexico City and Guadalajara, the two largest cities of the country, extract significant amounts of water from the basin for their water supply. The irrigated sector utilizes around 68% of the consumptive water use in the river basin (Wester *et al.*, 2003), and has historically always been the largest water user and greatest economic activity within the basin (Marañon-Pimentel & Wester, 2000). At present it has been put under harsh pressure as an increasing need to release water out of agriculture is felt.

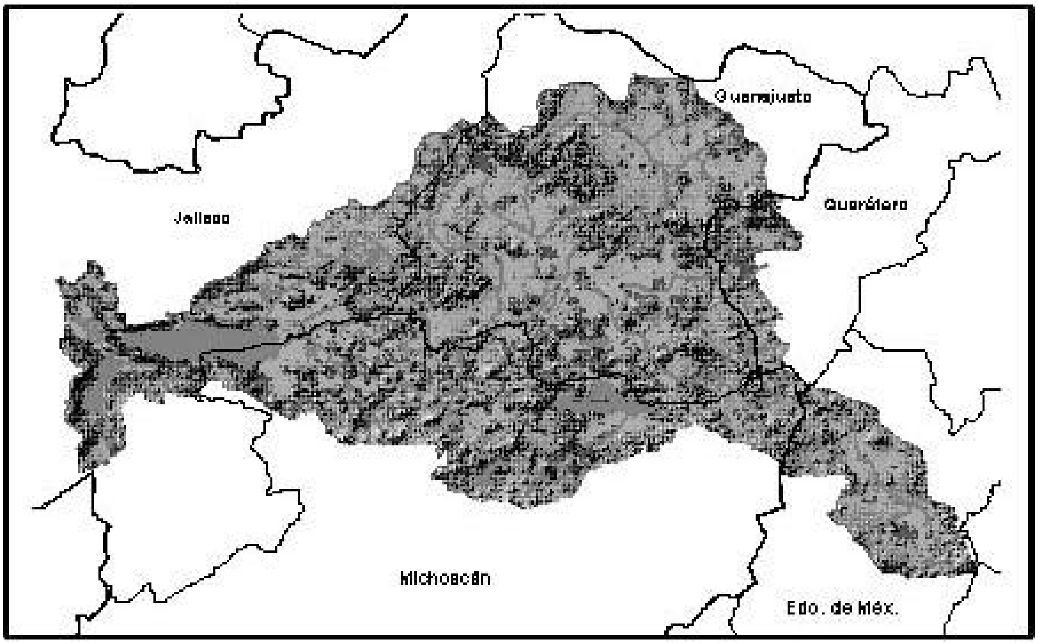


Figure 1.1 The Lerma Chapala River Basin (SEMARNAT, 2001)

Within the Lerma-Chapala basin all exploitable surface water is allocated and groundwater now supplies around 50% of the used water (SEMARNAT, 2001). The result is a heavy non-sustainable groundwater exploitation resulting in an alarming decline of aquifer levels in the whole basin and especially in the State of Guanajuato, which has an overall growing water deficit (CNA & World Bank, 1999; Wester *et al.,* 1999; Scott *et al.*, 2003). Considering that some 380,000 ha in the basin are groundwater irrigated and that the industrial and domestic sectors depend almost entirely on this resource it is fair to state that groundwater is strategic for society in the basin (Wester *et al.*, 2003). A great challenge in water management has surged in the Lerma-Chapala Basin, which the *Comisión Nacional del Agua* (National Water Commission, CNA) and other water stakeholders, especially the state governments and the users in the basin need to deal with.

1.3 The State of Guanajuato within the Lerma-Chapala Basin

Guanajuato occupies 44% of the Lerma-Chapala Basin (CNA, 1993) and has an area of 30,768 km^2, of which 83% falls in the basin (CEAG, 2001). It has a population of 4.7 million[1] and contributed 3.1% to the GNP of the country in 2000 (PROMMA, 2002). Its annual water availability per capita is 749 m^3; far below the national average (CEAG, 2001). Mining of groundwater in the state has triggered the threat of depletion, quality deterioration and a reduction in the social benefits extracted from this resource. As society enters the third millennium, Guanajuato is facing serious water scarcity problems. In the future this problem is expected to grow as water resources become scarce and the population keeps on increasing (Baker *et al.*, 2000).

Guanajuato has most of the agricultural production of the basin with 416,690 ha of irrigated agriculture out of which around 60% are dependent on groundwater (SAGARPA, 2002). This dynamic agricultural sector, which in the 1990's consumed 75-85% of extracted groundwater in the State (Wester *et al.*, 1999), has been put under great pressure to reduce its water consumption. The government of the State of Guanajuato has invested a lot of resources in increasing water use efficiency in irrigation in the last eight years as well as in promoting a 'water culture'. Guanajuato is an interesting state to study groundwater exploitation because the government has taken a very active role in trying to find solutions for the groundwater crisis.

There exists a lot of national and international literature on water and water users in the Lerma-Chapala Basin. Nevertheless most studies have focused on Irrigation Management Transfer (IMT), social transformation, participation processes, and surface water irrigation in the *Distritos de Riego (Irrigation Districts*, DR's). In the literature groundwater exploitation, use and management has received far less attention than surface water.

1.4 Research question and methodology

In the groundwater socio-ecology of Guanajuato, which mechanisms and relations determining groundwater irrigation practices and water control are crucial for designing measures aimed at reducing overexploitation of groundwater?

In this thesis groundwater management and irrigation are seen as sociotechnical phenomena and thus the research integrates concepts from technical, social and economic sciences. This means that the organizational and political situation of the arenas in which groundwater use dynamics evolve are an important element of this study.

For the operationalisation of the main research question there is a need to make sub-questions. I have chosen to divide the sub-questions in themes, which receive attention in this thesis. The themes chosen for operationalization of the research question are: the present situation of groundwater resources, *water control* and *irrigation practices*[2], and implemented technical and social measures aimed at reducing groundwater exploitation (see Annex 1).

This thesis research began with a literature study in the Netherlands. The field research took place in Mexico from the end of April to the end of August 2003. The approach taken for the study is an actor oriented approach in which actors are seen as the most important subject of study. Through the analysis of actors, the water management institutions and actor's responses to implemented measures are analyzed. During the field research period, actor's practices were studied and in doing so I tried to understand these practices by

1 (http://www.inegi.gob.mx/, 25-09-03)

2 See glossary

interacting with the actors involved. I thus strongly relied on formal and informal interviews and observation. The actor groups I interviewed are farmers, researchers, staff of the different governmental institutions and 'external' (non-farmers) actors. By interacting with the actors involved (observation), driving through the fields, being with farmers and living in the culture I learned what a lot of spoken words can not say. This field work is supported by extensive literature compilation and study.

The field work started with several interviews with contacts of my assessor Flip Wester. The first interview took place in Mexico City with Gabriela Monsalvo, ex-researcher of the International Water Management Institute (IWMI) in Mexico. She introduced me to her network in the agricultural- and water-sector in the state of Guanajuato. In the second week I visited the *Instituto Mexicano de Tecnoloía del Agua* (Mexican Instiute of Water Technology, IMTA) in Jiutepec, Morelos where I spoke to our local supervisors Erik Mollard and Sergio Vargas. After these introductory interviews, the research was divided in basically three phases: a) interviews with staff of the *Comisión Estatal del Agua de Guanajuato* (Guanajuato State Water Commission, CEAG), b) interviews with staff of the *Secretaría de Desarrollo Agropecuario* (Secretary of Agro-pecuary Development, SDA) of Guanajuato and the state office of CNA, in Celaya, and c) interviews with the staff and farmers of the DR 011 and the different *Módulos de Riego*[3]. Parallel to these, interviews were held with farmers and agro-industrialists that operate in different conditions and under different modes of production, as well as some other key informants (for an extensive list see Annex 2). The followed method for the interviews with the officials and ex-officials of the different institutions was a 'follow-the-network approach' which worked very well in Guanajuato.

In this thesis, as in every research, the researcher is seen as an actor that interprets phenomena according to his or her views and ideas. Furthermore the interviewed people 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 that I interviewed, the informants and the supervisors also set their print on the information that is presented and analyzed. Thus we create and interpret the world according to our own set of beliefs, choices and social interactions.

Another important factor that is often left out is the time and change factor. The situation that prevails at this moment might drastically change in a very short time just as the people that I interviewed and their views. The following section shortly gives an outline on how this thesis is structured.

1.5 The sketch: a short outline of this thesis

This thesis consists of six chapters. The first and present chapter gives a short introduction to the groundwater management challenge; the objective of this thesis; and the background information of the Lerma-Chapala Basin and Guanajuato. This chapter also presents the research question and the followed methodology.

In Chapter 2 the legal and institutional developments of groundwater management are described. Coupled to these the development of the agricultural sector in Guanajuato in the past 50 years is described. To explain the inefficiency of these developments in controlling groundwater over-abstraction, water control, the water hydrocracy and some intrinsic aspects of groundwater are analyzed. Coupled to these the theoretical framework for this thesis is presented.

Chapter 3 shows the dynamics of present day groundwater exploitation. The most recent figures on extractions, recharge and the degree of overexploitation is analyzed. The chapter

3 Irrigation Modules, see glossary.

wraps up by describing the consequences overexploitation of aquifers has brought with it.

Chapter 4 analyses groundwater irrigation practices. To understand these, attention is given to the main production modes that exist in Guanajuato as well as the main mechanisms that affect irrigation practices. This chapter makes it clear that it is important to understand irrigation practices and water control for analyzing and designing measures aimed at reducing groundwater use.

Chapter 5 describes the measures that have been implemented to increase water productivity and reduce groundwater over-extraction in Guanajuato. This study concentrates on the efforts made to save water within the agricultural sector. These different measures have had different impacts on irrigation practices and extraction levels, but none has, until now, significantly reduced groundwater extractions.

The final chapter, Chapter 6, is a search for theoretical and pragmatic solutions to deal with groundwater overexploitation within the agricultural sector in Guanajuato. This chapter points out how important it is to understand the socio-economic and cultural context, through irrigation practices, institution’s practices and water control, when designing and coordinating measures aimed at reducing groundwater extractions.

Chapter 2

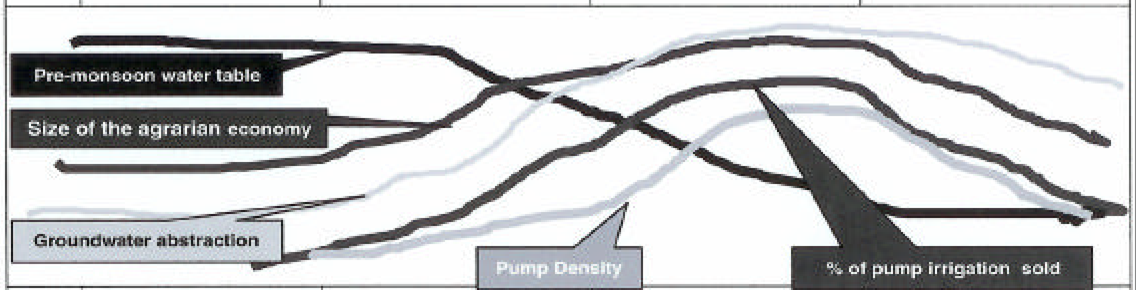
The path to groundwater over exploitation

Development of groundwater exploitation in Guanajuato started in the 1950's on a large scale with the rise of tubewell technology. Fifty years later, almost all cities, industry and 60% of irrigated agriculture in the state depend on a resource (groundwater) that is being exploited at unsustainable levels. This chapter deals with the institutional and legal developments of groundwater management that have taken place in the past 50 years in Guanajuato, and shows why the state, as a bureaucratic institution, has failed to regulate groundwater exploitation. Later in the chapter the theoretical framework, that is based on the concepts of *water control* and *irrigation practices* (Mollinga, 1997-1998), is described. This framework presents irrigation practices and water control as the link between the individual water users and the implemented measures aimed at reducing groundwater use in the agricultural sector. This concept is further worked out in the rest of this thesis and shows why, for a better design of measures aimed at reducing groundwater extractions, irrigation practices and water control have to be studied.

2.1 Development of the groundwater socio-ecology of Guanajuato

IWMI's past research on the dynamics of groundwater socio-ecologies in South Asia indicates some recurring patterns (Shah *et al.*, 2003). Figure 2.1 illustrates the typical progression of groundwater socio-ecologies. This progression usually follows the following four steps: (1) groundwater potential unleashes with the rise of tubewell technology followed by (2) an agrarian boom, that leads to increasing exploitation of the resource until (3) it reaches unsustainable levels which finally causes (4) the socio-ecology to go overboard because restraint is not exercised on time. This framework is used for the analysis of the development of the socio-ecology of Guanajuato in the next section.

	Stage 1	Stage 2	Stage 3	Stage 4
Stages	The rise of green revolution and tubewell technologies	Groundwater-based agrarian boom	Early symptoms groundwater over-draft/degradation	Decline of the groundwater socio-ecology with immiserizing impacts.



Examples	North Bengal and North Bihar, Nepal Terai, Orissa	Eastern Uttar Pradesh western Godavari, central and southern Gujarat	Haryana, Punjab, western Uttar Pradesh, central Tamil Nadu	North Gujarat, coastal Tamil Nadu, coastal Saurashtra, southern Rajasthan
Characteristics	Subsistence agriculture; protective irrigation; traditional crops; concentrated rural poverty; traditional water lifting devices using human and animal power.	Skewed ownership of tubewells; access to pump irrigation prized; rise of primitive pump irrigation 'exchange' institutions. Decline of traditional water lifting technologies; rapid growth in agrarian income and employment.	Crop diversification; permanent decline in water tables. The groundwater-based 'bubble' economy continues booming, but tensions between economy and ecology surface as pumping costs soar and water markets become oppressive. Private and social costs of groundwater use part ways.	The 'bubble' bursts. Agricultural growth declines; immiseration of the poor is accompanied by depopulation of entire clusters of villages. Water quality problems assume serious proportions; the 'smart' begin to move out long before the crisis deepens. The poor get hit the hardest.
Interventions	Targeted subsidy on pump capital; public tubewell programmes; electricity subsidies and flat tariffs.	Subsidies continue. Institutional credit for wells and pumps. Donors augment resources for pump capital; NGOs promote small farmer irrigation as a livelihood programme.	Subsidies, credit, donor and NGO support continue apace; licensing, siting norms and zoning system are created but are weakly enforced. Groundwater irrigators emerge as a huge, powerful vote bank that political leaders cannot ignore.	Subsidies, credit and donor support reluctantly go. NGOs and donors assume a conservationist posture. Zoning restrictions begin to be enforced, with frequent pre-election relaxations. Water imports begin for domestic needs. A variety of public and NGO-sponsored relief programmes start.

Figure 2.1 Rise and fall of groundwater socio-ecologies (Shah *et al.,* 2003)

2.1.1 Stage 1: The rise of green revolution and tubewell technologies (1900- late 1940's)

During various centuries, the exploitation of groundwater resources enjoyed almost total freedom. At the end of the XIX and beginning of the XX century this freedom was justified and stimulated by the national policies aimed at extending the irrigation frontier to stimulate economic growth. Under such policies the state assumed the role of creating, managing and controlling the infrastructure for utilizing surface water for irrigation leaving groundwater uncontrolled and unregularised (Sánchez-Rodríguez, 1998).

State involvement in irrigation development received a legal push with the promulgation of the Water Law (Ley de Aguas) of 1910 that states that all waters are public property for common use. Article 27 of the Constitution of 1917 made it explicit that ‘land and water property belong to the Nation’, but the Nation has the right to transmit these property rights to individuals. At the same time it recognized the right of the owner of a piece of land to prospect for and use the water underlying his land as established in the constitution of 1884 (Sánchez-Rodríguez, 1998). Until the rise of tubewell technology around the 1940’s irrigation in Guanajuato was almost exclusively dependent on surface water irrigation through small irrigation works. Technological development triggered the unleashing of groundwater use for agriculture since the 1940’s.

2.1.2 Stage 2: Groundwater based agrarian boom (late 1940’s- early 1980’s)

As in many other areas of the country, the extraction of groundwater in the basin began, on a large scale, in the early 50’s driven by urban growth, industrial development and above all emerging groundwater irrigated agriculture (Scott & Garcés-Restrepo, 2001). With the ‘first’ green revolution in the Bajío, in the 1950's, commercial farming started.

In the 1940's, Mexican agrarian policy shifted to commercial production. From 1934 to 1965, Mexican agricultural production increased 325 percent, due to heavy government investments in agriculture (Kloezen, 2002). During the period of 1936 to 1956 the irrigation policy with regards to groundwater was to finance the perforation, equipment and rehabilitation of tube wells through the Banco Ejidal, while the SRH tried to establish some order in groundwater exploitation in some *veda* zones (See Figure 2.2) and promoting the sinking of new wells in others (Sánchez-Rodríguez, 1998).

In the 1960's the ‘second’ green revolution emerged bringing with it ‘modernization’ of agriculture above all in the irrigated sector (Marañón-Pimentel & Wester, 2000). During the 60’s and 70’s, hundreds of wells were sunk to extend the area under irrigated agriculture or to complement irrigation requirements in areas already under irrigation (Sánchez-Rodríguez, 1998; Marañón-Pimentel & Wester, 2000; Scott & Garcés-Restrepo, 2001). In 1968 the Plan Nacional de Obras de Pequeña Irrigación (National Plan of Small Irrigation Works), which supplied small farmers and *ejidatarios* with water for irrigation, especially in the semi-arid and arid zones of the north and center of the country, started to operate. The aim of the program was to increase the food production, to slow down the migratory flows to the growing cities and to stimulate the development of the rural areas (Marañon-Pimentel, 2000). This plan operated in the state of Guanajuato, where between 1970 and 1976, though the construction of new small irrigation works and sinking of new wells, 13,741 ha got access to irrigation water through 216 works. At the end of the 1970’s continuously dropping water tables and clear signs of overexploitation started to raise concern about the sustainability of groundwater exploitation.

2.1.3 Stage 3: Early symptoms of groundwater over-draft (early 1980’s –2000)

In response to the overexploitation of aquifers, the entire state of Guanajuato was placed under *veda* in 1983. Nevertheless there was no strict enforcement; the number of wells and the irrigated area kept on increasing (see figure 2.2). Since the creation of the CNA in 1989 there have been several attempts to regularize groundwater exploitation but without success. Since at least the early 1980’s Guanajuato is characterized by a permanent decline of water tables, a deterioration of the ecology and the social costs of declining water tables started to be felt.

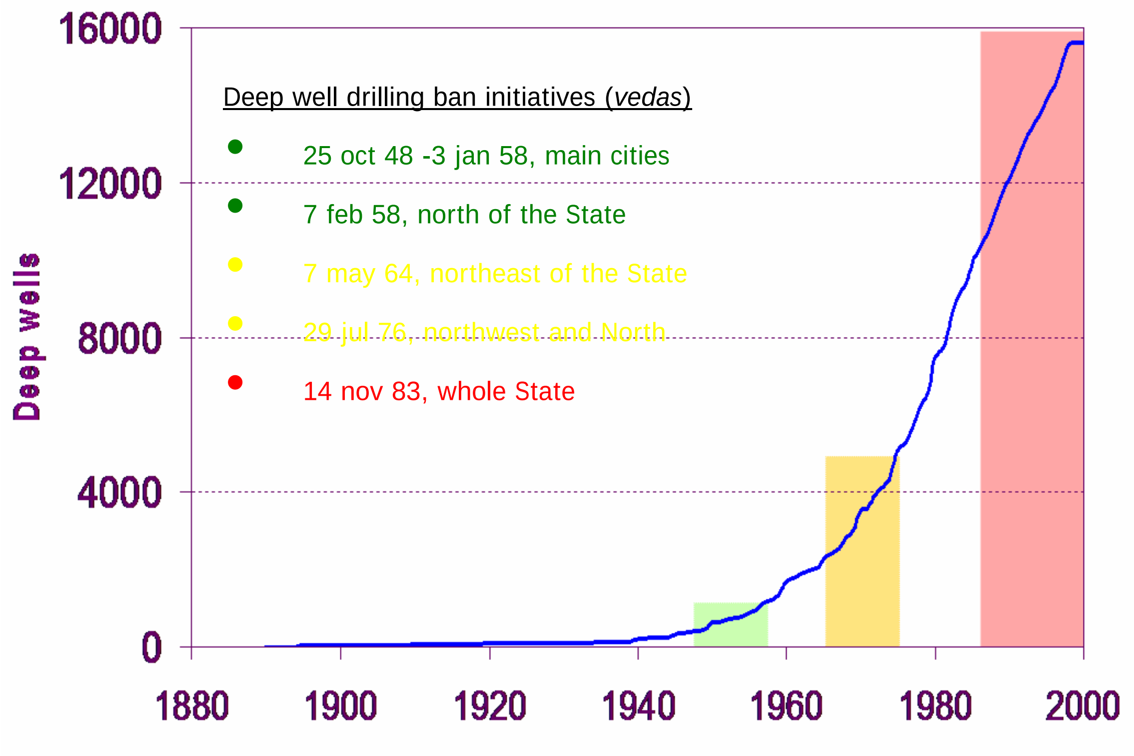


Figure 2.2 Evolution of number of wells and *veda* decrees in the State of Guanajuato, Mexico (CEAG, 2003)

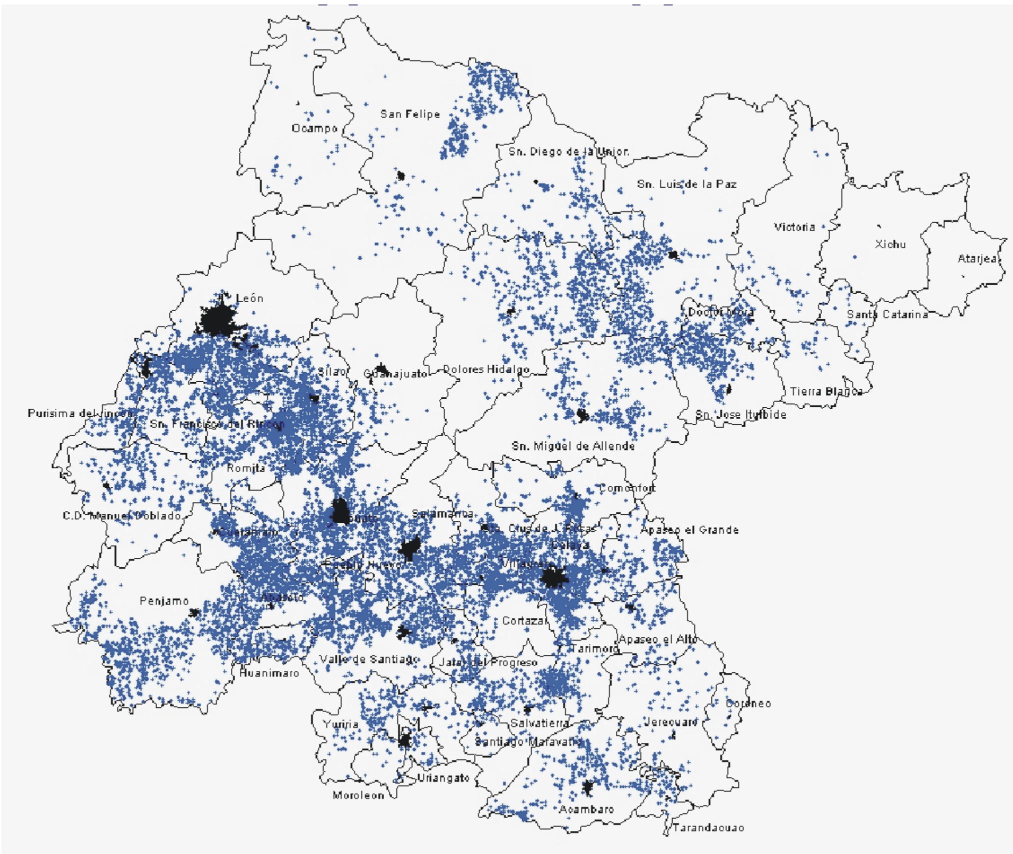


Figure 2.3 Distribution of wells in the State of Guanajuato (CEAG, 2003)

2.1.4 Stage 4: Decline of the groundwater socio-ecology (some regions of Guanajuato)

At present the irrigated agricultural frontier in Guanajuato has stopped expanding. In some regions wells start showing water quality problems or dry out. The poor are hit the hardest and often migrate to the USA or the bigger cities. The state and other institutions have started to implement measures aimed at reducing groundwater use in an attempt to save the aquifers. Nevertheless these have, until now, not been effective in significantly reducing overexploitation.

The development of groundwater exploitation in Guanajuato is reflected in the evolution of the number of wells. In 1958 there were approximately 2,000 wells; this number increased to more than 16,500 in 1997 (Wester *et al.*, 1999) and exceeded 17,200 in 2002 (See Figure 2.2). A significant growth in the number of wells can be observed starting in the decade of the 70`s which coincides with the implementation of the Plan Nacional de Obras de Pequeña Irrigación. The result of the government plans to expand the irrigated agricultural frontier was effective (see Table 2.1)

Table 2.1 Expansion of irrigated agriculture in the 20th century in the Lerma-Chapala Basin (SEMARNAT, 2001)

Year	Irrigated area (ha's)
1926	65,000
1950	179,000
1980	660,000
2000	798,000

Interviews with state officials suggest that the above mentioned figures on the number of wells in Guanajuato are conservative. An ex-functionary of the CNA and a present functionary of the same institution coincide in their estimation that, at the moment there are around 19,600 wells in the state (20% of the total amount in the country). Of these wells around 16,000 are inscribed in the *Registro Público de Derechos de Agua* (Public Register of Water Rights, REPDA), 2,000 are in the process of being regularized and the rest is irregular.

The highest concentration of wells is in the region of the Bajío, which coincides with the largest, urban, industrial and agricultural concentrations in the State. Another high concentration area is the aquifer of Laguna Seca in the North-east of the State (see figure 2.3). This area is very suited for the production of high valued export vegetables and water use is almost exclusively for agricultural production.

2.2 The State's failure to regulate groundwater exploitation

Groundwater in the Lerma-Chapala basin has become, as in many parts of the world, a direct and intimate link among people and between the people and their environment. It has triggered the development of a great agricultural production process, permitted the growth of cities and industries and the development of human activities in general. Nevertheless exploitation has reached unsustainable levels and regulation by the state has failed to set restrictions on groundwater use. An analysis of the hydrocracy helps us understand this failure.

The Mexican hydrocracy has its origin in the *Comisión Nacional de Irrigación* (National Irrigation Commission, CNI), created in 1926 as the first government agency solely devoted to the design and construction of irrigation districts and their subsequent management. Rap *et al.* (2004) give a very good analysis and historical review of the developments of the Mexican hydrocracy from 1926 to 1989.

In January 1989, under the influence of neo-liberal government policies, president Carlos Salinas de Gortari created the Comisión Nacional del Agua as an autonomous water authority of the *Secretaría de Agricultura y Recursos Hidráulicos* (Secretary of Agricultura and Hydraulic Resources, SARH) (Rap, *et al.*, 2004). Since then CNA started establishing itself as the only water authority in the country. Some responsibilities of CNA are listed in Box 2.1.

Although CNA got a lot of credits for its successful Irrigation Management Transfer (IMT) programs it has lacked the same success and determination with regards to the management and administration of groundwater resources. Government efforts to control groundwater exploitation have existed. In 1945, in view of a need for controlling groundwater extractions, a new amendment was added to paragraph 5 of Article 27 of the Mexican Constitution. This amendment states that:

> "Groundwater may be freely brought to the surface through artificial works and appropriated by the owner of the land, but, when it is in the public interest or if it affects the supply of other users the Federal government may regulate its extraction and utilization, and even establish prohibited zones, in accordance to that which applies for other waters of national property" (Wester, *et al.*, 1999: 11).

In 1948, the first *veda* decree was established in Guanajuato to regulate groundwater use around some of the bigger cities (Sánchez-Rodríguez, 1998). These decrees entail that it is prohibited to sink new wells without permission from the federal government. Since then several additional decrees were emitted (See Figure 2.2). Nevertheless as a CNA official confirmed: “the *veda* decrees and regulations regarding the control of groundwater exploitation stayed on the tables of bureaucrats in the offices of the *Secretaría de Recursos Hidráulicos* (Secretary of Hydraulic Resources, SRH)” and were never applied in the field.

Box 2.1 Some responsibilities of the CNA

- Propose policies and define and monitor national plans related to hydrological developments;
- Define criteria and guidelines for the integration of government plans and activities in the field of water;
- Coordinate all administrative institutions that deal with water;
- Administer, regulate all national water and hydraulic infrastructure;
- Program, study construct and manage new hydrological facilities and structures;
- Grant user concessions and register these in a Public Register of Water Rights;
- Promote efficient use of all national water;
- Assure and supervise the coordination of all water related programs and assign public funds to carry out these programs;
- Study, propose and execute financial systems that allow the development of water related infrastructure and the provision of water related services.

Source: Article 8, Ley de Aguas Nacionales, 1992.

In 1956 during the government of Adolfo Ruiz Cortinez another amendment was added to paragraph 5 of Article 27 of the Mexican Constitution. It established that, in order to exploit groundwater resources, users had to have a concession or permit emitted by the SRH. In this way, the SRH became the official manager of all groundwater concessions (Sánchez-Rodríguez, 1998). Based on a ruling of the Supreme Court in 1983, groundwater is now considered national property, although this is not reflected in the Constitution or the 1992 Water Law (Wester *et al.*, 2003).

The last effort of the CNA was to regularize all wells in order to get some control over extraction volumes. Since its creation in 1989, CNA administers the titling and concessioning of all water rights (both surface and groundwater) which are written in the REPDA. Concessions are granted to users for a specified annual volume over a specific period of time varying from a minimum of five years to a maximum of fifty years (LAN, 1992; Art. 24). In addition to specifying the annual volume concessioned based on discharge of the well and the area of irrigable land reported, the title spells out the norms regarding repositioning of the well, cessation of rights for unutilized volumes, the transfer of rights, etc. (Scott *et al.*, 2003). It also specifies that users must install volumetric flow meters and that they have to report pumped volumes to CNA twice a year (LAN, 1992).

The regularization process is slow and new illegal pumps are still being installed. As a logical result, users and CNA alike admit that pumped volumes exceed concessioned volumes (Scott *et al.*, 2003). The development and present day state of groundwater extraction in Guanajuato shows how groundwater regulation by the federal government has not helped preserve groundwater resources.

According to Oorthuizen (1995), state bureaucracies' possess characteristics that hamper the quality of their work. He presents three points of critique on management by state bureaucracies. I add three points of critique which are essential to understand the failure of the CNA to regulate groundwater exploitation:

1. *State bureaucracies are hierarchical and centralistic.*

Within the CNA planning is usually top down, follows standard administrative procedures and is centrally monitored through extensive hierarchical controls. Staff performance tends to be based not on producing outputs, but on conformity to higher authorities regarding the use of inputs. Consequently, management behavior is too much constrained and top-down to be able to deal effectively with dynamic field conditions. Guanajuato has one central office of CNA from which all operations and controls are executed.

2. *Lack of personnel at field level to exercise control*

The regional office of Guanajuato has two groundwater inspection- and control teams for the almost 18,000 wells (Sandoval, interview 09-05-03). It would take the inspection teams 44 years to check all the wells the State has (*idem*); as a result CNA has no control over groundwater abstractions. The fact that there is so little personnel employed for controlling groundwater exploitation clearly shows that groundwater control is not a priority for the CNA.

3. *Rent-seeking in the bureaucracy* seems to be a worldwide phenomenon.

Nuijten (2003) gives a very good description of how bribes are a common way of 'getting things done' when dealing with the bureaucracy. In her account of a land conflict in Mexico, she clearly shows how the exchange of 'bribes as favours' between actors are a day to day practice that is embedded in Mexican culture. In my own fieldwork I observed that, when dealing with the CNA, 'things get done' in the same fashion as described by Nuijten. Control teams, easily accept bribes in exchange for 'favours'. This process of exchanging favours is a contested negotiation in which both parties try to get the most out of the counterpart. The example below gives a nice example of how such 'favours' work.

> Officially wells can only be legalized if they can prove to have been operating for a long time. Nevertheless new wells can be regulated with a negotiated 'bribe'. An ex-CNA functionary explained how such a process works. *"You drill a new well, and then you set the paperwork in motion for legalizing your well. An inspection team comes to check on the well and whether you can proof its antiquity. When the inspectors come you have to have some old tubes, maybe even an old motor, spill some diesel around the well; and have a bribe ready. The inspectors make pictures and the file is made. Old receipts of use of diesel and other inputs, to prove the historical functioning of the well are needed, but in most cases the inspector can do the 'favour' of providing those for an 'extra little' sum of money. In this way users get a legal water use title (concession) for a new well and the CNA functionaries get an extra sum of money to complement their salary. It is a win-win situation"*.

Through this mechanism of 'mutual favours' the law has become a power mechanism which enables rent seeking. The laws and regulations seem to be a phantom, which justifies control and creates fear amongst users. At the same time is leaves enough space open for actors (both users and functionaries) to speculate with it and use it for their own interest.

4. *Bureaucracies are often subject to political influences.*

Groundwater has become a pillar in the sustainability of essential activities such as; food security, domestic water supply, and rural, urban and industrial development (Burke & Moench, 2000, Palacios-Vélez, 2000, Baker *et al.*, 2000). Since the creation of the first government agency for controlling water resources in Mexico the struggle of the hydraulic bureaucracy in Mexico revolved mainly around the construction, settlement and management of medium and large-scale surface water irrigation districts. It entailed control over large sums of money as well as political control over the selection of beneficiaries of government programs (Rap *et al.*, 2004). Because restrictions on groundwater extractions are socially not popular there were no political incentives to control or regulate the exploitation of aquifers.

On paper, the Mexican state has regulated groundwater exploitation, nevertheless, the political will to apply the legislation is weak and is easily understood if one acknowledges that the protection of the aquifers entails reshaping the groundwater dependent socio-ecologies. The government with a constant pressure of poverty alleviation, economic growth, development and political interests gives priority to present day social benefits instead of conserving the groundwater resource.

5. *The lack of legal power of the CNA to control extractions.*

Although CNA officially regulates the exploitation of water is has few legal means to reinforce it. CNA does not have the faculty to close irregular wells. The only way in which CNA can close a well is if another water user denounces an illegal well by means of a *queja* (complaint) in which it is proven that the water supply of his well is reduced by the other well.

Legally all water users that have a concession have to report extracted water volumes to CNA twice a year. This is, for most users, impossible as the majority of the wells lack flow meters[4] (although legally they are complied to do so and are liable to sanctions if they don't possess one (LAN, 1992)). Furthermore, fines on overexploitation of water are low compared with the revenues users get from trespassing the law. Thus, for farmers, there are little incentives to 'play by the rules'. An ex-functionary of CNA and CEAG set it as follows "legal water control over groundwater extractions will not be effective until the 'transgressions' committed for over-exploitation or pollution of water become a punishable crime instead of an infraction".

6. *Impunity.*

Rent seeking is only possible in a widespread manner in a system where impunity prevails, and where users and functionaries are not punished for their irregularities. Nevertheless, impunity, just as rent seeking is part of a culture in which people don't bother with other's peoples' business as they don't want others to mind with their own business; it is part of the cultural ethics.

As can be seen in the section above the political will and institutional capacity to apply the existing legislation is weak and hampered by several factors. Triggered by the inefficiency of the state and the socio-economic and cultural context in which groundwater exploitation takes place, a vicious circle is formed (see figure 2.4).

The diagram shows how the repeated change in regulations for controlling groundwater overexploitation by the state form a vicious circle. The starting point of the circle is the situation where the resource is exploited under CPR regimes. State responses emerge to try to solve the problem of overexploitation. The implementation of these regulatory measures is hampered by different factors, which make them ineffective. As a result no control is achieved and the circle starts again. In most cases the problem that arises is not because the

[4] Most users refuse to install water meters or boycott them in fear that restrictions will be applied to their water use.

regulations are poorly structured but because the context in which they are put hampers proper implementation. The state has tried to solve the problems by structuring new interventions; nevertheless the solution to the problem has to be tackled in the conditions that impede implementation and it is these that have to be analyzed.

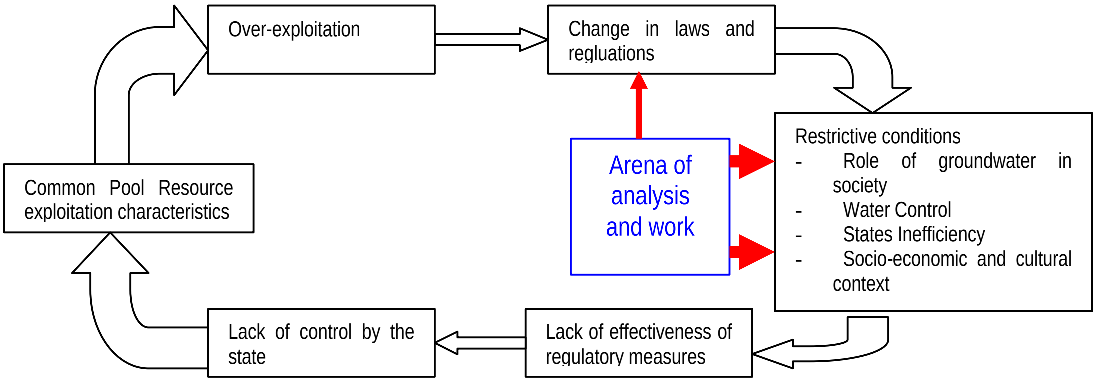


Figure 2.4 The vicious circle of state interventions and over-exploitation of groundwater

2.3 Water control; a political process of contested resource use

To operationalise the practices in the struggle over groundwater extraction for irrigation, the core concept to be used is *water control*. 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.* Groundwater 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).

Water control is a widely used term in the irrigation literature. The complementarities of the different meanings of water control makes it a suitable concept to relate the three dimensions of irrigation (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.

2.3.1 Technical water control

Physical control of water flow by means of irrigation technology. In Mexico technical water control over groundwater is defined by two factors: a) access to water in an aquifer and b) access to technology to extract groundwater. Water is, in first instance, controlled by the possibility of access to the resource. In the case of groundwater this is often dependant on the existence of an aquifer underlying the land of the users. In Guanajuato aquifers underlie great territorial extensions and the limitations to access these are only economically and technically determined. Access to technology to extract groundwater in aquifers which are being exploited has two components:

- *the technology itself* in the form of pumps, tubes, etc. which are easily accessible for whoever has economic resources. It is flexible infrastructure, and does not occupy a lot of space; it brings with it economic benefits to its owner and permits owners to search water at ever increasing depths (Sánchez-Rodríguez, 1998). Even though officially companies (providers) can only drill wells if the owner possesses a concession to replace, deepen or renew a well, there is no control (Pers. comm. operator drilling machine, 05-2003). Thus, access to pumping technology is limited by the financial possibilities of individuals.
- *access to fuel or electricity to operate the technology*. Access to fuel can be divided in two sources of fuel: diesel and electricity. Diesel (most used fuel for water pumps with internal combustion engines) is distributed everywhere by the state oil company PEMEX. Internal combustion engines are only used in areas where groundwater can be extracted at shallow depths, which in Guanajuato, can be found in the aquifers of Cuitzeo, Ciénega Prieta, Moroleón and Pénjamo-Abasolo (CEAG, 2000). In the other regions, because of greater aquifer depths access to electricity is essential to extract water. In Mexico, CFE regulates all electricity supply. Until a few years ago access to electricity for pumping was granted to whoever requested it. In view of the importance of electricity for water control some changes have taken place in the last years (Scott *et al.*, 2003). Since 2000 CFE and CNA have agreed to work together with regards to energy delivery for agricultural users (subsidized *tarifa 09*). To deliver electricity with *tarifa 09*, CFE now requests a copy of the water concession papers emitted by CNA. There are several producers that have large debts with CFE; nevertheless CFE has little tools to cut energy supply at field level. Large *commercial farmers* with political and economic influence have debts of up to US$6,000 and higher with CFE and no actions are undertaken to collect these debts.

2.3.2 Organizational water control

Organizational control is about regulation and control of human behavior, particularly with regard to forms of co-operation that are necessary to make irrigation systems function. Organizational control over groundwater has different levels. At field level there are basically two kinds of wells, privately owned wells and common property wells (ejidales). For privately owned wells there are little organizational aspects as the owner controls and manages the whole system. In common property wells there exist different arrangements for water distribution[5] (Kloezen, 2002). Thus, for the phenomenon of groundwater irrigation very little organizational control exists. This makes regulation of it very difficult as control mechanisms deal with individuals instead of other institutions as is the case with organized surface irrigation systems. In a state with over 18,000 unorganized well users the control task becomes almost an impossibility.

2.3.3 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*. This capacity depends on the economic

[5] See Chapter 4 for a full description of the different arrangements of organizational water control for wells in Guanajuato.

possibilities of producers to pay for technology and energy which is, in one way or another, linked to the region's economy, revenues from the agricultural production system and access to government subsidies, grants and water titles. *Commercial farmers* have socio-economic and political water control. They do not have severe restrictions on their access to water. Small producers have more restrictions, which are mainly linked to a lack of capital, information, organizational skills and political power.

The three dimensions of water control analyzed above present the phenomenon of irrigation. This implies they are inextricably linked. A change in one dimension may trigger a change in the other dimensions. For example, the ever increasing energy required to extract groundwater have made the pricing of electricity a highly political issue. This medium has been used by CFE and CNA to put pressure on illegal well owners establishing that users that are not inscribed in the REPDA are not entitled to the subsidized electrical tariffs for agricultural consumption (tarifa 9).

Mollinga (1998) argues that the concept of power binds the three dimensions of water control together. He bases his argument on the meaning of the concept of control. In its general meaning power refers to bio-physical and social processes. The central definition of 'power' that Mollinga uses is:

> "Power in the narrower, rationale sense is a property of interaction, and may be defined as the capability to secure outcomes where the realization of these outcomes depends on the agency of others. It is in this sense that men have power 'over' others. This is power as domination" (Mollinga, 1988; p.29).

In the struggle for power over water exploitation, the state is supposed to be the institution with power to control and manage water exploitation. Nevertheless, as shown above, in Guanajuato, the agricultural producers have *water control* in their hands.

2.4 Groundwater control; a problem of Common Pool Resources

The development and present situation of groundwater extraction in Guanajuato shows how groundwater regulation by the federal government has failed to preserve groundwater resources. As such, groundwater in Guanajuato is characterized by the basic resource features identified by Ostrom (1990) as Common Pool Resources (CPR). Common pool problems or dilemmas arise when individually rational resource decisions bring about a result that is not optimal when considered from the perspective of the exploiters as a group; thus CPR are public goods with finite, or subtractive benefits (Ostrom, 1990). In the case of groundwater, when one user uses more, less remains for the others. When no one owns the resource as is the case of groundwater, users have no incentive to conserve for the future; the self interest of the individual users lead then to over-exploitation. In the past two decades, four analyses of CPR dilemmas have dominated the views held on CPR exploitation. They are useful for understanding groundwater exploitation and are shortly explained below.

1. *Tragedy of the commons*: Each groundwater user is motivated to extract more and more water because he receives the direct benefit of 'his own' agricultural production and bears only a share of the costs resulting from overexploitation.
2. *Prisoner's dilemma*: The problem is that of a lack of information; groundwater users are unable to share information and thus produce a sub-optimal outcome; extracting groundwater from ever increasing depths at ever increasing costs.
3. *Logic of collective action*: Unless the number of individuals is quite small or there is coercion or some other special device to make individuals act in their common interest, rational, self-interested individuals will not act to achieve sustainable groundwater exploitation which is in their common interest. The 'hidden' nature of

groundwater makes coercion difficult as users' actions are not easily noticeable for each other.

4. *Free riding*: At the base of these dilemma's is the free rider problem. Whenever one person cannot be excluded from the benefits that others provide, each person is motivated not to contribute to the joint effort, but to free-ride on the efforts of others.

According to Young (1992), one can find the roots of the problems associated with CPR in inadequate economic and institutional frameworks within which resources are exploited in an 'open access' framework according to *a rule of capture*. To regulate CPR appropriation for achieving sustainable exploitation several policies have been designed and implemented. These policies are based on the four analyses of CPR's discussed above. According to Ostrom (1990), the policy solutions that emerge out of these analyses mostly fall under either: 1) State control; 2) market regulation or 3) (neo)-institutionalism, and added to these; 4) technologically induced more efficient resource utilization (Fussler & James, 1996; Wester, 2002). As shown in this chapter, state regulation has not been effective in regulating groundwater use. In Chapters 4 and 5 other solutions and implemented measures aimed at reducing groundwater use in the agricultural sector are analyzed[6].

2.5 Irrigation as a practice

When considering groundwater irrigation in Guanajuato, we have to uncover the 'irrigation black box'. The study of irrigation practices and water control are good concepts to do so. An analysis of *irrigation practices* gives insights that help analyze and design measures aimed at reducing groundwater abstractions in Guanajuato. In the remainder of this chapter first the concept of irrigation practices is presented, and then the theoretical framework used for this thesis is explained.

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 heterogeneous elements. People are the most important elements of the irrigation network, because they are the network builders 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 activities in their context. To understand the dynamics of an irrigation system and to enable qualitative analysis of irrigation activities, Mollinga (1998) suggests employing two concepts: (1) Study *irrigation practices* and (2) analyse *water control* (as has been done in the section above).

Practices are what people do in a structured and structuring fashion (Mollinga, 1998). Mollinga (1998) distinguished four characteristics of human behaviour that drive irrigation practices: a) Human agency, b) Strategies and resources, c) Arenas or domains of interaction, and d) Rules and routines.

2.5.1 Human agency

The concept of human agency in irrigation aims at understanding what motivates people's behaviour (what drives them and what governs their encounters) and how that behaviour

6 In this thesis *state control* is analyzed in the present Chapter. *Market regulation* is analyzed in the last sections of Chapter 4 as part of the analysis of *irrigation practices*. *(Neo) institutionalism* and *technologically induced more efficient resource use* are reviewed in Chapter 5 as part of the analysis of the state programs aimed at reducing groundwater exploitation in the agricultural sector of Guanajuato.

should be analyzed (Mollinga, 1997). People are knowledgeable and capable actors; 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).

The position of people in water management is a complex matter, whereby the rationality of the behaviour of actors cannot be reduced to a single characteristic such as ‘people as profit maximisers’. The relationships in which an actor finds him/herself both constrain and enable his/her possibilities of action; therefore, people’s behaviour can never be assumed (Mollinga, 1998).

When farmers mine groundwater resources for irrigation from season to season without restricting the level of extraction, doesn’t mean that they are not aware of the unsustainable situation or are acting irrationally. The way people use their resources can be inspired by different motivations than intentional and strategic motivations. Moore (1990) states that there is a rich variety of traditions that see action as the product of internalised social norms rather than as narrowly purposive or utilitarian. He stresses the importance of how different people understand and operationalise a concept of self-interest (Knegt, 2000). Mosse (1997) caries this emphasis further by stating that, in general, there has been a failure to take cognisance of the fact that strategizing is mediated by concepts, meanings and values that are constituted in culturally and historically specific ways. Material interests are often inseparable from social relationships, and choices are mediated by shared assumptions about such things as justice, fairness and reciprocity. These views are strengthened by van der Ploeg (1991) when he analyses agricultural development. He 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".

2.5.2 Strategies and resources

People devise plans to meet their objectives. To implement plans and to achieve their objectives, actors make use of certain resources or 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 politics, institutions, etc.

2.5.3 Arenas or domains of interaction

The boundaries within which practices take place are technological, social/institutional and are defined by space and time, this we will call a domain. 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 may be negotiated in the practices going on within them (Mollinga, 1998).

The characterizing feature of irrigation is the need to achieve a locally specific temporal allocation of water in space. Technological and social boundaries define the first level of the arenas/domains. In this study an arena or a domain will be understood as a place where particular practices take place. The groundwater irrigation arena is the place where different actors employ strategies and resources to acquire access to groundwater or certain technologies to extract and apply groundwater and use it for irrigation. This arena is embedded in other arenas of institutional, social, economic and political domains that all influence the groundwater irrigation arena.

2.5.4 Rules and routines

According to Mollinga (1998) rules and routines cannot be taken for granted, but have to be reproduced continuously. These practices have regular patterns and consist of routines which are structured by rules. This implies cooperation and coordination of action. These routines will differ according to the calculus in which irrigation practices take place and can vary in space and time; nevertheless they are determining for understanding these practices and how they evolve.

2.6 Understanding interventions through irrigation practices

Aquifers are exploited by human decisions (Young, 1992). Nevertheless these decisions are taken at different levels in society. Policy makers at the highest levels, field workers, different institutions and the individual users all take decisions with regards to the use and management of groundwater. These decisions are interlinked and affect each other in a complex network. Figure 2.5 presents the framework used in this thesis to understand the interactions that determine groundwater exploitation. In this framework, measures aimed at reducing groundwater exploitation are placed in an interrelated social, political, institutional and economic network of domains which determine *irrigation practices*. *Irrigation practices* are guided by the farmers' *calculus*, which depends on human agency, strategies and resources, arenas/domains of interaction, rules and routines and *water control* (Mollinga (1997 & 1998). These *irrigation practices* are seen as the link between the aims of the government programs and the results hereof (reduced groundwater extractions in agriculture). Therefore, irrigation practices form the central pivot of this research.

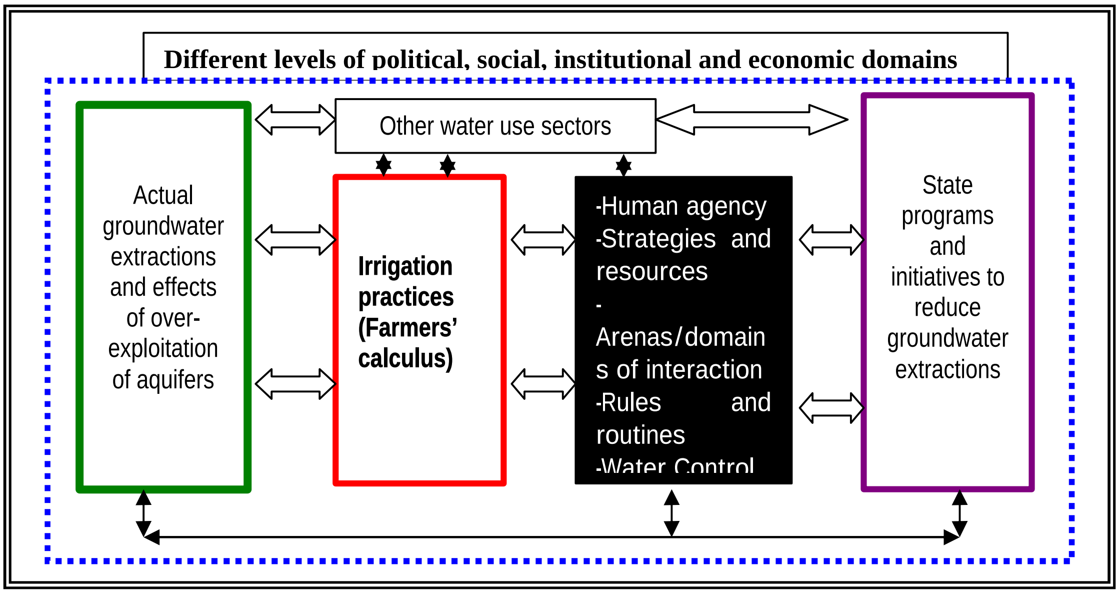


Figure 2.5 The interrelated network in which groundwater exploitation takes place

Beside the agricultural sector, other sectors also take part in groundwater extractions and have to be included in the analysis as their water demand is increasing. All groundwater users are immersed in different social, political, institutional and economic domains that form an interrelated network that shapes and guides the rationale for decision-making regarding groundwater use. The term interrelated is used in its broad meaning: *"Having a mutual and/or reciprocal relation or parallelism" (Webster's, 1983)*

This study focuses mainly on the groundwater irrigated agricultural sector, yet to better understand it, it is not seen as an isolated entity, but rather as the point of focus within a wider interrelated network (context). The management of water resources requires not only an in-depth understanding of physical flows, human activities, socio-economic conditions, societal, political and cultural contexts, but also of how they interrelate with each other. In addition, as most river basins are quite large, the spatial heterogeneity of all these factors, as well as their scaling-up, are critical issues that need to be addressed. To understand the interrelatedness and different dimensions of water management it is of utmost importance to understand the complex situation of water use dynamics.

2.7 Water control, state interventions and irrigation practices

This chapter described the history of groundwater development since the rise of tube well technology in the early 1950's and shows why the state has not been able to regulate groundwater use. In this chapter I presented the framework used in this thesis to understand how measures aimed at groundwater use can be analyzed through the study of *irrigation practices* and *water control* in their context. The role of the government and the farmers is central to this research. The government is seen as the institution that should create the conditions, and structure the mechanisms that guide farmers and other users to sustainable levels of groundwater exploitation.

Chapter 3

The situation of groundwater in Guanajuato

Groundwater overexploitation in Guanajuato is a fact, but: To what extent? This chapter first shows that the present socio-ecology of Guanajuato depends on groundwater for its sustainability. The other two issues that become clear are; a) that despite the different measures aimed at reducing groundwater exploitation, extractions have kept on increasing in the last five years, and b) that the different studies show great variations.

In this chapter, first an analysis of current water use and distribution is given. Later on, the studies of both CEAG and CNA on the dynamics, exploitation and recharge conditions of the different aquifers' that underlie Guanajuato are analyzed and compared. The chapter wraps up with the negative effects the overexploitation of groundwater brings with it.

3.1 Water use and distribution in the State of Guanajuato

Beside the incredible growth of the agricultural sector, which in the 1990's consumed 75-85% of extracted groundwater (Wester *et al.*, 1999), during the past 60 years, a growing industrial and urban sector have become dependent on groundwater. Population in the basin has increased significantly, doubling from 2.1 million inhabitants in 1930 to 4.5 million in 1970 and then more than doubling again to 11 million in 2000. The population of the basin will again double in the next 30 years if the population growth rate of 2.16% remains the same (Wester *et al.,* 2004). The result hereof is a decreasing water availability per capita per year, which at the moment lies at 749 m^3 compared to the national average of 4,067 m^3 (CEAG 2001)(See Figure 3.1).

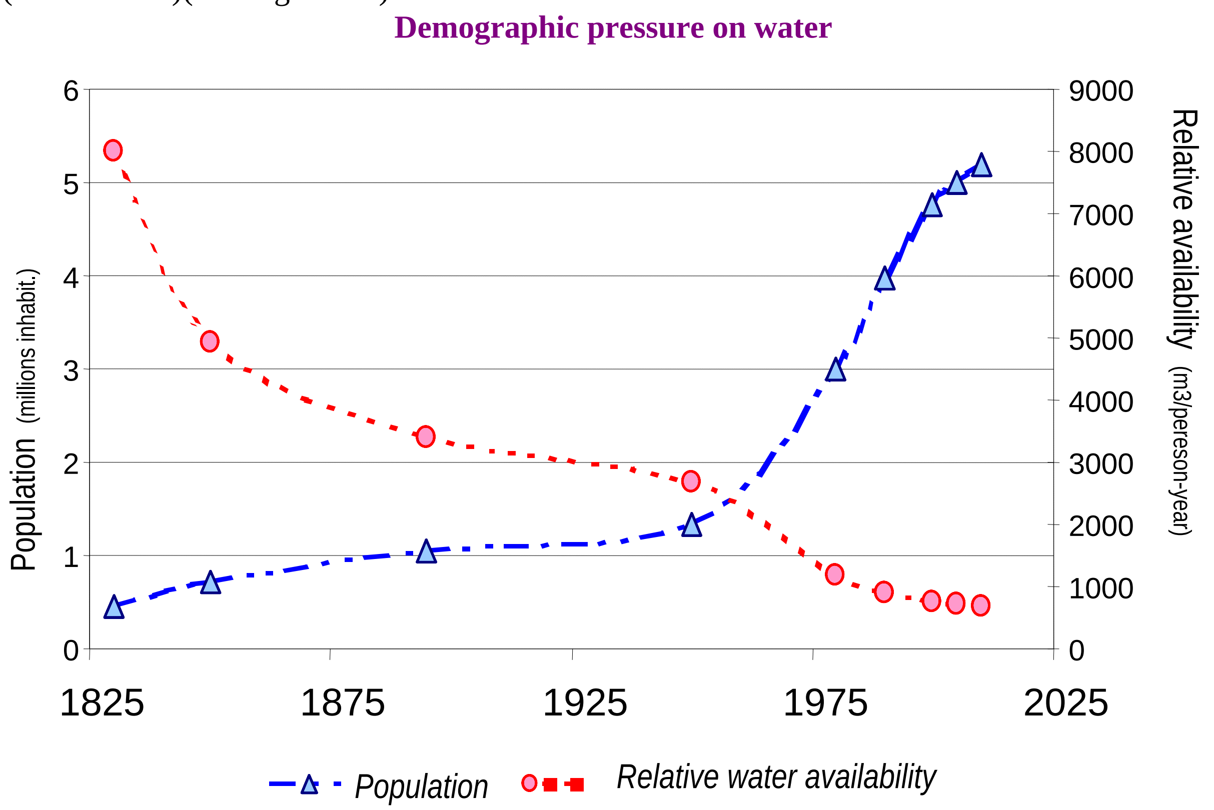


Figure 3.1 Development of water availability per capita per year in the state of Guanajuato. (CEAG, 2003p)

Guanajuato has become a state that uses more water than it gets through precipitation. The State has a mean annual runoff of 1,364 MCM while its demand for surface water is 1,557 MCM, of which 99.73% gets used up by the agricultural sector in the *Unidades del Riego para el Desarrollo Rural* (Irrigation Units for Rural Development,URDERALES) and the DR's 011, 085 and 087. Thus, surface water use is 193 MCM above natural rainfall. This "extra" water comes from the basin head (CEAG, 2001).

Groundwater is the largest and most important water source in Guanajuato. Although there is still great variation in the numbers presented on groundwater resources, it is fair to say that the mean annual groundwater use is around 4,200 MCM while recharge only accounts for around 2,950 MCM. This situation creates a yearly deficit of around 1,200-1300 MCM that are not renewed through recharge (CEAG 1998, 2000, 2001a; CNA, 1999).

In Guanajuato 99.3 % of urban and domestic water supply depends on groundwater (CEAG, 2003p1) and with it, it accounts for 15% of the total groundwater use (CEAG, 2001) (See Table 3.1). Industry only uses a small amount of water (1.3% of the total water use) and strongly contributes to Guanajuato's economy. It is nevertheless a great source of water pollution.

The situation of water in Guanajuato is critical. In the present a lot of resources are being invested in water management by the Guanajuato State Government[7]. CEAG, which was created in 1991, is one of the instruments the State Government has used to try to tackle the water problem. One of the main activities CEAG has undertaken is to study the aquifers; the results of these studies are analyzed in the following sections.

Table 3.1 Percentile water use per sector in the state of Guanajuato (CEAG, 2001)

	Agriculture (%)	Industrial (%)	Public (urban & rural) (%)
Surface water	99.73	0.00	0.27
Groundwater	83.20	1.80	15.00
Global water use	87.81	1.30	10.89

3.2 Studies on the aquifers

Groundwater is water filling spaces between rock grains, or in cracks and crevices in rocks. In the Bajío region, most aquifers are unconfined aquifers formed in alluvial sediment formations which reach depths of more than 600 m (CEAG, 2000). In these deposits water is stored in the pores that can be found in-between the alluvial material that consists mainly of gravels and sands which are interrupted in some places by impermeable clay layers. In some places the alluvial sediments are interrupted by basaltic and/or other rock formations that form elevations and delimit the aquifers (CEAG, 2000).

Until the 1960's the technical capacity to study aquifers in detail was not present. In 1966 the *Dirección de Aguas Subterráneas* (Directorate of Groundwater) was created within the SRH. This directorate was charged with evaluating and monitoring the groundwater sector in Mexico through the realization of a national groundwater inventory. Nevertheless during the 1980's due to economic recession and a lack of funds these studies and their updating ceased. In 1995 in view of a lack of information, the CEAG started studying the aquifers of Guanajuato. By the year 2000 all these studies were finished and officially validated by CNA. These studies include: physiography and surface hydrology, geology, hydrogeology, hydrochemistry, a conceptual model of the functioning of the aquifer, a water balance of the aquifer, a mathematical model of the functioning of the aquifer (with which different scenarios have been worked out), and recommendations regarding the future development of water use for the aquifer (CEAG, 2000). The balances of the studies are updated once a year and a network of control wells is used to monitor the aquifers. In December, 2000 CNA published its own studies on the availability of groundwater of different aquifers in the country.

[7] See Chapter 5 for an analysis and description of the different programs financed by the State Government aimed at water.

3.2.1 Discrepancies over aquifer limits and aquifer study results in Guanajuato

The first step that was taken by CEAG was to make the division of the different aquifers in Guanajuato. CEAG identified 15 aquifers in 2001[8]. Of the 15 aquifers, 11 belong to the Lerma Chapala Basin, one is a self-contained valley that administratively belongs to the Lerma Chapala Basin (Laguna Seca), one to the Rio Santiago Basin (Ocampo), and two belong to the Río Pánuco Basin (Jaral de Berrios and Xichú-Atarjea) (CEAG, 2001).

CNA identifies 19 aquifers in Guanajuato instead of 15 (See Annex 3). The division of aquifers used by CNA is the national official division of aquifers, and was published in the Diario Oficial de la Federación (DOF) on the 31st of January, 2003.

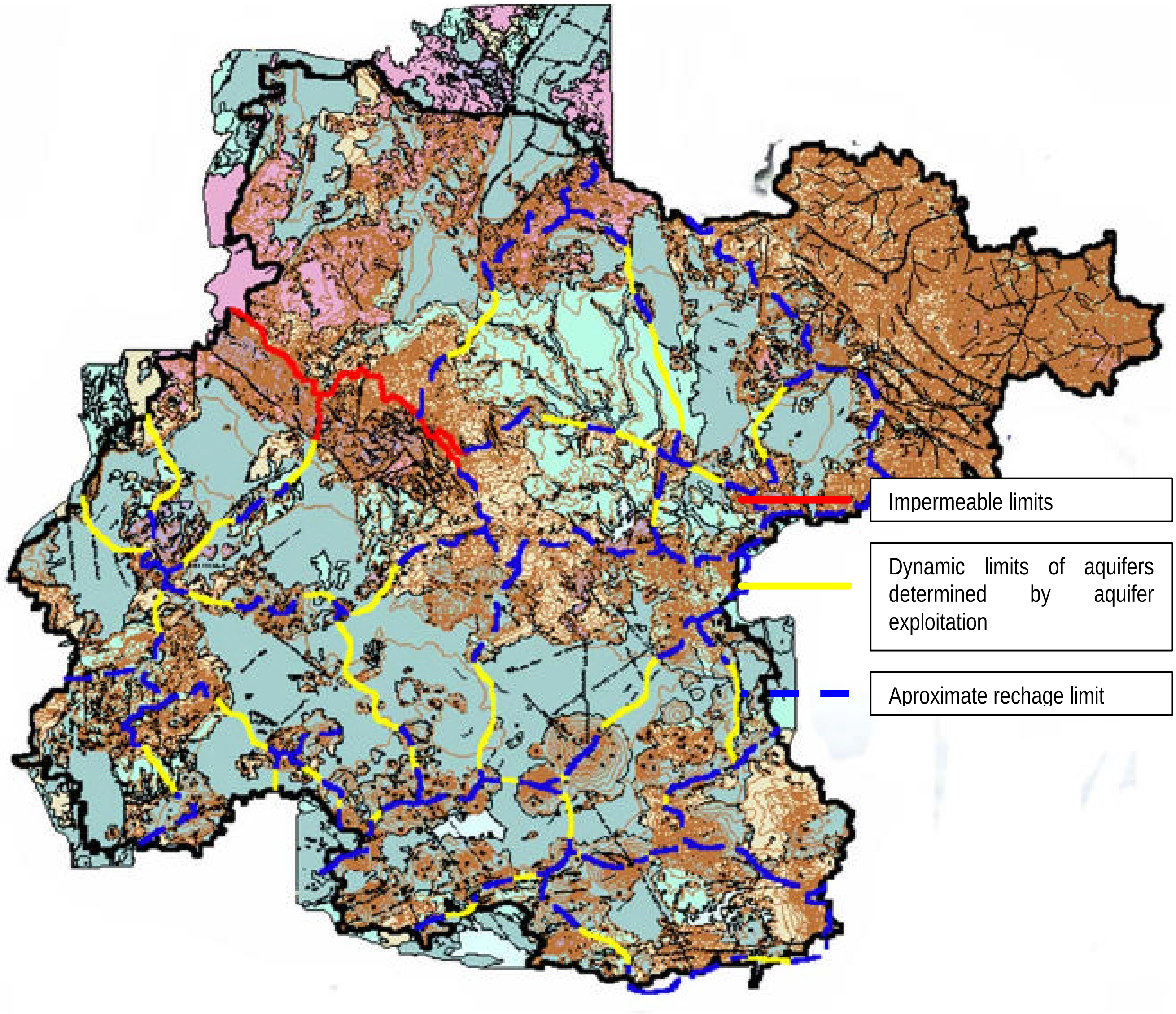


Figure 3.2 Natural aquifer limits (CEAG, 2003: p1)

8 CEAG identified 15 aquifers in 2001, nevertheless the studies of the aquifers of CEAG as presented in the Sinopsis de Estudios Hidrogeógicos y Modelos Matemáticos de los Acuíferos del Estado de Guanajuato, 1998 and 2000, on which the information of this chapter is based on identifies 17 aquifers. In the publication of 2001 the aquifers of Salvatierra and La Cuevita are merged (Savatierra-La Cuevita) as well as the aquifers of Valle de Acámbaro and Lago de Cuitzeo (Acámbaro-Cuitzeo).

Scientists of the *Universidad Nacional Autónoma de México* (National Autonomous University of Mexico, UNAM) make yet another aquifer division. They consider only two unconfined aquifer systems in the State (See Figure 3.2). The two identified aquifer systems are: a) in the north, the aquífero de la Independencia, b) the Bajío aquifer in the south of the State. The latter includes the whole Bajío region and its limits are not within the state as the aquifer extends into the states of Querétaro, Jalisco and Michoacán (Ortega-Guerrero *et al.*, 2002 & Ortega-Guerrero, Interview 03-07-03).

Beside the discrepancies amongst institutions on where aquifer limits are established, there also exist discrepancies between the methodologies and assumptions made to calculate extractions and recharge of the different aquifers (See Annex 3). As a result the studies also show different numbers as will be seen in the section below.

3.3 Groundwater extractions

Since 1998 CEAG has monitored and followed the static levels in monitoring wells in Guanajuato and produced information on calculated groundwater extractions for the different aquifers. Information of CEAG is available from three different years; 1998, 2000 and 2001. CNA has also done studies of which the most recent are the ones of 1999 and 2000. The results of these studies per aquifer that belong to the Lerma Chapala Basin are presented in Table 3.2. The different studies show a clear annual increase in extraction levels in most of the aquifers.

Table 3.2 Evolution of groundwater extractions in MCM/year per aquifer belonging to the Lerma Chapala Basin in Guanajuato (CEAG, 1998, 2000, 2001, CNA, 1999, 2003)

Aquifer	CEAG 1998	CEAG 2000	CEAG 2001	CNA 1999	CNA 2000
Laguna Seca	N.A.	395.0	408.4	200.0	485.0
Laja-San Felipe	278.2	278.2	291.2	211.0	412.0
Silao-Romita	305.4	381.1	389.6	291.0	440.4
Valle de León	248.9	312.6	315.1	204.0	204.5
Valle del Río Turbio	148.4	191.3	196.0	183.5	148.0
Valle de Celaya	593.0	593.0	599.5	579.0	593.0
La Cuevita	9.2	9.2	12.2	47.0	8.5
Valle de Acámbaro	161.9	161.9	166.4	190.0	161.8
Salvatierra	109.2	109.2	113.7	210.0	109.0
Irapuato-Valle de Santiago	702.0	641.7	675.0	217.0	563.0
Pénjamo-Abasolo	721.1	503.3	534.8	333.0	440.2
Lago de Cuitzeo	39.7	39.7	39.7	11.0	39.7
Moroleón-Cienega Prieta	124.4	124.4	159.5	78.0	129.8
Apaseos	282.4	240.4	247.0	N.A.	N.A.
TOTAL	**3723.7**	**3980.8**	**4148.1**	**2754.5**	**3734.9**

When comparing data of CNA and CEAG, CNA has conservative figures. Nevertheless both sources indicate an increase in groundwater extractions since 1998 which is attributed to an increased number of wells in the State. The studies give a good indication of the extracted groundwater volume per year. Nevertheless some critical remarks can be made about the accuracy of the studies:

- The studies present approximations to the extracted amounts of groundwater. The studies calculate extractions not on measured amounts on flow meters, but on assumptions on well discharge and average pumping hours per year per well. The census of the wells is not updated every year and some wells have run dry or have a lower discharge while others have been improved and deepened and new wells have been installed.

- The assumptions for calculating extractions do not take into account climatological circumstances which greatly affect the irrigation behavior of farmers.
- The assumptions made do not take shifts to more efficient irrigation technology into account.
- The studies do not evaluate irrigated area and the kind of crops.
- The measurement of static levels gives a good indication of the loss of volume in an aquifer but is also an approximation of reality.

3.4 Recharge conditions and balance

To get to know the extent to which groundwater exploitation is surpassing sustainable levels of exploitation it is necessary to know the recharge conditions of the different aquifers. CNA and CEAG have done studies on recharge conditions in which the total numbers are more or less the same but in which there is great difference between one year and another in the aquifers (see Figure 3.3).

Table 3.3 Annual recharge per aquifer in MCM/year (CNA, 1999, 2000; CEAG 1998, 2000, 2001)

AQUIFER	CEAG 1998	CEAG 2000	CEAG 2001	CNA 1999	CNA 2000
Laguna Seca	N.A.	176.8	176.8	100.0	177.0
Laja-San Felipe	171.2	171.2	179.0	122.0	139.7
Silao-Romita	272.1	316.8	308.6	234.0	301.0
Valle de León	316.9	264.3	258.4	96.0	156.3
Valle del Río Turbio	122.0	150.6	154.7	144.0	110.0
Valle de Celaya	431.7	431.7	435.1	463.0	286.6
La Cuevita	7.0	7.0	8.0	44.0	5.9
Valle de Acámbaro	119.9	119.9	129.1	156.0	160.2
Salvatierra	75.0	75.0	74.0	169.0	82.0
Irapuato-Valle de Santiago	528.7	386.7	472.4	175.0	522.2
Pénjamo-Abasolo	538.4	426.5	421.0	197.0	225.0
Lago de Cuitzeo	27.2	27.2	29.7	11.0	27.2
Moroleón-Cienega Prieta	92.6	92.6	122.7	57.0	85.0
Apaseos	248.4	174.6	182.2	N.A.	N.A.
TOTAL	**2951.1**	**2820.9**	**2951.7**	**1968.0**	**2278.1**

Recharge of aquifers, just as extractions are calculated on the basis of assumptions. These assumptions are still internationally discussed and debated but are out of the scope of this study. It is important to know that studies done by the institute of geology and hydrogeology of UNAM in the area of the aquifers of Laguna Seca and Laja-San Felipe suggests that recharge in this area is extremely over valued (Ortega-Guerrero *et al.*, 2002), which suggests that the problem of overexploitation of aquifers is more severe than presently presented by the different studies of CNA and CEAG.

Although the recharge and extraction values of groundwater are estimations, they give a good indication of the graveness of over-exploitation the aquifers have at the moment (see Table 3.4).

It is clear that the problem of overexploitation of groundwater is severe in the aquifers of Guanajuato and that it is worsening despite the institutional efforts undertaken in the past years to control overexploitation of aquifers. This overexploitation brings with it a range of problems that are described below.

Table 3.4 Groundwater balance of the aquifers of Guanajuato that belong to the Lerma Chapala Basin (CNA 1999, 2000, CEAG 1998, 2000, 2001)

Source	Recharge	Extractions	Balance
CNA 1999	1968	2755	**-787**
CNA 2000	2278	3735	**-1457**
CEAG 1998	2951	3724	**-773**
CEAG 2000	2821	3981	**-1160**
CEAG 2001	2952	4148	**-1196**

3.5 Consequences of overexploitation of the aquifers

3.5.1 Fall of static water levels

The average water level drop in Guanajuato is 2 m/year with extremes of up to 5m/year (Scott, *et al.*, 2003). Especially around the major cities of the State water extractions create severe depression cones (CEAG, 2000). Table 3.5 shows the mean annual drop of static levels per aquifer. To exemplify the extent to which groundwater levels have dropped in Guanajuato; in Celaya in 1956 static water levels were between 10 and 15 m, at present they are around 90 to 105 m (CEAG, 2003p1). This extreme drop in water levels characterizes almost all aquifers in the State.

Table 3.5 Average annual descent of water tables per aquifer in Guanajuato (CEAG, 2001)

Aquifer	Average annual fall of static levels (m)
Laguna Seca	2.50
Laja-San Felipe	1.20
Silao-Romita	3.00
Valle de León	1.50
Valle del Río Turbio	2.00
Valle de Celaya	3.00
La Cuevita	0.50
Valle de Acámbaro	2.00
Salvatierra	1.50
Irapuato-Valle de Santiago	2.00
Pénjamo-Abasolo	3.00
Lago de Cuitzeo	1.00
Moroleón-Cienega Prieta	1.25
Apaseos	3.50
State Average	**2.03**

3.5.2 Compaction of alluvial deposits

In the sedimentary alluvial deposits that form most of the aquifers in the area, water occupies the pores in between the sedimentary material (rocks, gravels and sands). As long as water fills those pores, they remain open. When water is extracted from the aquifers the pores are emptied and water can no longer give structural support. As a consequence the sedimentary materials begin to move and rearrange themselves filling the pores that were occupied with water. This results in a loss of porosity of the sedimentary materials and a compaction of alluvial deposits in the aquifers, which brings with it the following consequence:

- Recharge and water holding capacity of the deposits diminishes (Cruz, interview, 19-05-2003). As the pores are filled with solid material, their water holding and transport capacity is reduced.
- Subsidence, settling and terrain fissures cause damage to infrastructure and increase the risk of polluting aquifers. One of the most affected cities is Celaya where in places subsidence reaches 2-3 cm a year and where in some places the faults have reached 2.7 m (Cruz, interview, 19-05-2003).
- Pollution of aquifers is a great danger especially around the city of Salamanca where the biggest oil treatment plant of Latin America is found. By subsidence and fissures, infrastructure of the treatment plant gets affected causing leaks that infiltrate to the aquifer (*idem*).

3.5.3 Increasing pumping costs

Ever increasing pumping costs for groundwater users related to deeper wells, larger motors or pumps and higher energy consumption is a fact in Guanajuato. Through time, the fall in static water levels led to the need to sink deeper wells; indigenous water buckets (‘norias’) were soon displaced by wells up to 100 m deep (Kloezen, 2002). Nowadays, depths between 200 and 400 m are common for new perforations (Operator of a well installation company, interview, 2003), and in the Salamanca area depths of 500 to 1,000 m have been reported. The resulting draw down of water levels has affected small surface water impoundments, which loose their storage rapidly through percolation (Scott, *et al.*, 2003).

3.5.4 Groundwater Quality Aspects

A less documented effect of extracting water from ever increasing depths is the decrease of water quality. Over time, Guanajuato’s groundwater has been experiencing an increase in the concentration of soluble salts, sodium, bicarbonates, SAR and pH, though the concentrations of Ca, Mg, and K (Castellanos, *et al*., 2002). This is due probably because the water quality in the lower strata of the aquifers is naturally of lower quality or because of intrusion of lower quality water from the recharge sources.

In the Independence aquifer (as identified by UNAM), to date, 15% of the total irrigated area presents moderate restrictions on sprinkler irrigation and another 10% presents restrictions on furrow irrigation due to the effects of increased sodium concentrations in groundwater (Ortega-Guerrero *et al*., 2002). The highest concentration of sodium in water is found in water extracted in the south-eastern zone of Guanajuato, where negative effects on soil and crops, such as sorghum, have been observed (Castellanos *et al*., 2002). It is to be expected that these negative effects resulting from decreasing groundwater quality for agricultural use will increase over time. Another big threat that is arising in most aquifers is the deterioration of water quality due to rapid transport of industrial contaminants and used remnants of fertilizer and pesticides (Scott & Garcés-Restrepo, 2001).

3.6 Conclusions

This chapter has shown how important groundwater has become for the socio-ecology of Guanajuato. It also makes it clear that groundwater resources are exploited at unsustainable levels in the whole state. The studies conducted to determine the extent of overexploitation are based of several assumptions and can be considered good estimates which indicate that there is an increasing extraction level of groundwater in all aquifers. Although quantitative studies of groundwater are necessary and useful, they serve mainly political purposes. In most places of the world such studies are not available and take a lot of time and effort to conduct. I propose that the best and easiest way of studying the degree of overexploitation of groundwater is to follow the annual variations of static levels. This information gives a fast and easy indication of the degree of overexploitation. With this measure it is easy to asses how groundwater exploitation develops through the years and how it responds to inter-annual climatic differences. Farmers are, in most cases, well aware of falling static levels and it is something they can monitor. I myself took a lot of time to analyze the studies on groundwater exploitation but these have given me little insights. The fall of static levels of aquifers is easy information which clearly shows that overexploitation is taking place. It is this measure which can easily show how aquifers respond to high or low rainfall years and climatic variations. Aquifer levels can also be used to asses if regulations are efficient in stabilizing groundwater or not with very simple means.

Chapter 4

Irrigation practices and agricultural production in context

The previous chapters described the present situation of groundwater resources. Agriculture is the largest user of groundwater, but: Who uses groundwater and for which crops, markets and under what kind of arrangements? How are decisions and practices shaped and under which factors?

In this chapter I describe the main production systems that exist in Guanajuato, the main crops that are produced and the different mechanisms that give farmers access to water. Based on these, this chapter identifies mechanisms and relations that determine groundwater *irrigation practices*. It shows that farmers' *irrigation practices* are determined by a complex context in which culture, markets, the price of electricity and the arenas of interaction of each individual farmer play an important role in determining practices. This analysis is used in the following two chapters when studying measures aimed at reducing groundwater use.

4.1 The different irrigated agriculture production systems in Guanajuato

4.1.1 The Context

In 1988 Mexico began to restructure the nature of state intervention in the economy by gradually dismantling the revolutionary nationalist legacy in favor of increased integration into the international market (Kloezen, 2002). Liberalization and internationalization of markets were particularly established through a process of gradually diminishing regulatory and tariff constraints. In 1987 Mexico entered the General Agreement on Tariffs and Trade (GATT). Tariff barriers were reduced and international agricultural trade was increased with the approval of the North American Trade Agreement (NAFTA) between Canada, the United States and Mexico, which entered into force on the 1st of January, 1994.

The consequences of these trade liberalization programs and agreements for Mexican farmers have shown mixed records. According to Kloezen (2002) beneficiaries of this 'global project' were primarily large *commercial farmers* with sufficient technological and market know-how to take advantage of opportunities to export to foreign markets. As for the small producers, these agreements sharply decreased the price of basic grains. This has promoted the migration of agricultural workers to neighboring USA or the growing Mexican cities.

The State of Guanajuato is characterized by a great heterogeneity of irrigated production systems. This heterogeneity is simplified in basically two kinds of farmers, the *semi-subsistence farmers* and the *commercial farmers,* and one mode of production; *contract farming*. Such a differentiation is arbitrary and generalisitc but it gives a good idea of the different production regimes that exist in Guanajuato and the way *water control* is organized. A description of the different types of producers is given below.

4.1.2 Semi-subsistence farmers

S*emi-subsistence farmers* (SSF) are usually, but not necessarily, *ejidatarios,* who produce basic grains on small land holdings and have income sources outside of agriculture. Many SSF are supported by family members that work outside the sector or work part time in other activities. Agriculture has become one of the many activities of these producers because of the fall of grain prices since the implantation of free-market policies and a changing socio-cultural context. "With the opening of the free trade market the basic grain growers got it really hard. Growers in the US can produce a lot cheaper and are subsidized. Competition is almost impossible for Mexican producers without subsidies" (Usabiaga-Reynoso, interview, 20-08-2003). In the following paragraph ejidos are explained because they are the source that gave most of SSF lands to cultivate after the Mexican Revolution.

Ejidos are lands that belong to the state but are worked by ejidatarios. In 1917 the *ejidos* were created as a result of the Mexican Revolution. These lands where given to *ejidatarios* mainly out of the land redistribution program that started in the early 1920's. The program caused some redistribution of land in central Guanajuato by expropriating land from the large *hacendados*. In Guanajuato 39% of the total amount of cultivated land was cropped by *ejidatarios* in 1982 (Kloezen, 2002). The average holding of the ejidatarios that have access to irrigation is 3-10 ha but there are extreme variations (Kloezen, 2002). The *ejido* system was changed with the 1992 revision of Article 27 of the Constitution of 1917. The new provisions allow *ejidatarios* to legally sell, rent, sharecrop, or mortgage their land as collateral for loans (Kloezen, 2002). This change in the constitution has basically set an end to the *ejido* system and has caused great changes in the dynamics of production. In this thesis both ejidatarios and private property holders that operate in semi-subsistence modes of production are included in the SSF term.

4.1.2.1 Migration

During the period 1995-2000, 3,5% of the population of the state of Guanajuato migrated either permanently or temporarily to the United States amounting to a total of around 165,000 people of which a little less than 50% come from the rural areas. More than 50% of the migrants send money to their families, which has a strong impact on the regional economy (Consejo Estatal de Población de Guanajuato, 2002). According to the Consejo Estatal de Población de Guanajuato (2002) the amount of migrants, both permanent and temporal in Guanajuato shows increasing numbers through the last years.

Of the interviewed SSF all had family members that had migrated either to the USA or to bigger cities in the country. Most of these emigrated family members give financial support to the producers. In most cases the children of the head of the holding had migrated because they did not see any future in agriculture. This is especially notable in big families with small holdings.

4.1.2.2 The production system of semi-subsistence farmers

Most ejidatarios have a deep rooted tradition of cultivating basic grains. The main grains that are cultivated are: maize and sorghum for the primavera-verano cycle[9] (P-V, spring-summer), and wheat or barley during the otoño-invierno[10] (O-I, autumn-winter) cycle. In some cases, when *ejidatarios* have access to groundwater, they produce alfalfa or vegetables but this is mainly regionally bound and conditioned by the enabling possibilities (See Box 4.1).

In most cases, markets determine which P-V and O-I crops will be sown. O-I crops in the DR's are determined by water availability. An example are the past years in which water scarcity in the DR 011 forced producers to switch from wheat to barley (Wheat needs four irrigation turns, barley only three) (Vázques-Martines, interview, 18-08-2003). SSF mainly produce basic grains instead of 'more profitable' crops which might seem an irrational choice; nevertheless, if one analyzes the advantages and disadvantages these crops have, decisions taken by farmers are very rational as explained below.

- If dependent on surface water for irrigation, farmers in the tail end *módulos* have no other option than to sow grains based on the amount of irrigation turns they get.
- If dependent on a communal well, in most cases, the pump discharge and water distribution arrangements impede flexible irrigation turns needed for other more water demanding crops.
- Grains are low input; low maintenance and low risk (secure) crops with fairly stable prices and relatively low water demand when compared to other crops. For farmers with activities outside of agriculture these crops are ideal because of these conditions.
- Most farmers are decapitalized and can't invest in crops that have high input costs. For some farmers *contract farming* has become a good option for changing their production system.

4.1.2.3 The future of ejidos and semi-subsistence farmers

Although not well documented up to date, there seems to be a growing tendency of land accumulation after it became possible to sell *ejidos*. This land accumulation takes place amongst SSF[11] but also by *commercial farmers* who buy *ejido* land. Many neo-liberal

[9] This cycle compromises the months of May-October.

[10] This cycle compromises the months of November-April

[11] I spoke a former *ejidatarios* and SSF that through land accumulation and hard work cropped more than 180 ha of sorghum while he started with a 5 ha holding.

oriented people see land accumulation as a good development. It is to enable more efficient production, capitalize the countryside and in the process create employment. How this will develop depends on the government policies with regards to grain subsidies, and free markets the coming years. It would not be strange if through land accumulation farmers disappear and migrate to the cities leaving agriculture to the large landowners just as it was before the Revolution of 1910.

Box 4.1 Manuel an example of a semi-subsistence farmer

I drive alone, in my Nissan Tsuru, at the end of the day on a badly paved rural road. On both sides of me sorghum fields ready to be harvested, rise with their deep colored grain tops to the sky. The warm August sun hovers low over the horizon casting yellow light through the clear sky. From the North some dark clouds appear on the horizon. I am looking for groundwater farmers to interview and wonder if I should do another interview or 'just call it a day'. As I think about this and the last interview I just had, I arrive in the community of Laborde Valtierra (Municipality Valle de Santiago, Gto). As I drive around the town square I see two people playing cards in front of the local tiendita (grocery store). I ask if they are farmers and if they are groundwater users to which I get a double "no-no". Nevertheless they indicate a door further down the road were someone is to be found who farms and manages the 'communal well'. I drive down the road and stop in front of a big blue door. Inside I hear the running engine of a tractor. After some time someone opens the door. I introduce myself and explain what I'm doing. The person that opened the door (Don Manuel) laughs and explains he is the manager of the 'communal well for potable water'. Fortunately it does not stop there.

Manuel is also an *ejidatario* that used to use groundwater until the well dried up two years ago. The well he had used, was a well managed by 10 users which produced mainly basic grains. When the well dried up, these *ejidatarios* did not have enough capital to invest in a new well and so they had to revert to rain fed agriculture. Access to other water sources was not possible. Four of the farmers decided to leave and risk a journey to the United States to look for work there. Their holding was left to the other users under share-cropping conditions to be sown in the summer or sold. Manuel decided to stay and keep on cropping his and others' land and switch to other activities. He has taken responsibility of O&M of the community water supply system and has started raising pigs. He receives some support from two of his elder sons that work in the United States. As we speak he explains that for a lot of *ejidatarios* it is not interesting to farm any more as it is more profitable to look for work in cities or abroad. The land that is left behind by migrants does not fall out of production and is taken over by other producers. As we stand there in front of his house he shows all the houses of people that have migrated. In that street alone 30 people have left to the United States. The clouds stir unrest in the sky, the first raindrops fall, and it is getting dark. I thank Manuel, step in the car and drive to Salamanca in the rain, wondering what the future of the *ejidos* will be.

4.1.3 Commercial Farmers

Article 27 makes provisions for private ownership of land up to certain limits. Private farmers are permitted to own 150 ha of prime irrigated land, nevertheless it is widely known that legal limitations on the size of individual holdings are ignored or skirted through the practice of distributing titles among members of a family, its retainers and other willing 'name lenders' (prestanombres) (Kloezen, 2002). It is not uncommon for small private growers to accumulate 500 ha or more through either ownership, or land rental (Kloezen, 2002). While in the last years there has been a trend in the Bajío and Laguna Seca to produce vegetables, there are also a number of dairy producing holdings and several very flexible farmers that 'go with the markets'.

4.1.3.1 The production system of commercial farmers

Although heterogeneity is extreme between these producers, some core characteristics can be found within the heterogeneity of these production systems:

- *Highly capitalized producers: Commercial farmers* are highly capitalized which makes them operate at the cutting edge of technological innovation so production becomes very efficient.

- *Diversified market and production systems:* Risks and opportunities can be taken in the fluctuating markets. Most producers are engaged in some kind of ‘secure’ income source such as *contract farming* either with national or international markets and also have a part of the production that is sold in free markets.
- *Farming is considered a business:* Under this rationale the enterprise has to be managed in a rational, efficient and flexible manner in order to move with the changing circumstances.
- *A high education level:* Most commercial farmers are highly educated. This makes them flexible, rational and more capable of following market trends.
- *High organization among users*: Producers work together and represent their interests in different governmental and external pressure groups.
- *Access to subsidies and support*: As most producers are well organized and well informed, they have easy access to government subsidies.
- *Political power*: The last two governmental administrations in Guanajuato have had *commercial farmers* at the head of SDA; besides important lobby groups have been formed.
- *Income activities outside of agriculture*: Producers often have diversified incomes and it is not rare for farmers to have another business related to or outside of the agricultural sector.

In the last years land-renting among commercial farmers has increased significantly as owners do not want to take the risks of production. Land is rented to producers that take the risks of production and some big manufacturing industries have started renting land as well. The rent of land varies from 500-700 dollars a year a hectare. This is land with good soil and groundwater. Land without water does not have any value. Once land is rented, renters can pump/use all the water they want (no restrictions).

4.1.3.2 *Commercial farmers* and free markets

Before Mexico entered GATT and NAFTA agreements, Mexican agriculture was highly subsidized to enable the *ejidos* to survive. Such a strategy was mainly aimed at social benefits. Under these high-subsidy conditions, for medium or large size farmers agriculture was a virtual ‘gold mine’. Since the markets opened the subsidies on agricultural inputs have virtually disappeared, just as the guarantee prices for agricultural products. With NAFTA, which a lot of *commercial farmers* consider beneficial for the country, the agricultural sector was left in the cold having to compete against the American and Canadian agriculture especially in the grain sector.

Today, in Mexico the production costs in the agricultural sector are not cheaper than in Canada or the US. Labor is cheaper, but this is compensated by the same or more expensive material input costs such as fertilizers, technology and energy. A problem with labor in Mexico seems to be that as a *commercial farmer* said “Workers do as if they work and we do as if we pay”.

The advantage Mexican growers have at the moment are the natural conditions and, up to the present, water that enables the production of fresh vegetables. The Bajío has become one of the greatest broccoli producing regions in the world as free markets permit companies to export the produce to the rest of the world, especially Canada, US, Japan and Europe. For these exporting companies free trade regulations have been beneficial. One such producer is the ranch “El Fuerte” which is described in Box 4.2.

Box 4.2 Rancho el Fuerte, an example of a *commercial farmer* in the Bajío.

Again I drive in my Tsuru, this time I'm accompanied by a young French lady, Laure-Anne. We drive through Cárdenas and take a dirt road that guides us beside one of the main channels of the Módulo de Riego Salamanca. My watch indicates it's somewhere around 9:20 am. We have an appointment with Don Gonzalo at 9:30 in his office in the ranch "El Fuerte". As we drive up the driveway of the ranch we are impressed by the old colonial buildings that stand there in perfect state, not showing the centuries they have endured. Laure-Anne and I walk to the office of Don Gonzalo that is found in a new building beside the colonial buildings. As I enter the office several "good practices" certificates issued by both Mexican and American companies capture my attention which is brought back by a gentle greeting of the secretary that sits at her desk working behind a computer. In broken spanish with a strong French accecent Laure-Anne asks for Don Gonzalo, which is then radioed though his NEX-TEL (Personal Radio Communication installed for the farm). As we wait we get a cup of coffee and while I drink, I observe in amazement that there are four people working in that office behind computers.

Don Gonzalo arrives and directly invites us to accompany him to the barn where garlic is being sorted, treated and packed for a super market. 20 workers are busy with the job. As we continue our walk to the control center of the newly installed drip irrigation system which also has fertigation, he explains that the barns we are walking through used to have pigs as that was the mainstay of the farm until vegetable production became more lucrative.

As he shows us the installation he explains that the fertigation system that is newly installed got co-financed by SDA support. Furthermore he got a loan from a Spanish bank that has the lowest interest rates for agricultural loans at the moment. The system he has is the newest technology there exists. To program the irrigation turns he has a small weather station on the ranch. For planning the fertilization of the crops with the fertigation system every year he does soil analysis, and the crops are constantly analyzed in laboratories.

Don Gonzalo owns 250 ha of irrigated land and rents another 100 ha from other farmers. Of these 150 ha are operated with drip irrigation systems since two years. The other 200 ha are still working with low pressure irrigation systems but will soon change to drip irrigation. His water supply consists of one 4" well, one 6" well and five 8" wells that have a static level depth of 60-65 m and a dynamic level of 90-110 m. Two to three times a year these levels are controlled and water quality is determined.

Don Gonzalo works together with his brother in a partnership in which the brother is fully responsible for commercial contacts and marketing and Don Gonzalo is responsible for production. On the farm he has 40 permanent workers which in the high season increases to 250-300 workers. Of these workers several are office workers that work with accounting, contacts, etc.

El Fuerte produces vegetables (mainly broccoli, lettuce and garlic) for three different contractors. Beside these contracts, they also have production that is for the free market either in Mexico or the US. At the moment Don Gonzalo is searching for holdings to rent in Laguna Seca because there temperatures and precipitation are lower, this enables year round production of vegetables. In the Bajío the winter season is the best for vegetables and in Laguna Seca it is the summer.

As we drive in his 4X4 through fields with lettuces in all stages of growth, he explains that most producers don't do accounting and loose a lot of money because they don't plan, "there is a lack of consciousness among producers". "If you take agricultural production as a business and apply business management, it is a very lucrative industry". He himself is very keen on good management practices which in his view are: clean production systems at field level, good and clear accounting, cleanness, rigidity in rules and regulations as well as policies for workers and a business mentality.

As we drive back from the fields Don Gonzalo gets radioed that a carton box supplier for the vegetables has arrived. Before he goes into 'businesses with the new 'Mexican' supplier that might replace the US-supplier he had, we thank him heartily and walk to the car. As we drive back to Salamanca, Laure-Anne comments to me "such farmers can keep development going" and I think of the words Vicente Fox (Elected president of Mexico from 2000-2006) once used "Que la vanguardia apoye a la retaguardia".

4.1.4 Contract Farming[12]

Contract farming has existed in the Bajío since the 1960's but constituted only a small percentage of the production. In the past decade, contract farming has drastically increased as

[12] This section is based on two extensive interviews with directors of contracting companies and several farmers that work or worked in the past under contract.

national and international contractors enter the region. Farmers have also moved toward contract farming. One of the main factors that promoted this shift is the free markets that make prices of agricultural products frail and uncertain. Contract farming gives farmers guarantee prices and a secure market for their production; *"farmers know what they are up to"*.

Contract farming works backwards when compared to regular farming. Farmers don't plant 'speculating' but with a contract; they plant what they know they can sell and under which conditions. Other farmers work the other way around; they produce and hope there will be a good market for their products; this often 'kills' them. Contract farming can create a win-win situation in which farmers produce and the company commercializes giving security to both.

Enterprises that work with contract farmers are as heterogeneous as the farmers themselves. The contracting enterprises vary in their mode of operation with regards to the contract conditions and the people they work with. Some work exclusively with commercial farmers, others contract only with SSR or a mixture of both. Most of the contracts that are set up between the farmer and the company include agreements on:

- *Financing by the contracting company*: In most cases companies finance producers with inputs starting at the beginning of the growing cycle. Sometimes the seeds, fertilizers and financial support are supplied to the farmer. The financing can go as high as 50-60 percent of the input costs, depending on the contract and the situation farmers are in.
- *Technical assistance*: Most contracting companies provide technical assistance to the producers to ensure quality standards and supply. This technical assistance compromises all aspects of crop production, from irrigation assistance to fertilization and pest control strategies.
- *Price of the product and payment arrangements*: A guarantee price for the product and payment terms are established as well as how the financing will be covered by the farmer. The 'agreed' price is bound to crop quality standards and in some cases to delivery time. The farmer is then forced to sell his production exclusively to the firm with the given quality characteristics. If the product does not have the quality parameters agreed on, the production is not paid for but the producer can't sell it to other buyers either. In most contracts farmers take the risks the environmental conditions pose on production as prices are based on quality and quantity of the product.
- *Quality standards*: Standards of product quality are set by the company. These standards can include agreements on concentrations and use of fertilizers and pesticides as well as water quality. For the production of vegetables one of the quality standards is the exclusive use of groundwater for production.

A very important aspect for contract farmers and some contractors is mutual trust. Most contracts run for just one growing season. Some of the producers contract with the same enterprise for years based on mutual trust, while other producers play with the markets and different companies. In the words of a farmer "If you sell to people you don't know, you are up to their mercy… you have to have a known buyer that you trust and that is ethical". Companies work the same way and prefer to work with trustworthy producers. The situations that lead to a lack of trust on both sides are described below.

4.1.4.1 The dark side of the moon

In contract farming there are problems and risks for both parties but mainly for the producers. The risk companies have is that some producers do not stick to the contract and sell their product to the best bidder. On the other hand, firms are very tricky and usually play safe. Companies usually contract an overproduction. For example, if they need 1000 ha, they contract 1200 ha in order to secure their supply. If no problems arise with the production, the firm has an over supply of product. This over-supply gets solved by setting the quality standards very high and violating the norms they themselves have set. In these cases sometimes only 60% of the delivered product gets paid to the farmers. When there is a lack of product, these same quality standards are lowered so their supply needs are met. Most firms treat farmers according to their needs. Farmers are aware of this problem but can't do much; they either play at the mercy of the free-markets or play it safe at the mercy of the contracting companies. Some farmers feel that they become virtual 'laborers' of the contracting company without having the guarantees a worker has.

Box 4.3 Carl, an example of a small contractor

It is Sunday in the afternoon as I drive up the driveway of the small organic ranch of Carl, in the outskirts of San Miguel de Allende, Guanajuato. Carl preferred to speak with me during the weekend because during the week he was too busy. When I step out of the car two golden retrievers come to greet me. Soon hereafter Cristina comes and invites me inside of their little lodge where Carl is enjoying some sweet corn from his own ranch with another American friend.

Carl (originally American) is a contractor specialized in baby pickles for the export. He has been doing this for the past 15 years and has secure contracts with companies in the east of the US. If someone has an order he produces it but only if he is sure he will sell the product.

With the pickle program he has around 200 ha contracted per year with *ejidatarios*. Most of the farmers he contracts, he contracts for only one season while the farmers would like to be employed the whole year round. 90-95% of the farmers have a temporary contract; the others produce the whole year round for Carl.

"It takes years to train farmers especially on specialized crops as baby pickles and if it is a lousy farmer he will not make any money on them. So when we go develop new areas we do get a lot of new farmers but we stay with about 40%, the rest we just dump. In some areas where we are a long time we have secure providers and they produce year after year for us. We provide technical assistance, 50-60 percent financing depending on the farmer and the financing he needs, we buy the crop from the farmer we process it, we pay the farmer every week when he delivers, on preset contract prices. That is how we do it on all our crops."

"We have around 185 farmers with the pickle program most are *ejidatarios* with small pieces of land; some have less than a hectare and up to 4 hectares. It depends per region, in Valle de Santiago most farmers have a bigger piece of land and that is easier for us. We have a lot of people that get their living out of this business and the government likes it. During the harvest season we need about 14 workers a day per hectare. The harvest season is 35 days so we create about 3000-4000 jobs. It is labor intensive and gives them all a living".

The business is run with two people; Carl and his wife, Crisitna. She does all the logistics and transportation aspect Carl works in the field on the production. Carl and Cristina are responsible to deliver to the final destination in the US, where the product is evaluated and checked and if it is no good they lose. To avoid this, they track the trailers all the way. They get sealed in Mexico, at the border they are opened and then sealed again until it reaches destination. At the border they have a free file with their products which is a tremendous help in transportation time. Such a free file is build up through years of work.

Beside the pickle program, Carl also produces/contracts organic vegetables for export for Europe and the US. This is done mainly with *small property producers* that are trying to diversify their crops. "These farmers understand a little bit more this kind of work… they are quite intelligent and they understand organic farming You'd be amazed about the level of consciousness of these farmers with regards to their soil and water. Down in the Bajío they'd laugh at me. The small farmers of the *ejidos* are really 'just workers', they lack education. If money speaks they will do. With bigger farmers it is the same but they are much more aware of the benefits of organic farming" (Personal communication, Carl, august 2003). For the organic farming Carl is certified by an inspection team of Oregon in the US. Every year a new certificate has to be purchased.

Carl has a relatively small contracting enterprise, there are big companies in the Bajío that grow up to 7000 ha a year in different vegetables. "We make agreements with them on ethical levels. What they grow I don't grow and also the other way around". After a delicious organic sweet corn, and a walk through his 3 ha 'hobby organic farm' on which he lives, I take the car and drive home thinking that sometimes free markets do have advantages.

Among contract companies sometimes mutual agreements are established as to the limits each company will impose on itself to let the others operate. This does not always work but in a lot of cases such 'gentleman agreements' exist and work very well.

4.2 Crops and water

Crops 'speak' to farmers through their management requirements and above all financial benefits these produce. In Guanajuato the most common crops are alfalfa, vegetables and basic grains. Although alfalfa and vegetables are high water demanding, it is money (good prices and markets) that make them very popular. Crop water demand plays a minimal role in the choice of sown crops. Basic grains are produced above all by SSR. They either have no other option because of water access problems, because they are secure crops or because of traditions. For the O-I cycle there has been a great shift to barley triggered by *Impulsora Agrícola* in the last years. The elements that work on the rationale of farmers for cultivating a specific crop strongly influence *irrigation practices* which are determined by the different arenas that form the context in which the farmers operate.

Flores & Scott (2000) did studies on cultivated areas per crop in Guanajuato based on satellite image interpretation (See table 4.1). These studies show the areas cultivated with the most important crops and the estimated water used by each crop. This information is compared to the official reporting by the SDA. Although not congruent both data show that alfalfa, broccoli, other vegetables, wheat, barley, maize and sorghum are the most important and widely produced crops in Guanajuato. The following section analyses why these crops are so widely cultivated in Guanajuato.

Table 4.1 Estimation of water use volumes and cropped areas in Guanajuato in 98/99 (Flores & Scott, 2000)

Crop	Estimated irrigated area (ha)	Reported irrigated area (SDA) (ha)	Volume applied per ha (1000 m^3/ha)	Volume applied on estimated area (1000 m^3)	Percentage of the total estimated volume (%)	Applied volume on reported area (1000 m^3)	Percentage of total reported volume (%)
Wheat/Barley	103,883	81,900	13.5	1,402,420	38.2	1,105,650	51.7
Lentils	501	1,356	8.6	4,309	0.1	11,662	0.5
Beans	12,222	4,331	8.6	105,109	2.9	37,247	1.7
Alfalfa	96,841	45,665	14.8	1,433,247	39.0	675,842	31.6
Onions/Garlic	2,563	5,533	8.6	22,042	0.6	47,584	2.2
Broccoli	25,151	6,596	5.3	133,300	3.6	34,959	1.6
Peppers	4,598	631	8.6	39,543	1.1	5,427	0.3
Lettuce	490	955	8.6	4,214	0.1	8,213	0.4
Strawberry	5,857	1,664	14.8	86,684	2.4	24,627	1.2
Other veggies	48,492	20,760	8.6	417,031	11.4	178,536	8.4
Maize/Sorghum	2,806	1,025	8.6	24,132	0.6	8,815	0.4
Total	**303,404**	**170,416**		**3,672,031**	**100.0**	**2,138,562**	**100.0**

4.2.1 Alfalfa

For a lot of producers that have access to groundwater for irrigation alfalfa has several characteristics that make it an interesting crop.

- *Easy management*: Alfalfa is, as an INIFAP (Instituto Nacional de Investigación Forestal, Agrícola y Pecuario) researcher said, a 'crop for dummies'.
- *Resilient crop*: Alfalfa is a crop of the desert regions of the Middle East and can survive water stress conditions very well. For farmers this is very attractive because, if necessary, they can skip an irrigation turn.
- *Low input crop*: Alfalfa is a perennial crop which has to be reestablished once every three to four years, furthermore only fertilization is needed for increasing the yields.
- *Secure markets*: Alfalfa has a secure price and a secure market. Although not extremely high, alfalfa has a more or less stable price on the market and can always be sold. Most of

the produced alfalfa in Guanajuato is exported to 'dairy producing regions' of the country, especially Aguascalientes and the Estado de México.
- *Continuous production*: If well watered alfalfa grows almost continuously throughout the year yielding up to 8-10 *cortes* (cuttings). This means that farmers can guarantee a secure income almost every four to six weeks.

Alfalfa is, with present irrigation practices, a high water demanding crop. It is not rare for alfalfa to get 8-12 irrigation turns and irrigation depths of 1.48 m a year (Flores & Scott, 2000). According to Flores & Scott (2000) alfalfa consumes around 39% of all water used for agriculture (see table 4.1). The price of alfalfa has not risen the last years; inputs and inflation have increased so it has become less economically profitable. Nevertheless for a lot of farmers it keeps on being a good alternative and research of INIFAP shows that water productivity of alfalfa can be raised from the present 1,300 l/kg to 450-500 l/kg. At the moment there are several pilot farmers trying these alternatives.

4.2.2 Broccoli & other vegetables

In Guanajuato the most commonly cropped vegetables are broccoli (and other crops that belong to the brassic family), onions, peppers, potatoes, garlic, strawberries and asparagus (See Table 4.1) (INEGI, 2002). These crops with the exception of potatoes are cultivated to a great extent for the export market. The markets of these products have triggered a shift toward the production of vegetables (primarily by *commercial farmers*) which have the following characteristics:

- *High water demand*: Most vegetables require between 8-15 irrigation turns per cycle.
- *High management requirements*: Most vegetables are very prone to drying out or to root rot, therefore irrigation has to be very precise. Drip irrigation is for a lot a very good option. Furthermore pest control and fertilization require high application accuracy in order to get the desired outputs.
- *High input costs*: For the production of vegetables a lot of labor hours are needed. Fertilizers, pesticides, electricity costs for pumping and required technology are also very high when compared to other crops.
- *High risks*: Most vegetables are very susceptible to diseases and plagues as well as to frosts or hail. Markets can sometimes also be a risk factor.
- *Highly remunerative crops*: If well arranged with market prices and no crop losses occur vegetables are at the moment the most economically interesting crops.

4.2.3 Basic Grains: Wheat vs. barley in the O-I cycle

Wheat used to be the most important basic crop for the O-I cycle because it was heavily subsidized by the government. With the opening of the free markets the prices dropped; nevertheless it remained being an important crop until barley started to take over. Barley was always produced in Guanajuato but its proportion was insignificant until Impulsora Agrícola S.A. de C.V. and a couple of dry years established the conditions that have stimulated the production of barley especially in the DR 011 and the Bajío region of Guanajuato.

- *Water scarcity in the DR 011*: The years 1997-1998 were the first years in which severe water scarcity appeared in the DR 011. During these years measures where taken to make 'the best' use of the existing water. One of the strategies used was to switch from wheat to barley as barley needs only three irrigation turns while wheat requires four[13]. "… for the

[13] Under 'normal' conditions, in the DR 011 and 087 there are four irrigation turns during the O-I cycle and two during the P-V cycle. Nevertheless in water scarce year these are reduced to three turns for O-I and one establishment irrigation for the P-V cycle.

second consecutive year, the Módulos de Riego of the DR 011 and 085 in Guanajuato and 087 of Michoacán ; and for the fourth consecutive year for the DR 013 and 087 in Jalisco, crops such as wheat were not established during the O-I cycle because of a lack of water" (Monsalvo & Wester, 2003; 18).

- *Impulsora Agrícola S.A de C.V.*: Impulsora Agrícola is the supplying enterprise of all the beer industries in Mexico. This company started to contract barley production in the Bajío on a large scale in the abovementioned drought years, especially since the O-I cycle 98-99 (see table 4.2). At the moment Impulsora Agrícola has established a virtual monopoly over the commercialization of this grain.

These two circumstances have created and/or forced a strong shift from wheat to barley production (see table 4.2). Beside the fact that barley requires less water than wheat it also has a more secure and often higher price. Because of this reason a lot of groundwater users have shifted to barley.

Maize and sorghum are typically crops grown during the P-V cycle and are mostly grown under rain fed conditions. If farmers have access to water groundwater or surface water, the crop can be established a few weeks before the rains come, giving the crops more chance of survival and, in a lot of cases, a higher production. If the rains fail, farmers with irrigation can save their crops with an irrigation turn. The choice for maize or sorghum is mostly guided by markets.

Table 4.2 Production of wheat and barley in the DR 011 O-I cycle from 1997-2003 and for the state of Guanajuato (INEGI, '99,'00,'01,'02 and SRL, 2003)

Reported surface per crop in hectares					
	Reported by INEGI for Gto.		Sub-cycle Fall-Winter (O/I) DR 011		
Year	Wheat	Barley	Wheat	Barley	Total of all crops
1997-1998	69,700	9,328	-	-	-
1998-1999	99,002	21,984	35.947,3	11.204,1	64.905,8
1999-2000	64,589	21,703	11.105,4	6.302,2	19.465,4
2000-2001	41,782	21,355	265,0	510,9	951,0
2001-2002	………	……..	8.288,4	31.650,9	51.671,7
2002-2003	………	……..	6.571,4	40.609,6	54.736,7

4.3 Access to water

4.3.1 Access to groundwater 'the liquid gold of the Bajío'

In Guanajuato, there are several categories of wells, which are managed under different arrangements. The most important distinction is made between the privately owned tube wells and the 'official' wells. Privately owned wells are either managed by individuals or groups of farmers (Kloezen, 2002). Individually owned tube wells are in most cases reserved for *commercial farmers* which have the capital for making investments and enough land to make the private investments economically interesting. Management of these wells is totally controlled by the users themselves. The majority of the wells in Guanajuato are managed in this way.

Joint private wells are most common in regions where relatively small land holdings and a dispersed distribution of these does not allow for financially viable management of wells for individual farmers (Kloezen, 2002). The organization around these wells varies from place to place. The amount of users varies from 4-20 farmers who in most cases communally invest in the sinking and development of wells. In addition of sharing the costs of capital investment, group members also share operation and maintenance (O&M) costs. A wide set of arrangements exists. In some cases members pay a fixed fee per hectare and per irrigation delivery. In other cases members pay a rate per pumping hour (Kloezen, 2002).

The ‘official’ tube wells were managed by CNA until the early 1990's when they were transferred to the *Módulos* under the IMT program. The *Módulos* have, on their turn, decentralized several wells to the users who have become responsible for O&M and for collecting the irrigation fees. Farmers who make use of official wells pay an irrigation fee to the *Módulos* to cover the O&M costs. These fees are generally higher than the fee paid for canal water as O&M costs are considerably higher and delivery is more secure (Kloezen, 2002). The degree to which the official wells have been decentralized varies a lot among *Módulos*.

Among users there seems to be an increasing consciousness about the critical situation of groundwater resources. Nevertheless, this consciousness does not seem to induce adaptive behavior with regards to water use. Among the interviewed, when questioned about their production system, the extremely uncertain markets, low prices for the products and the high input costs, were the most pressing issues. Sustainable water exploitation is not the main concern of farmers that are trying to make a living. “What interests us as farmers is to: produce more, get more money for your produce and if possible use less water”.

For a lot of farmers the main concern about water are the increasing pumping costs (electricity pricing), the reduction of the discharge of their wells, the ever-increasing depth of the aquifers and the question as to how much longer the water supply will last. Although farmers are aware of the unsustainable exploitation levels little actions are undertaken to change the situation at farm level. Farmers don’t believe that their personal efforts will help reduce groundwater overexploitation (CPR behaviour).

4.3.2 Surface vs. groundwater in the DR 011

In the DR 011, 21,249 users irrigate a total of 112,670 ha; of these 76,709 ha are irrigated with surface water and 35,961 ha are irrigated with groundwater from 1,718 private and 174 ‘official’ deep tube wells (SRL, 2002). Although users are officially only entitled to one water source according to the law there are several means by which users can access both water sources.

Although surface water is allocated and concessioned to surface water users, all *Módulos* have legal means for groundwater concession holders to access surface water. The rules and regulations for acquisition of surface water for non-concession holders are established by the *Módulos*. For example the *Módulo of Salamanca* sells water to groundwater users whose pump has broken down or if, after all regular users have had their irrigation turn water is left over. This surface water is sold at a higher price to non-concession holders than to regular users. The *Módulo de Cortazar* sells water under the same conditions but at the same cost as to regular users. Although not officially recognized, a lot of users are able to close deals with the *canaleros* (ditch tenders) in order to access surface water, although they are not officially entitled to it. Most groundwater farmers buy surface water because of the following advantages: a) Discharge is larger so irrigation can take place faster and in a more efficient way. For some users this is very important in relation to sowing times and seed emergence; large holdings have a great advantage if the first irrigation turn is fast and over the whole surface area. With groundwater this is difficult to achieve because of discharge limitations. Furthermore as irrigation is paid for per hectare, in a lot of cases more surface water can be applied, which permits a wider spacing between irrigation turns. b) In general surface water is a lot cheaper than groundwater.

The disadvantages of surface water are that it is supply bound and non-concessioned water users have no security on access to water. Water quality and, in most *Módulos*, availability makes this water source only suited for the production of basic grains.

The advantages of groundwater are: a) Water can be used and bought on demand. This enables users to crop water demanding crops that have a higher value and have flexibility in the sowing times. b) High water quality sets no restrictions on crops quality standards established by markets. On the down side, groundwater is, in most cases, more expensive than surface water and because of discharge restrictions, it takes a lot of time to irrigate. In communally owned wells there are often restrictions on access to water imposed by the groups-size. Groundwater markets are not well developed and work mainly as agreements between neighbours. In most cases groundwater is only bought for “riegos de auxilio” (auxiliary irrigation turns).

In dry years surface water users are restricted by the irrigation turns the *módulos* offer. Groundwater users are less bound to yearly rainfall variations and enjoy a secure water supply for their crops. During drought years groundwater exploitation increases significantly because of higher water-crop requirements and, in the DR, because supplemental irrigation with surface water is not possible. In years with abundant rainwater deep wells can have long rest periods during which aquifers show some recuperation of static levels[14]. There is a direct link between surface water irrigation and the levels of aquifers. Groundwater farmers are aware of this fact; and a lot of them see restrictions on surface water allocation to the DR’s as a threat to their groundwater supply. Furthermore, if possible, they prefer to irrigate with surface water to let the aquifers recuperate.

4.4 Groundwater Irrigation practices

The way in which farmers use groundwater in their day to day irrigation practices can best be structured with the help of the conceptual framework (See chapter 2). In this framework I consider the use of water for irrigation purposes as a practice that is determined by :

4.4.1 Human Agency

Groundwater farmers take decisions on the use of water for irrigation guided by several internal and external factors that affect their production systems. Internal factors determining groundwater use are culture, personal ethics and social norms. These three elements determine how farmers deal with each other, their context and which choices are accepted as rational and or correct. Most farmers in Guanajuato have an internalized production oriented culture. This means that farmers see themselves as producers, not as aquifer managers. Under this rationale water is seen as an input for production just as fertilizers, labor or technological innovation, and its’ use is guided by the same rationale as the other inputs. Farmers, rationally choose crops that best meet their personal priorities that fit within their specific context (Interview Sandoval, COTAS Rio Laja, COTAS Celaya, SDA personnel, farmers). For example, farmers trying to maximize production farm the largest area possible with the well they have. Most farmers have their pumping equipment running around the clock (24hrs) whenever the crop requirements demand it. During the months of March-April-May and until the first rains arrive this is a normal practice and electricity bills of US$4,000-6,000 a month are not uncommon.

[14] Both farmers and canaleros confirm that during years of high surface water availability the static levels of the wells stabilize and rise, while in drought years the fall of static levels is significantly higher.

In the context of groundwater irrigation in Guanajuato the most important external factors that influence the practices of farmers are:

- Access to water: The source of water and how the internal rules for distribution and water payment are organized affect the decisions farmers make with regards to irrigation turns, and chosen crops.
- Electricity costs: Electricity costs for operating deep tubewells have increased the past years and now account for around 30-60% of the total input costs of crop production. Increasing electricity costs have triggered conservationist behavior with regards to water use (Scott *et al.*, 2003). Not only has it triggered more conservative water use; it has also stimulated farmers to invest in more efficient irrigation technology.
- Markets for crops: Markets for specific crops play a great role in the choices farmers make as to what to produce. These markets are determined by the local, regional, national and international demands. These markets influence each other at different levels and farmers operate with the different markets in heterogeneous ways, in a constant restructuring of market niches.
- Government programs: Government programs aimed at stimulating more efficient water use through technology implementation give an incentive to farmers to use other irrigation technology. This new technology brings with it specific characteristics that influence farmers practices (farmers with drip irrigation take very different decisions than farmers with furrow irrigation simply because of the technology they use).
- Lack of implementation of regulations on groundwater exploitation: The fact that water use is not controlled influences the way farmers make choices for specific crops and how they use their water.
- Social interactions: Farmers interact amongst each other but also with other sectors; these interactions affect the behaviour of farmers in different and complex ways which are hard to trace.

4.4.2 Strategies and resources

People devise plans to meet their objectives. When looking at the different strategies used, one has to understand them in the cultural context in which they take place; furthermore they can only be understood when coupled to human agency. In this analysis I describe some of the commonly used strategies of farmers for whom the main objective is to make a livelihood out of irrigated agriculture. Commonly used strategies and resources for increasing and maintaining agricultural production are:

- Irrigation technology: technology is used to extract water out of aquifers and to deliver it at field level. Because of increasing energy costs and often reduced discharges farmers are increasingly adopting more efficient water delivery systems such as low and high pressure irrigation systems. In this way they can use water more efficiently while reducing energy costs. The support of the SDA (See Chapter 5) often works as a good incentive to do so.
- Financial resources: Financial resources are used for acquisition of material resources such as technology and other inputs. Yet in other cases there resources are also used to “get things done” through bribes to inspectors and controllers. These are often strongly linked to social relations.
- Social relations: Farmers often establish relations with buyers (contractors or other), input suppliers, other farmers, and their remaining social networks which they use in different ways to meet their objectives. For some farmers political networks and good relations with high functionaries are very efficient strategies for getting things done.

- Social organization: Farmers organize themselves to achieve certain objectives. For surface water the Módulos are a very good example of farmers organization. Groundwater farmers have also started to organize themselves in a lobby that is trying to reduce energy prices.

4.4.3 Arenas or domains of interaction

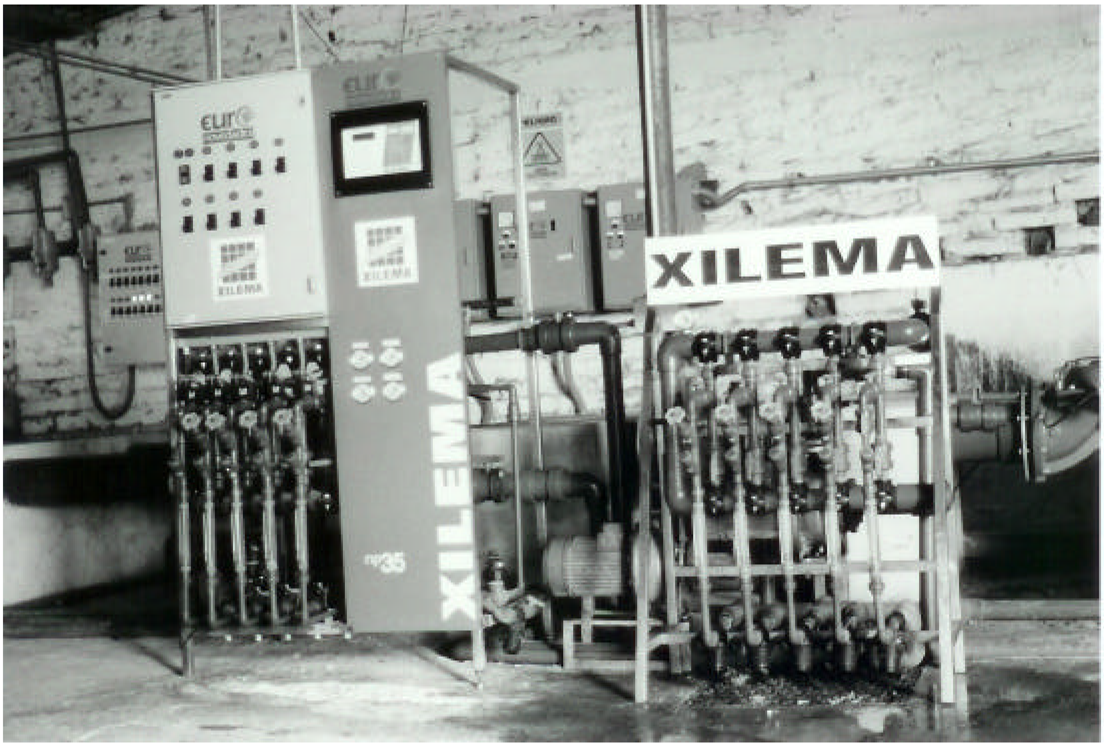
The arenas and domains of interaction for farmers are multiple and at different levels. The lowest level is at field level where farmers interact to give form to the production process through irrigation and other means. The next level is the arena where farmers negotiate and arrange how they interact with their immediate contacts which are other farmers and family, the suppliers of inputs, the buyer of the production, the inspectors of CNA and the *Comisión Federal de Electricidad* (Federal Electricity Commission, CFE), etc. The third and highest level of interaction is the level where farmers as a whole (group) interact with the different institutions, markets, laws and regulations, etc. These three levels or domains are interlinked and take place within a changing local, regional and international society. This society determines and affects how the domains of interaction work while at the same time it is formed by these interactions. Technology plays an important role in these interactions and how society operates. For example the rise of cellular telephony has affected how farmers interact and communicate amongst themselves and the rest of society which affects how markets operate, control is exercised, etc.

4.4.4 Rules and routines

It is very important to understand the rules and routines farmers and society have. This helps us understand irrigation practices. For instance it is important to know how the rules and routines around bribery and “mutual favours” work in the Mexican society. But, these rules and routines have to be studied also at regional and local level both in and outside of institutions. For instance the rules and routines of contract farming are not the same as free market rules and the social rules that prevail in Salvatierra are not the ones of Laguna Seca or Irapuato and, dealing with a CFE official is different from dealing with a CNA official. At the same time one can not take for granted that the same rules and routines operate in other places in Mexico or the world.

4.5 Conclusions

This chapter has analyzed agricultural production and *irrigation practices* in their context and through it some of the mechanisms that might help to reduce groundwater exploitation are identified. These identified mechanisms are energy pricing, market mechanisms and technological improvements through pressurized irrigation systems. In order to understand how these mechanisms operate and function it is necessary to understand what drives human agency, what strategies and resources are utilized in which arenas and domains of interaction and under which rules and routines. In the following chapter the government initiatives that have emerged in the last years to try to reduce groundwater extractions by the agricultural sector are analyzed in detail.



Chapter 5

Institutional responses to groundwater overexploitation

Everywhere in the world there are problems, everywhere in the world there has been chaos and disorder…... it is necessity; the presence of a problem that makes people change and adapt.

- Miguel Ángel Solis Montemayor

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The Guanajuato State Government has recognized the pressing need to reduce groundwater extractions in the state's aquifers. Since 1995 various measures have been implemented aimed at reducing groundwater use in the agricultural sector. The investments of the government are channeled mainly through two institutions: SDA (through the Sub-Secretaría del Riego) and CEAG. Through different programs these institutions have worked on; a) increasing water productivity and; b) increasing user participation in aquifer management. The federal government has also acknowledged the need to implement new mechanisms that stimulate and/or change agricultural users' behavior to use groundwater more efficiently. The measures implemented by the federal government are energy pricing and buying up of water use concessions. The different efforts that have been undertaken in the past ten years are described and analyzed in this chapter based on the analysis of irrigation practices made in Chapter 4.

5.1 The Secretaría de Desarrollo Agropecuario

The SDA, formerly Secretaría de Desarrollo Agropecuario y Rural (SDAyR), was created on the 14th of August, 1995 with the aim of 'promoting the sectorial development and strengthening the agricultural and livestock sector in the rural areas of the state of Guanajuato'. It's mission is to reactivate the productive activities of the rural areas of Guanajuato through stimulating a 'new' generation of agricultural producers, based on organization, the rational use of natural resources, new technologies and exploiting the possibilities global markets offer. The SDA assumes the responsibility of working for the conservation, rehabilitation and improvement of the exploitation systems for the use of communal natural resources. The producers are seen as main actors; therefore their demands receive a punctual and feasible response.

Most of the programs of SDA are based on the demands of the rural communities and operate in a proactive manner. The programs give producers access to financial support, be it in the form of financial or in kind subsidies. The programs tecnificación del riego (technification of irrigation systems) and nivelación de tierras (plot leveling), analyzed in this thesis, operate with the aim of inducing a more efficient use of natural resources. SDA has within its administration the Sub-secretaría del Riego (Sub-secretary of Irrigation). It is within this sub-secretary that all the irrigation programs operate[15] (see Table 5.1).

SDA works in two different schemes: A) together with the federal government (mainly SAGARPA and CNA) in a program structure that is called "Alianza Contigo", formerly "Alianza para el Campo" and; B) programs that operate under the State Norms of Guanajuato (http://www.guanajuato.gob.mx/, 06-10-2003).

Table 5.1 Investments and benefits of the programs operated by the Sub-Secretaría del Riego (SDA, 2003)

	Investments from 1996-2003 ($ Mexican Pesos)				Beneficiaries	
PROGRAM	Guanajuato gov.	Federal gov.	Users	Total	Users	Hectares
Modernization of gw irr. systems	249,436,301	197,210,344	371,303,357	817,950,003	28,112	140,435
Plot leveling	22,274,963	-	27,828,146	50,103,109	7,389	32,527
Modernization of Irr. Districts	84,652,034	111,075,803	31,207,553	226,935,391	10,019	40,076
Modernization of URDERALES	35,396,238	29,199,528	23,842,339	88,438,106	9,034	34,831
Efficient water and energy use	2,088,111	4,375,426	1,690,664	8,154,201	42	1,260
Total investments	**393,847,647**	**341,861,101**	**455,872,059**	**1,191,580,810**	**54,596**	**249,129**

15 For the ease of reading I will refer to the SDA in the below section while it is the Sub-secretary of Irrigation that operates the programs.

5.2 Rationale for technological programs

Locally-managed irrigation needs assistance in increasing water productivity (Wester, 2002). Based on the premise that resources are limited and that demographic growth and other factors increase competition and threaten the resource, Fussler & James (1996) see the only solution in more efficient ways of exploiting natural resources. Sustainable development requires radical improvements in product services; they must provide the same output with much lower levels of environmental impact. Nevertheless, one of the biggest threats to locally managed irrigation is the low profitability of agriculture and the high costs of agricultural production (Wester, 2002). Based on this rationale the SDA programs aim at increasing water productivity. For these results technicians try to maximize water use efficiency through technology. This approach has the advantage for designers that it provides a rational solution to the problem they are faced with (Diemer, 1998).

The conveyance and application of groundwater to the fields, after is has been pumped to the surface, has generally been through gravity flow in Guanajuato. The conveyance of water through earthen channels causes conveyance losses of up to 40% and reduces the overall efficiency of the irrigation systems to 33% (Magaña, 2001). By saving water through more efficient irrigation technology, energy consumption is reduced, decreasing input costs for farmers and the extraction levels in aquifers.

5.3 Technification of groundwater irrigation systems

The program *Tecnificación del Riego* started to operate in Guanajuato in 1996 under the name Ferti-irrigación (Fertigation), as a component of the federal programs “Alianza para el Campo”. Since then, the federal and state governments have set aside technical, economic and financial resources for operating this program (FAO-SAGARPA, 2002). The aim of the program as stated in its base documents is:

> “To increase the productivity in the agricultural and livestock sector under groundwater irrigation based on projects that include the rehabilitation of wells, pumping equipment and the installation of irrigation systems and fertigation that make water use and management more efficient while reducing the costs of energy and fertilizers and increase the crop production. At the same time these systems must decrease overexploitation levels of the aquifers” (Translation of the author[16]).

The aim is to motivate producers to improve their irrigation systems through financial support for installing better and more efficient irrigation technology on the parcels. It is estimated that at the end of 2001 the area with improved irrigation systems was 210,000 ha (FAO-SAGARPA, 2002), which accounts for 84% of the total groundwater irrigated area. It is claimed that the program of *Tecnificación de Riego* accounts for more than half of this area. Most of the improvements have been with low-pressure conveyance systems (*tubería de compuerta*) and an increasing number of sprinkler and drip irrigation systems.

The program operates with the participation of many different actors of the federal and state government and some organized groups of producers as well as with the providers of irrigation technology. The operation of the program that is in charge of SDA, is conducted within a Federal Agreement in which the SAGARPA plays a normative role and the *Fideicomiso de Riesgo Compartido* (FIRCO, Fund of shared risks) assumes the role of technical agent. The detailed scheme of operation of the program and how beneficiaries can apply and get support is given in Annex 4.

The program *Tecnificación del Riego* has operated in Guanajuato since 1996. The investments by the different partners and the producers as well as the benefited area and users

[16] (http://www.guanajuato.gob.mx/, 06-10-2003)

can be seen in table 5.1. Of the investments most resources were used for installing low pressure irrigation systems (*riego por compuertas*). Up until June 2003, 90% of the benefited area with these programs had low pressure systems installed, while sprinkler irrigation only accounted for 6% and drip irrigation 4% of the benefited area (Magaña, interview, 30-06-03). Nevertheless there is an increasing demand for drip and sprinkler irrigation systems among the producers (*idem*).

The claimed water savings of this program are 357 MCM/year, which is based on the premises that the installed irrigation systems raise the water application efficiency of the system and that there is no expansion of the irrigated area. For the calculations the figures shown in table 5.2 are used.

Table 5.2 Application efficiency of the different irrigation systems (SDA, 2003)

Irrigation system	Application Efficiency (%)
Earthen Channels	40%
Low Pressure Systems	60-65%
Sprinkler Irrigation	75-80%
Drip Irrigation	85-90%

Out of fieldwork, it seems that for procedures the 'strong' regulations established to get the support from SDA are a mayor drawback. A lot of *commercial farmers* have modernized their irrigation systems without the support of SDA as they claim that when the technical support is not needed, it is as expensive to do the investments without support as with. For drip irrigation it is a different story, as technical support for the installation and operation is always needed. Although the program claims a lot of water savings this is not reflected in the aquifer studies of CEAG and CNA. The water savings claimed by SDA can not be taken as hard facts but this program should not be evaluated on water savings but on the changes it produces in water use efficiency. The program is well structured and well functioning; it increases water productivity at field level for farmers and reduces the electrical energy input per irrigated hectare.

5.4 *Plot levelling*

The plot leveling program (*Nivelación de tierras*) started to operate in 1997. The program is funded solely by the State Government of Guanajuato and operated by SDA. The vision of the program is to: "Achieve that the producer learns and acquires the culture of leveling his parcel so that it becomes a common practice of soil preparation and that producers do these works on their own in the short term[17]" (Translation author, http://www.guanajuato.gob.mx/, 06-10-2003).

In Guanajuato there are at the moment more or less 40 companies that do the work of laser leveling. Of these around 40% are co-operatives of producers such as the *Módulos* and 60% are private enterprises. The prices of soil leveling are set by each enterprise and respond to free market competition. Producers can choose who will do the work and applies for support of SDA. SDA gives the support and monitors the execution of the work with own laser technology. If the work is well done and according to SDA standards the support is

[17] 'Through the uneven water distribution at field level within the irrigated agricultural sector, inefficient water use and a suboptimal use of resources at field level increases. The leveling of soils with laser technology creates the possibility to increase the water use-efficiency at field level through a better water distribution while at the same time it increases crop performance (http://www.guanajuato.gob.mx/, 06-10-2003).

liberated to the producer, in case this does not happen, the producer has to pay the whole sum on his own. This mechanism ensures that the farmers take responsibility over the work that is done on their parcel.

The program works on a similar basis as *Tecnificación del Riego*. Farmers have to pay the investment and come with the initiative. Once the farmer wants to level his parcels he can access subsidies to pay for the work. Leveling of a parcel costs between US$160-350/ha depending on the provider of the services and the amount of soil that has to be moved. The cost per cubic meter of soil lies between US$ 0.7-0.8.

Regardless of the price the leveling of the soil costs, SDA gives a subsidy of US$80/ha for work on parcels smaller than 20 ha. Parcels larger than 20 ha and up to 50 ha receive a support of US$40/ha and above 50 ha, the farmer has to pay the extra hectares without subsidy. The support for plot leveling is given for the initial work; once a parcel has been leveled the producers become responsible for giving it maintenance. Maintenance has to be given more or less every two to three years and at the moment costs around US$60/ha. To control which parcels have been benefited by the program SDA registers all the benefited parcels with a GPS system.

There exists great variation in the beneficiaries that use plot leveling as well as their motivation for doing so. Most of the beneficiaries are found in the Bajío region of Guanajuato because the soils present the conditions that make this technology very feasible.

The program of soil leveling with laser technology has operated for almost seven years, the investments, benefited hectares and users can be found on table 5.1. It is assumed that with leveled soil irrigation efficiency increases from 40% to 60% at field level, this permits water savings and a reduction in pumping hours for the groundwater users. Furthermore, because of better water distribution at field level there is a claimed 10% yield increase. With the work that has been done, a claimed 1,5 MCM/year is saved (Muñoz-Hernández, interview, 16-06-03).

5.5 Modernization of URDERALES

Guanajuato has a total of 284 small surface irrigation works (URDERALES) with a surface of 51,143 ha and a total storage capacity of 522 MCM (SDA, 2003). Most of these are the property of *ejidos*; the total number of users in Guanajuato is 17,500. Before the creation of CNA, URDERALES were the direct responsibility of SRH and most of them were left unattended. This promoted the emergence of self interest groups that impeded development. Since the creation of CNA most have been turned over to the users without any real support. The management structures in the *unidades* are diverse, and may consist of informal WUAs, government recognized WUAs, water judges, pump groups or commercial management (Silva-Ochoa, 2000). At the moment only 54 URDERALES in Guanajuato are organized in water user associations. Most of the UREDERALES in the state are old dams and old infrastructure. There is only one new dam in San Felipe Torrez Mochas which was built in 1992. The rest of the dams are older, many were built in the nineteenth century. Around 80% of the dams are in a state of semi-abandonment of the infrastructure (Méndez-Torres, interview, 04-07-03).

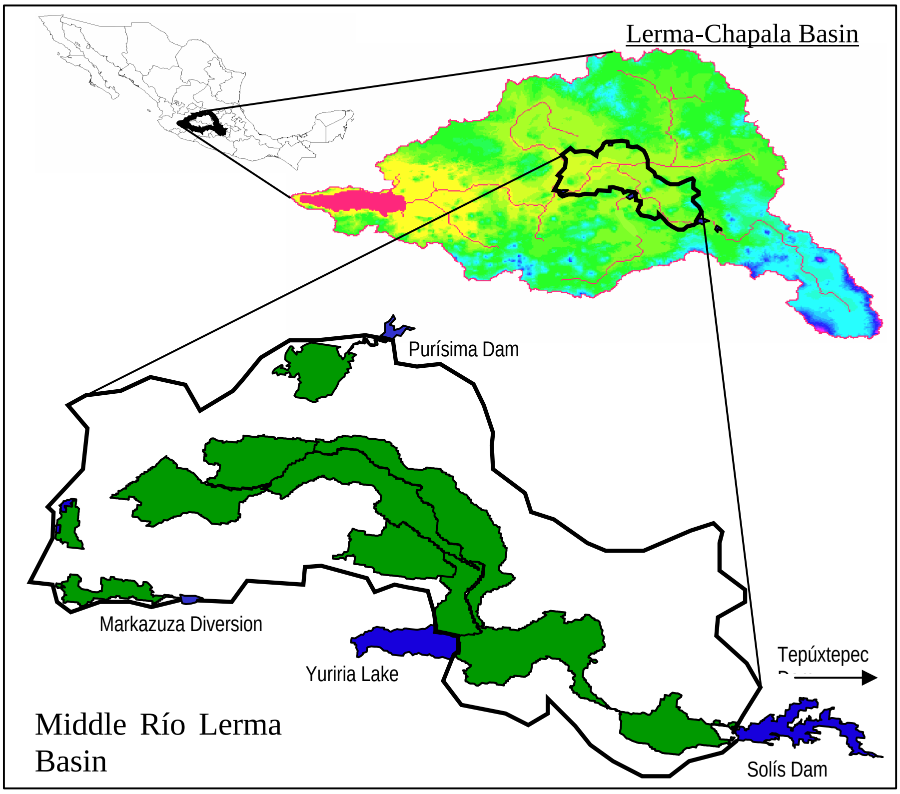
In 1997 SDA started the program Modernización de URDERALES (Modernization of URDERALES) which consists mainly of two components: a) organizing the users in WUA's and; b) improving the existing infrastructure (see Annex 5 for a full description of the program). The investments made and the achievements can be seen in Table 5.1. This program is well structured and successful in making water use and distribution in URDERALES more efficient. Since 1998, mainly in relation to the drying out of Lake Chapala, there have emerged some frictions between this program and CNA.

Since 1995 CNA has prohibited the construction of surface water storage facilities because all water in Guanajuato has already been concessioned. Furthermore the growing tensions that have surged as a consequence of the drying up of Lake Chapala have triggered an even more restrictive handling of surface water concessions. Because of the growing tensions around Chapala, it has become very difficult for SDA to get projects through.

5.6 Modernización de Distritos de Riego

The DR 011, Alto Rio Lerma, was created in March 1939 and was managed by the hydraulic bureaucracy until 1992 when IMT started in Mexico. In November 1992 the secondary channel system was transferred to the users and the eleven *Módulos de Riego* were created as water user associations responsible for the delivery and management of the irrigation systems (Kloezen, 2002). In December 1996 the user associations (*Módulos*) created an umbrella organization which got constituted as the Sociedad de Responsabilidad Limitada DR 011 (SRL de DR 011). In February 1997 the primary channel system was handled over to the users by transferring the responsibility to the already existing SRL (SRL, 2002).

Figure 5.1 Middle Río Lerma Basin with Alto Río Lerma Irrigation District (Scott & Garcés-Restrepo, 2001)



The DR 011 has a surface of 112,772 ha and 23,486 users. Of this surface, 76,709 ha is irrigated with surface water and is managed by 21,249 users. The remaining 35,961 ha are irrigated with groundwater from 1,718 deep wells of which 1,544 are privately owned and 174 fall under the responsibility of the *Módulos* (*pozos oficiales*) (SRL, 2002). In the DR 011 there are 11 *Módulos de Riego* in Guanajuato and one in Michoacán. The water that is used within the DR 011 comes from four dams (Solis, La Purisima, Yuriria and Tuxtepec). Within the DR 011 there are 475 km of primary channels and 1,183 km of secondary channels. 97%

of the conveyance infrastructure is built in earthen channels. The overall system has an operation efficiency of around 46% which can be attributed mainly to infiltration losses in the conveyance channels (SRL, 2002). To try to give response to the low operation efficiency the CNA and SDA have set up the Modernization of Irrigation Districts Program in the DR 011 (*Modernización de Distritos de Riego*).

This program is operated under the supervision of SDA and CNA. Its main aim is to stimulate and support the *Módulos de Riego* to improve their irrigation infrastructure. The ultimate goal is to reduce water 'losses' to enable two full crop cycles (PV-OI). In Guanajuato this program has operated mainly in the DR 011. The program has supported the SRL of the DR 011 and the *Módulos de Riego* in their investments aimed at improving conduction and water delivery systems.

The program is operated on a demand basis that is operated through the *Módulos de Riego* or the SRL and operate in the same scheme as the program of *Tecnificación del Riego* in which first a proposal has to be made. The proposals are scrutinized, sometimes amended and once they are approved by SDA-CNA, the funds are liberated and work starts.

Parts of the main channels have been modernized and improved by the SRL and a lot of work has been done in the *Módulos*. Up to the moment several secondary channels have been installed as low pressure systems in the tail-end *módulos.* At the moment work is being started in the *Módulo de Riego* Cortazar and Jaral del Progreso.

The program is financed by CNA (50% of the investments), SDA (25% of the investments) and the users (25%) through the *Módulos* or the SRL. The program has operated in its present structure since 1997. In the *módulos* the investments are paid exclusively by the benefited users through an increase in their irrigation fee. Decisions over the improvement and modernization within the *Módulos* are taken in the general assembly. The investments in this program from 1997 to the present account for a total of US$22,695,339 with 10,019 benefited users and 40,076 benefited hectares (See Table 5.1) (SDA, 2003).

5.7 Conflicts between CNA and the Módulos de Riego

Created water scarcity in the *Módulos* during the past years has been a politically contested issue. Because levels in Lake Chapala have been dropping, in November 1999 the first transfer of 240 MCM from the Solis dam to Lake Chapala was made by CNA. A second transfer of 180 MCM followed in November 2001, as lake levels continued to deteriorate (Wester *et al.*, 2003a). These water transfers met with staunch resistance from farmers who consider the transferred water as their irrigation water. Because of the water transfers to Chapala, farmers in the *Módulos* have had restrictions on their irrigation turns, on the area they can irrigate and even the crops they can grow. In 1997-1998, 1999-2000 and 2000-2001 for a lot of producers the O-I cycle did not exist (Monsalvo & Wester, 2003). This situation has triggered the loss of confidence of the users in CNA, which is reflected in the way the subsidies for the program *Modernización de DR* are handled by the *Módulos*. These have accepted support from CNA for their modernization projects under the strict condition that their water concession and allocated water is not reduced. Producers fear that CNA uses the water efficiency programs to get water out of the agricultural sector. The rational of the farmers is that if they save water, it is also they that will benefit from these savings. The *Módulos* as institutions see modernization programs as an opportunity to increase their revenues and/or reduce the irrigation fees. The *Módulos* only get paid for irrigated hectares and not for 'lost' water. If well managed, these measures can reduce the pressure on aquifers as 'excess' water can be sold to groundwater users and reduce their groundwater consumption. Nevertheless, according to Scott and Garcés-Restrepo (2001), rehabilitation and modernization programs aimed at saving water often neglect the influence of surface water management on groundwater levels. Their studies show that, in water-short basins, the sustainability of groundwater is intrinsically linked to the management of surface water, and is highly sensitive to the area and type of crops irrigated, as well as surface water management practices. Conventional initiatives to rehabilitate or modernize irrigation infrastructure may simply reduce a third party's water supply. In river basins where surface and groundwater resources are coupled—this is the case in most basins—'low efficiency', or 'leaky' surface irrigation systems play an important aquifer recharge function (Scott and Garcés-Restrepo, 2001).

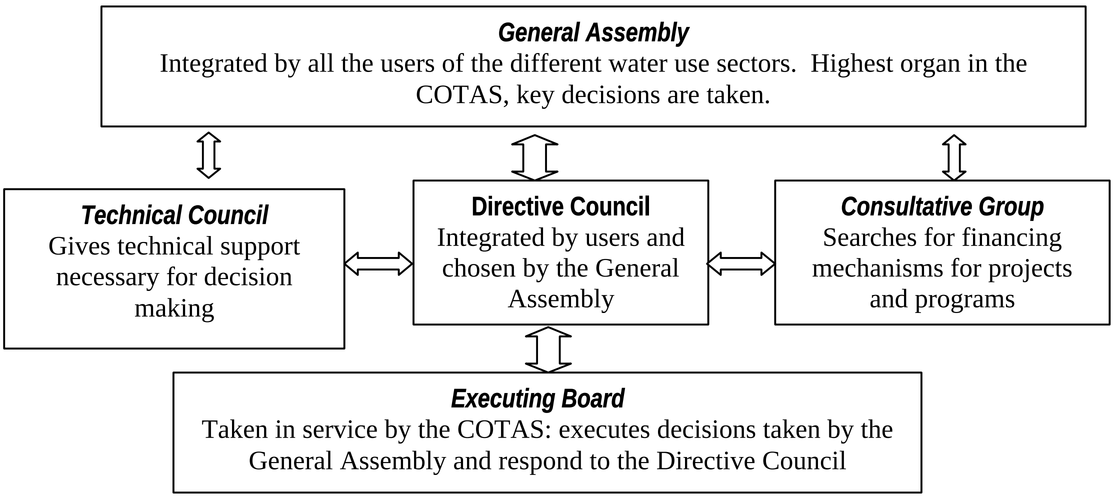
5.8 CEAG and COTAS

Since the creation of CNA in 1989 the federal government has encouraged the modification of the federal laws to promote the participation of state governments in water management through the creation of State Water Commissions, the response has generally not been enthusiastic. This is not the case in Guanajuato, where the CEAG has taken on its new role with vigor (Wester *et al.*, 2003).

In 1995 the Guanajuato State Government set the problem of water scarcity as a priority on its agenda. A large sum of resources was channeled to the SDA and CEAG. CEAG has since then become a 'new' institution for water management through financial and political support. In the last six years the state government has invested more than US$ 7,000,000 in CEAG (Sandoval, interview 05-09-03). CEAG has aimed its resources at two defined goals:

1) to get to know the situation and balance of water in the state so plans and projections could be made as was seen in Chapter 3, and
2) to start a great social program aimed at promoting "the water culture" ("La cultura del agua"). With this objective the *Comités Técnicos de Aguas Subterráneas* (Aquifer Management Councils, COTAS) were stimulated and subsidized as one of the largest projects of the CEAG (Sandoval, interview, 05-09-03).

Figure 5.2 Flow chart on internal functioning of the COTAS (CEAG, 2002)



Based on neo-institutional theories of self-regulation for CPR management (See Ostrom, 1990), at national level COTAS are defined as full-fledged user organizations whose membership consists of all the water users of an aquifer. They are to serve as mechanisms for reaching agreement on aquifer management by the various sectors using groundwater (Wester *et al.*, 2003). Through the establishment of COTAS, the CNA is seeking to stimulate the organized interaction of aquifer users with the aim to establish mutual agreements for controlling groundwater depletion (*idem*).

The first COTAS in Guanajuato were created in selected aquifers by CNA and SDAyR in 1995 as pilot projects. Since then CEAG enthusiastically promoted the creation of COTAS in the rest of the State by giving financial, logistical and human resource support to these institutions (Guerrero-Reynoso 2000; Wester *et al.*, 1999) which have become the most advanced COTAS at national level. At present in the State 14 COTAS and one *Comité Estatal Hidráulico* (Hydraulic State Comitee, CEH) have been established as independent civil associations that work with the different users and stakeholders (see figure 5.2).

Among the COTAS there are great differences in the focus and strategies used. These differences greatly affect the impact they have had. While some are just emerging out of the administrative consolidation phase, others are actively working with the users on mechanisms to reduce groundwater extractions. The differences among COTAS take form based on the members of the organizations. A central role in determining the functioning of the COTAS is taken by the Directive Council. For instance the COTAS Pénjamo-Abasolo has focused a lot on user participation because the directive council had that as priority, while Celaya focuses a lot more on studies, and two pilot projects (Barrera-Mejía, interview, 27-05-03).

Although CEAG is the institution that set up most of the COTAS, it has come to play an external role. It has become an external support organ that tries to guide and assist the COTAS in their functioning. It tries to stimulate and asses the directors of the COTAS while these function in their own manner (Ollivier, interview 20-06-03). Nevertheless, most of the technical and institutional support the COTAS get comes from CEAG, which is reflected in their focus and policies.

Most of the COTAS are still very young institutions with a small budget, little user's participation and low impacts on groundwater use. Furthermore the COTAS have focused mainly on the agricultural and domestic water supply sectors. The main function the COTAS have assumed is to represent users at CNA and other instances (CEAG, 2003p). Most COTAS have become intermediaries between SDA and the users for the programs of *Tecnificación del Riego* and *Nivelación de Tierras* (CEAG, 2003p2). Some efforts have been made by SDA and COTAS to concentrate the efforts of the programs in certain areas as pilot projects so results are visible (CEAG, 2003p2), nevertheless the overall impact remain minimal. The COTAS have become, for a lot of agricultural producers, a help desk that supports them by mediating with other institutions and not an organ in which solutions for reducing overexploitation of groundwater are searched for.

The lack of effectiveness of the COTAS to implement widespread aquifer management programs can be attributed to several factors which lie at three different levels: the users, the institution and the general context in which they operate (see Box 5.1). To get to the phase where all users agree on management and conservation of aquifers a lot of changes have to take place within and outside of the COTAS. The first obstacle COTAS have to overcome is the lack of trust and widespread participation of the agricultural users and the implementation of efficient control over groundwater consumption.

At the moment COTAS are financially dependent on grants from the state government through CEAG. The Executive Boards of all the COTAS are financed by CEAG who also pays the operation costs of offices and personnel[18]. For projects COTAS have to get grants from other sources (Ollivier, interview, 20-06-03). Until now most projects have been research projects and some small implementation projects but these are mostly done between two institutions; for instance between the municipalities and the COTAS. In these agreements

[18] This money all comes from a grant that expires at the end of 2004.

the COTAS mostly play a facilitating role. Other sources of income different COTAS have are:

- Grants and support from municipal governments
- Contribution fees of users (but this is only symbolic)
- Other external grants
- Contribution of the public urban water sector's operating organisms.

In general progress on the ground has been slow and the results on groundwater use and exploitation have been minimal. On the positive side, COTAS are gaining ground in the minds of the users. The awareness that aquifers are being over-exploited and that something has to be done slowly grows amongst users. The question that arises is: Is the development of COTAS fast and efficient enough?

COTAS are very enthusiastic about their own development and the results hereof. Most find the lack of financial resources, the lack of control mechanisms and the lack of widespread users' participation the greatest constraints. The existence and importance of the COTAS is recognized by governmental and non-governmental institutions but not by the users. As it is not a grass roots initiative a lot of producers don't see these institutions as instruments for self-governance in groundwater management and planning. Most COTAS have a participation of between 30-100 users, which represents 3-10% of the water users (Barrera-Mejía, interview, 19-05-03). The numbers are low but they can be the beginning of a widespread participatory process in the aquifers. If this sprout will fully germinate and grow to its potential or dry out is a difficult question to answer; it depends on the enthusiasm and trust of users and support institutions.

Box 5.1 Challenges the COTAS face in Guanajuato (Interviews & CEAG, 2001p)

1. *The users*: Most of the users in the state are agricultural users that depend on water for their income. This water-use sector is characterized by a lack of participation in the COTAS, which can be attributed to several factors:
   - lack of organizational culture
   - lack of consciousness with regards to the scarcity of water and the need for aquifer management mechanisms
   - lack of trust in institutions because of bad experiences in the past
   - fear of control over their water consumption
   - lack of trust in the other water users
   - most farmers are elderly people in which change is very difficult
   - for most farmers the most pressing issue is not water availability and overexploitation of aquifers but, markets for their products, high pumping costs and the costs of inputs
   - A lot of users don't want the risks of using less water
2. *The institution*: The institutions have several internal drawback which are mentioned below:
   - Little personnel and financial resources for the great territorial extensions they cover; most COTAS operate on the basis of three to four employed people, in areas with often more than 1000 deep wells used for agricultural production. "*One technician for 5000 square kilometers is not enough*".
   - Lack of legal power to implement control: COTAS work basically on the good will of the users as all the faculties to control groundwater extractions are controlled by the CNA.
   - Origin; a question arises with regards to the character of the institutions themselves. How can an institution, which should be based on the widespread participation and self-interest of the users, get support by the users if it is imposed from outside and not from a need the users themselves identify? Can the need for an institution be created by external mechanisms?
3. *The context*: The COTAS are very young institutions and as such they have had to gain the trust of other institutions as well as from the users. Furthermore, most agricultural producers are in a *race to the pump house*, characterized by CPR behavior. The lack of control and regulation by the CNA and the corruption within this institution bodes ill for the work the COTAS do.

At the end of 2004 the grant of CEAG, which created and maintains the COTAS in Guanajuato comes to an end and will set the first fire proof on COTAS. Will it be extended?

Most probably it will as CEAG has assessed the development of the COTAS as positive; stopping the support would, in a lot of the aquifers, destroy the work that has been started (Barrera-Mejía, interview, 19-05-03). Some voices within the CEAG call for strict guidelines regarding the functioning of the COTAS if the grant is extended[19]. An interesting question arises at this moment: Are the COTAS institutions of the users, or are they a government institution aimed at controlling the users?

Ostrom (1990) presents several examples of successful long-enduring, self-organized and self-governed CPR's and distinguishes eight design principles that characterize long-enduring irrigation institutions (Ostrom, 1992). These principles be applied to groundwater management organizations and are the following: 1) clearly defined boundaries; 2) proportional equivalence between benefits and costs; 3) collective choice arrangements; 4) monitoring; 5) graduated sanctions; 6) conflict resolution mechanisms; 7) minimal recognition of rights to organize; and 8) nested enterprises. COTAS are, at the moment, far from complying with all these different design principles and still a lot has to change within the institution. Some changes have to come from within and other from outside (see Chapter 6). If over-exploitation wants to be reduced strict implementation of rules and regulations on water use is needed. The existing COTAS can play an important role in this control, in which case the users become the control mechanisms of the exploitation of groundwater. Empowering users to co-manage and control the use of their groundwater resources, under strict control of CEAG or CNA, might lead to more participation of the users.

Now that the grant for COTAS expires at the end of 2004 a strategic decision has to be taken with regards to COTAS. They should either; a) be strengthened both financially and with responsibilities so they become serious aquifer management institutions with enough financial means and legal powers to apply control and sanctions, or; b) they should not be financed anymore and the resources should be invested in other water management efforts (see Chapter 6).

5.9 Buying of Water Title Concessions (Water Markets)

Market regulation is in Mexican history a relatively new concept for the state. Starting in 1982 the government initiated the adoption neo-liberal policies. The developments in the water sector have since then been guided little by little by these principles. This can especially be seen in the developments of surface water irrigation systems. For groundwater irrigation developments have been slower. Nevertheless water markets are operating since 1992 when the National Water Law established, in Article 64 that "The water rights derived from water concessions can be transmitted among users within a basin when it concerns surface water and within an aquifer when it concerns groundwater if these concessions are inscribed in the REPDA". Based on this right SAGARPA has proposed the Water Rights Acquisition Program (Programa de Adquisición de Derechos de Uso del Agua) which was published in the Official Diary of the Federation (DOF; Diario Oficial de la Federación) on the 12th of August, 2003.

The aim of the program is to promote the sustainability of the *Distritos de Riego* with water availability problems, whose priority is derived from recurring droughts and the loss of capacity of the supply sources, as determined by studies of CNA, through the acquisition of the water use concession titles (for the exploitation and use of water for agricultural, animal keeping or forestry activities) emitted by CNA. SAGARPA wants to promote the recuperation of water volumes that will benefit the aquifers and basins and support the

[19] As independent organisms the COTAS have done what interests them most and the CEAG has only been able to council them without setting out a clear path which some functionaries of the CEAG find frustrating.

producers in such a way that the sustainability of the water sources gets insured in the long term.

This program will operate at a national level and will start in several *Distritos de Riego*, where extreme water scarcity is identified. These DRs are: 005 Delicias, Chihuahua; 006 Palestina, Coahuila; **011 Alto Río Lerma, Guanajuato**; 025 Bajo Río Bravo, Tamaulipas; 026 Bajo Río San Juan, Tamaulipas; 031 Las Lajas, Nuevo León; 037 Altar-Pitiquito-Caborca, Sonora; 066 Santo Domingo, Baja California Sur; **085 La Begoña, Guanajuato**; 086 Río Soto la Marina, Tamaulipas y 090 Bajo Río Conchos, Chihuahua.

For the operation of this program the federal government, through SAGARPA, has set aside resources to buy groundwater concessions from users who want to sell their groundwater concession and in this way reduce the amount of water used. The price of the concessions is established by SDA and is set at US$250 for every thousand cubic meters of groundwater concessioned by CNA. For this program the CNA, SAGARPA and state governments have signed agreements.

Water markets for groundwater have been operating for a long time in Guanajuato where a lot of agricultural concessions have been sold to the industrial and urban water use sector. The lack of control over groundwater extractions has triggered a lot of irregularities. Concessions can be sold in parts; this mechanism has only worked as an extra legal mean for drilling new wells and operates in the following way: A concession is sold and a new well is drilled and starts to operate in full legal terms while the old well keeps on functioning. This same mechanism works when concessions are only partly sold. Both wells have a title and are legal. As there are no mechanisms to control extracted volumes both wells operate to their full potential and the amount of extracted water increases. These mechanisms will probably also be used if this program is implemented.

5.10 Energy pricing (SAGARPA-CFE)

Electrical energy supply and pricing are primary driving forces behind groundwater pumping for irrigation; policies to address groundwater overdraft must take energy-water linkages into consideration (Scott *et al.,* 2003). Groundwater extractions with deep water tables are entirely dependent on submersible or turbine pumps driven by electrical motors. As the agricultural sector does not have to pay water rights to CNA, the cost of water for farmers is directly linked to electricity and maintenance costs (Scott, *et al.*, 2003).

The Mexican Government through the CFE has implemented several mechanisms to try to control groundwater extractions and a more rational use of water through the electricity pricing. Paying according to use is assumed to increase the efficiency of resource use as. Groundwater that generates income by enabling irrigation, will no longer be extracted free of costs. The groundwater appropriation is subject to costs on the short term, so it is expected to prevent costs on the long term by avoiding a tragedy of the commons. Nevertheless, for most *commercial farmers* pumping costs still do not represent a major constraint for the economic viability of the production of high value vegetables (primarily broccoli, cauliflower, peppers, carrots, strawberries, etc.) and fodder (alfalfa) crops (Scott & Garcés-Restrepo, 2001).

The costs of energy for agricultural production (*tarifa 9*) in Mexico are highly subsidized and only cover 25% of the costs of supply (Scott, *et al.*, 2003). A recent attempt by the state to use this mechanism to control groundwater extractions is the effort to regularize groundwater extractions and energy consumption through a decree mandating that all unregistered agricultural wells will not be entitled to the subsidized electrical power tariff but will instead have to pay the regular tariff (deadline Oct. 2002). This measure has worked in that new electrical concessions are not extended to non-concession holders.

CFE has little control over resources once electricity is delivered; a lot of the water users have large debts with the CFE. A decree mandating that the users that are updated with their payments will receive a 5% discount on the energy price has been put into operation. This measure has stimulated users to get in line with their energy payments. In order to create a greater impact on groundwater extractions, there are two proposals that are being evaluated or at the brink of getting implemented, these are the following:

1. *Tarifa de riego de noche*: A proposal has been made by SAGARPA and CFE to implement a night irrigation tariff. This tariff would imply that *tarifa 09* would be halved during night hours for agricultural producers. This measure would stimulate farmers to irrigate at night which has several advantages:
   - Electrical power would be used by the agricultural sector during the low demand hours of the day, reducing the peak demand which is more profitable for the CFE.
   - Farmers' energy costs would be reduced by half
   - Irrigation at night usually implies fewer losses due to evaporation.
2. *Tarifa graduada de consumo de energia eléctrica*: Although only in the paper phase of implementation, this measure would imply a gradual energy cost increment. The idea is that, based on the water concession and the electro-mechanic efficiency of pumps a subsidized consumption rate gets calculated that corresponds in pumped-water terms to the water concession. If the energy consumption rises above this (permitted) level, the cost gradually increases to normal unsubsidized rates.

Although the two mentioned programs are not congruent and could not be implemented at the same time, the proposals are interesting. The first one is based mainly on the interests of CFE and a search for lower pumping costs for users. The second proposal is fully aimed at controlling groundwater exploitation through energy pricing. The second program is difficult to implement but would have the most far-reaching effects. If well implemented it could make smaller scale farming (based exclusively on the concession) and efficient water use more profitable. As mentioned above these programs are still in a paper phase.

Although earlier attempts to regularize groundwater extractions have had minor impacts, a scope for hope can be seen in energy pricing policies as adaptive conservationist behavior on the part of groundwater users is visible (Scott *et al.*, 2003). Scott & Garcés-Restrepo, (2001) foresee that continued groundwater mining will deplete the present aquifers to a point where all but the highest value crops cease to be profitable because of pumping costs. Given that the installed electricity generation capacity in Mexico will soon be surpassed by demand, unit energy costs will invariably increase.

5.11 Irrigation practices and programs

Farmers are guided in their actions by their context and external factors. One of the external factors that affect irrigation practices are interventions by the state. These shape the behaviour of farmers to a certain degree, but on the other side farmer's behaviour also affects how programs are implemented and what impacts these have. As seen in the forgoing chapter farmers see themselves primarily as producers and not as aquifer managers. Therefore, interventions have to be analyzed through the eyes of the farmers for whom the interventions are implemented. From this perspective, programs will be effective in reducing groundwater exploitation if they affect the production system. From this perspective the abovementioned programs are analyzed on their success and or failure.

- *Modernization of groundwater irrigation systems and plot leveling*

These programs have been effective in increasing water use efficiency at field level. In the evaluation of FAO-SAGARPA (2002) it is reported that there have been significant water savings and pumping hour reductions (superior to 30%) while the increase in irrigated area is minimal. The improvement of conveyance systems and more efficient water use is strengthened by field work. Whether less water is pumped out of the aquifers remains unclear because of the expansion of the irrigated area. The expansion of irrigated area is done above all by *commercial farmers* who have the possibilities.

Interviewed farmers see pressurized irrigation technology and plot leveling as essential for efficient crop production and most have some kind of system installed in at least some plots of their holding. All interviewed producers were very positive about the systems they had, and are planning to implement high pressure irrigation systems in the future. The most important drawback most farmers see are the high investment costs these irrigation systems have.

For *semi-subsistence farmers* the most interesting investments and in a lot of cases the only economically accessible ones are the low-pressure irrigation systems (riego por compuertas). It encompasses basically the conveyance of water from the pump to the furrows with PVC tubes. For basic grains and the absence of capital to invest this system is very adequate because all the aspects of the production system remain constant and thus a shift is easy to manage.

Commercial farmers started primarily with low-pressurized systems but a rapid shift toward high-pressure systems is observed. Drip irrigation is applied especially where vegetables are produced. Sprinkler irrigation systems are used primarily for alfalfa but not exclusively. In most cases a change to a high-pressurized system implies changes in management practices and large investments. For some *commercial farmers* these efficient irrigation systems have created the opportunity to reestablish irrigation on lands that, because of a reduction of well discharge, had fallen out of production. As a *regador*[20] mentioned: "Now that drip irrigation has been installed in the whole property, it has been possible to reestablish lands that had fallen out of production… The pumps are not stopped for a longer time now but the water is used more efficiently". For farmers, the most important rationale for installing more efficient irrigation technologies is that they reduce (electricity) input costs and in many cases increase production (especially drip irrigation).

- *Modernization of URDERALES and DR's*

These programs have been well accepted by the farmers and the *Módulos* as long as they do not affect their water concessions. Farmers are willing to invest and work for better and more efficient water delivery systems if they will be benefited by these investments. The problems between the Módulos and the CNA show that farmers are only willing to make investments if they will profit from them.

- *COTAS*

COTAS have had little impact on groundwater extractions and user participation is very low. This can be explained by the fact that farmers don't see what benefits they can get from participating in the COTAS. As long as there are no restrictions on groundwater use and farmers can keep on pumping there will be no motivation for them to participate. The fact that COTAS have become intermediaries between the farmers, the CNA and SDA clearly shows that farmers will only participate in such a project if there are visible benefits for them. The insights on CPR (See Chapter 2) clearly explain why farmers do not participate in the COTAS.

- *Buying of water title concessions*

This program will be effective in making some farmers rich but not in reducing groundwater exploitation. This program is established under premises of open water markets, but as the markets are imperfect because of a lack of control over new drillings of wells and extracted amounts of groundwater. A lot of wells have dried up while still holding a concession. If

[20] Irrigator: person that is in charge of irrigation of parcels of a farm.

these titles are bought, there will be no effect on groundwater extractions. A lot of wells operate without a concession and control is weak; buying a water title will not directly imply stopping a well.

- *Energy pricing*

Conservationist behavior on the part of groundwater users is visible. The fact that electricity costs have constantly increased because of ever increasing pumping depths have made farmers very aware of the expenses of electricity for water. High energy costs have become very important in shaping irrigation practices and in stimulating more efficient water use. As it is the single most important input affecting the price of water it promises to be a strong control mechanism.

5.12 Conclusions

The State Government of Guanajuato has invested a lot of resources in water since 1995 through CEAG and SDA. SDA operated mainly through five programs aimed at reaching a more efficient water use within the irrigation sector through the implementation of pressurized irrigation technology. In total around US$120 million have been invested by the SDA, CNA, SAGARPA and users for this purpose since 1996[21] which represents a governmental investment of around US$180 per irrigated hectare over a period of seven years (this would represent an investment of around US$25-30 a year per irrigated hectare). The results hereof are the improvement of irrigation systems that benefit 251,602 ha and 54,600 users. If compared to subsidies farmers get in the US and Europe these investments can be considered minimal and yet very effective in increasing water use efficiency.

If groundwater exploitation wants to be reduced in Guanajuato measures have to be designed that affect the production systems and thus move farmers towards conservationist behaviour by working on measures and interventions that affect human agency, and irrigation practices. Energy pricing coupled to more efficient irrigation technology or subsidies on certain low water consuming crops are interventions that directly affect farmers' rationale.

[21] See Figure 5.1 for a detailed decomposition of the different investments per program and per institution/users.

Chapter 6

Searching for solutions to groundwater over-exploitation

Based on Chapters 4 and 5, this final chapter deals with *water control* and *irrigation practices* and how these can be influenced by different policy, institutional and market changes. The aim of this chapter is to explore possibilities that the regulating institutions and government have to influence water use. This chapter builds on the preceding chapters and tries to set them together in plausible solutions for controlling over-exploitation of groundwater in the State of Guanajuato. In this chapter, three options are explored for reducing water use in the agricultural sector; institutional change, energy pricing and market mechanisms. Coupled to these some theoretical considerations are discussed.

6.1 The State and water control

Water control is a widely used term. As seen in Chapter 2, it is a useful tool when analyzing irrigation processes and phenomena. In the struggle for power over water exploitation, the state is supposed to be the organ with 'power' and capacity to control and manage water exploitation. The CNA is charged with defining water policy, granting water concessions on volumetric basis and wastewater discharge permits, establishing norms for water use and water quality and integrating regional and national water management plans. These faculties are clearly established in the LAN 1992 (Wester *et al.,* 2003). The legal faculties theoretically enable CNA to control water use and extractions. Nevertheless the state has failed to regulate groundwater use in spite of institutional and legal changes in the past 50 years.

Analysis of the state bureaucracy and why it has failed to regulate groundwater has given good insights in understanding the CNA as an institution and its failure in managing groundwater. Based on this analysis (presented in Chapter 2), in the following section a proposal is made to decentralize the CNA and through such an institutional reform arrive at a more efficient groundwater regulation in Guanajuato and eventually all of Mexico.

6.2 Decentralization of the CNA

The LAN, 1992, promotes decentralization, stakeholder participation, better control over water withdrawals and wastewater discharges, and full-cost pricing. Bundling extraction rights in an aquifer and concessioning this to decentralized institutions is feasible under the Mexican Water Law (Wester *et al.,* 2003).

Placing management in the hands of the users, under the supervision of the River Basin Council, State Water Commissions and the CNA is possible and has been implemented to a large extent in the management of surface water for irrigation through IMT (Kloezen, 2002). The results are promising. A similar approach to groundwater management shows more scope for controlling extractions than the current system of *vedas* and federal regulation (Wester *et al.,* 2003). There exist several possibilities for decentralizing CNA within the existing institutions. The option to decentralize the responsibilities of CNA to the State Water Commissions and other locally existing institutions is analyzed below.

At present the State Water Commission of Guanajuato seems to be a well structured and well functioning institution. It is charged with a lot of responsibilities but no faculties and/or rights to control, manage and/or plan water use; its role is primarily advisory (Wester *et al.,* 2003). It is legally possible and sensible to decentralize water control to the CEAG at state level. In contrast to CNA, which is mainly concerned with national water policy and an enormous bureaucratic institutional system which impedes its effectiveness in controlling groundwater exploitation, CEAG is a relatively small institution concerned only with water issues in Guanajuato. This 'smaller' institution is bound to the Guanajuato government and the people in the State. The work that has been done until now speaks well of the institution.

In Mexico, at river basin level, there exist River Basin Councils which after the implementation of the Water Law in 1992 require stakeholder participation in water management (Wester *et al.,* 2003). They are defined by the law as "coordinating and consensus-building bodies between the CNA, federal, state and municipal governments and water user representatives… The stated goal of the councils is to foster the integral management of water in their respective river basins through proposing and promoting programs to improve water management" (Wester *et al.,* 2003a; 802). The Lerma Chapala River Basin Council (LCRBC) to which Guanajuato belongs was the first council established.

Until the end of 1997 the Governing Board of the council was very top heavy and still decisions are made by the state governors and the CNA (*idem*). A challenge that remains is to ensure effective user participation, to which the water bureaucracy and some state governors resist through political games.

If water control would be decentralized from CNA, CNA would become a normative and controlling institution as stated in the law, while implementation would become the responsibility of the decentralized institutions, in this case the LCRBC and CEAG. In the following section, based on the theoretical framework of Ubels (1997) a couple of key changes that should take place in order to improve water management and control in Guanajuato and eventually Mexico are described. According to Ubels (1997), in order to analyze an institution and to make changes in these institutions it is necessary to look at eight aspects that affect the functioning of the institutions. These eight aspects are intrinsically linked to each other and a change in one has repercussions on the others. Here these are used to give form to the proposed decentralization (see figure 6.1).

Strategy: The strategy is to decentralize water management and control in a couple of steps in which the 'lower' organizations will become accountable to the institutions above them and in which user participation will play a central role.

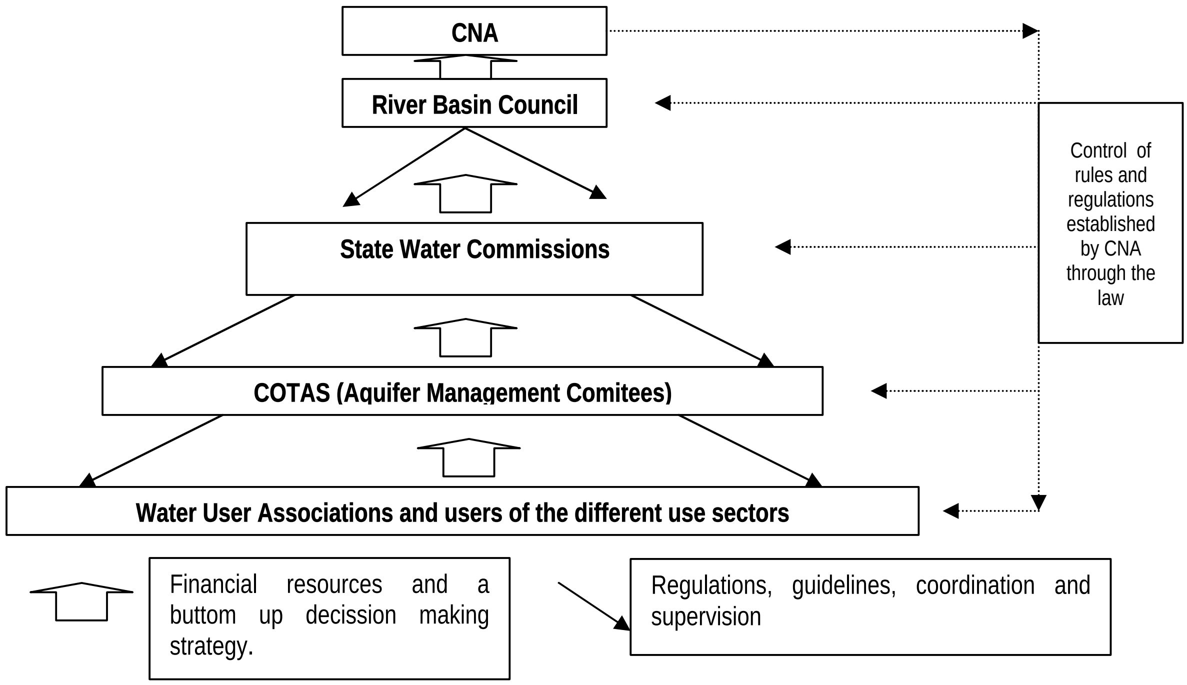
Structure: The structure of the water management institutions is to be decentralized. In such a structure the existing institutions remain in existence, but their responsibilities and roles will have to change.

- *CNA:* The role of CNA will change form a central bureaucracy that is responsible for water management at all levels in Mexico to a regulating and controlling institution at national level. The CNA is to establish rules and regulations as to how water is to be managed, controlled and concessioned (quantitative and qualitative issues). It will also control the river basin councils and Water State Commissions to ensure that these comply with the established rules and regulations. The CNA will be responsible for coordinating water management and control at national level. The CNA will be the organ to solve eventual interstatal water conflicts that can not be solved in the River Basin Councils. These changes are all feasible under the present law.
- *River Basin Councils (LCRBC)*: The LCRBC will coordinate water management at river basin level and will decide on water programs and proposals made by the State Water Commissions and other stakeholders as well as control the central budget to fund these programs. Within the LCRBC the concessions of water volumes to the states can be discussed and if necessary amended based on general consensus agreements of all the stakeholders represented in the council. The representation of the states in LCRBC should be done by the State Water Commissions and not the governors of the different states. Key decisions of water management at river basin level will be taken in this organ. The CNA again only controls this organ and sets the rules and regulations to which the councils have to comply.
- *State Water Commissions (CEAG):* The role of the State Water Commissions will change from a pure advisory role to a real management and implementation role. The State Water Commissions will become responsible for creating and implementing water management plans for the state that comply with the rules and regulations established by CNA. If these plans affect other states in the river basin they will have to be approved by the LCRBC. Coordination of COTAS and eventual conflict resolution within the state will become the responsibility of the State Water

Commissions[22]. These will control the functioning of the COTAS in accordance to CNA established rules. The State Water Commissions will concession a certain water volume both surface and groundwater to the COTAS based on consensus established between the different COTAS.

- *COTAS:* These institutions will, based on a multi-sectoral users' participation, come to agreements as to how the water concessions (both surface and groundwater) they have will be used and distributed between the different users. In these organisms compensation mechanisms and market working might be established depending on what users find the most feasible solutions. These organisms will become responsible (eventually together with the CFE[23]) for controlling the individual use of water resources in their administrative region. To make this possible COTAS must have the legal power to impose sanctions and penalties on infractors. These organisms will be controlled directly by the State Water Commissions and indirectly by the CNA.
- *WUA's:* WUA's will become members of the COTAS and as such they will as a group receive a certain concession of water which they internally have to manage as is the case at present in the DR's and some URDERALES.

Figure 6.1 Representation of decentralization of CNA responsibilities



Culture: By decentralizing the CNA to newly formed institutions which operate under a different culture based on multi-stakeholder participation and agreement reaching, and aimed at control and management instead of expansion and construction, the culture of the water management bodies will change.

Management: Decisions on rules, regulations and guidelines are established and controlled by the CNA at national level; by River Basin Councils at watershed level; by Water State Commissions at state level, and by COTAS at aquifer level by which the lower levels have to comply with the upper ones. Decision making at WUA's and COTAS level will be in the hands of the organized users. By stimulating self-governance and participation through the

22 At the moment CEAG already does this and has created the Consejo Estatal Hiráulico (State Hydraulic Council) for this purpose.

23 See following section on Energy Pricing

proposed changes it is expected that users will become more aware and interested in water management issues.

Systems: It is of utmost importance for such a strategy aimed at control over water use that the legal framework changes and that overuse of water resources becomes a serious legal infraction with high penal (financial) consequences. These need to be implemented and worked out in a fast and efficient manner at decentralized levels. The first step for groundwater control is the installation of flow meters on all pumps and strong infractions on the fraudulent use of these. Besides it is necessary that the law enables the decentralization of the CNA responsibilities to full fledged decentralized institutions.

Finances: At present water is for free in Mexico and this will stay. In this proposed change strategy, users will have to directly pay the institutions charged with water management for operation and maintenance of these institutions just as in the DR's[24]. The scheme established with IMT for the DR's and the *Módulos* can be used as example. The only difference is that fee collection will be the responsibility of the COTAS (where users decide how high the fees will be) and these will in turn pass resources to the Water State Commissions for their O&M costs and eventually these will again pass resources to the River Basin Councils and CNA (see figure 6.1). Beside fee collection, the different institutions at the different levels, will also receive funds from imposing sanctions. At the beginning most institutions will need initial investments by the federal and state governments to make these changes and strengthen the institutions; nevertheless once such a structure works these sources of funding can be retreated.

Technology and Facilities: In Guanajuato almost all COTAS and the CEAG have an office, personnel, vehicles and most also have software and measuring devices for controlling static levels of aquifers. At the moment these institutions are too small and should expand their personnel, instruments and facilities which are feasible in such an intervention. The basis to build on already exists.

Human Resources: Within the new institutions new people will need to be employed. Mexico has a lot of excellent professionals with expertise that can work in water management institutions without having an engineering background. With this change the culture of the organizations can become a control and management culture instead of an engineering culture which is mainly aimed at construction and expansion.

The above mentioned changes are all relatively small changes that operate within already existing structures and frameworks. The success of IMT shows that such structural changes on a large scale are possible; furthermore it has set the basis for the proposed intervention. This intervention entails basically the same as IMT but now not only with irrigation water but with all water and all users. In the presence of political will and the right context which seems to be formed by the CEAG in Guanajuato such a change could take place in a couple of years in which a lot of changes would have to be implemented at the same time. Guanajuato could become a 'pilot project' within Mexico.

6.3 Irrigation practices and interventions aimed at reducing groundwater use.

Beside state control several mechanisms can be effective in reducing groundwater use. These mechanisms directly affect the rationale of farmers and influence their behaviour. The different measures that have been implemented in the recent past in Guanajuato where studied in Chapter 5. Mechanisms are effective in changing farmers' behaviour if farmers change their behaviour by rational choices aimed at maintaining high production and enough

[24] At the moment users do not directly pay the water management institutions, these are financed by state expenditures.

incomes to make a living. Some of the analyzed measures have been effective and bode scope for the future. Here some alternatives that can be effective in changing the behaviour of farmers to use less groundwater are presented.

6.3.1 Energy Pricing

Energy pricing based on consumption has not been effective for inducing widespread rational groundwater use in the agricultural sector. "When compared to other countries or regions with water scarcity problems, the agricultural sector in Guanajuato is producing high water-consuming, low-economically productive crops. Something has to be changed: look at Israel or other regions in Mexico such as Culiacán; there agriculture is highly productive, market oriented and flexible (Usabiaga-Reynoso, interview, 08-03, Celaya)." One of the reasons that is attributed to this situation is the 'low price of water'. Although not the only factor, within free market thinking, one of the problems to solve this low-water productivity and overexploitation is to let water pricing work on the water use behaviour of the agricultural sector. The markets are to stimulate farmers to rationally use resources and thus induce efficient water use.

Of all the water users' agriculture is the only sector that does not have to pay for water. The only costs of groundwater are extraction costs which fall on electricity which is highly subsidized for agricultural use. Water for irrigation is almost for free, when compared to the other water use sectors. In this section the most feasible solution that exists for water pricing and the coupled control of groundwater extractions is analyzed.

- *Graded Energy pricing*

Graded energy pricing based on the groundwater concessions was discussed in Chapter 4 and seems to be a good mechanism that needs a narrow collaboration between the water management institution(s) and the CFE. If implemented, graded energy pricing needs great investments to start the process. If this instrument would be implemented in conjunction with the COTAS/CEAG/CNA and the installation of flow meters on all electricity run water pumps, it can become a very feasible project. CFE workers, that at the moment control electricity consumption by all users, could become the ones that control the flow meters on a regular basis. If both of these data are coupled (energy and water use) it is not hard to control the amounts of water pumped out of the aquifers through energy pricing and sanctions.

This control mechanism, if well structured, could be very effective because it works on the primary resource that is needed to have access to groundwater. Furthermore it can be very effective in controlling the amount of water extracted as pumping hours within the permitted range for every user can be charged very low at heavily subsidized rates; energy consumption beyond the permitted quota can be charged at real production prices established by CFE. This mechanism would stimulate the CFE to have control through energy prices on the farmer's consumption of groundwater.

Other forms of energy pricing are possible but this alternative is the one that can work the best in a pro-poor and pro-agricultural producer's manner by establishing low water prices as long as the water consumption is within the concessioned amounts.

6.3.2 Market Mechanisms and Subsidies

Markets have great influence on water use as seen in Chapter 4. If markets have good prices for high water consuming crops such as vegetables and alfalfa the producers will produce those high water consuming crops. If markets develop that have good prices for low water consuming crops, farmers will revert to these. A very clear example hereof is the change of wheat to barley in the past years. The prices of wheat dropped, and a market for barley developed and as such, farmers switched form a crop that needs four irrigation turns to a crop that only needs three irrigation turns. Such changes, stimulated by the markets of agricultural products, could develop for low water consuming crops such as canola or chick peas. These changes could be stimulated by the industry and free markets as is the case of Impulsora Agrícola S.A. de C.V. On the other hand such market mechanisms and changes could also be stimulated by the government and or farmers as was the case with the GTEPAI initiative (Paters, 2004). If governments are to invest in such market development strategies, they can do it alongside control over water extractions while giving farmers a good alternative to their current practices and crops. These could be coupled to subsidies that stimulate farmers to adopt specific production practices.

There is a lot of discussion on whether subsidies and or incentives should be used by governments within the agricultural sector. With the GATT a lot of subsidies were eliminated or cut back in Mexico so the 'free markets' could develop. Nevertheless subsidies still exist in the form of subsidized energy, subsidized technology and subsidies for special crops such as maize amongst others (See programs of Alianza para el Campo). The question that arises is whether these subsidies are the most desirable ones. It seems that most of the existing subsidies do not revolve around water. For example subsidizing agricultural electricity (*tarifa* 9 and 9a) is one way of, through subsidies, stimulating water use in the agricultural sector. A plausible solution could be to take the subsidies of the energy pricing and use these funds in other forms of subsidies aimed at reducing groundwater use in agriculture by increasing water productivity.

The government-resources (subsidies) that are used within the agricultural sector in closed basins, where annual consumption exceeds supply, should revolve around increasing water productivity and enhancing sustainable exploitation levels. In the world there are enough examples of what can be done with subsidies: If in Europe and the US farmers can live on subsidies aimed at leaving land barren and unproductive, one can imagine that in water short basins farmers could be subsidized not to irrigate in the winter season. There are several options for using subsidies for reducing groundwater use and for increasing water productivity within the agricultural sector in a pro-poor equitable manner. The political will to do this has to arise and politicians have to acknowledge the great water problem that exists in the Lerma-Chapala Basin.

6.4 Conjunctive water management in the Cuenca Lerma Chapala

Integrated River Basin Management (IRBM) is a relative new concept in the 'water world'. The Lerma Chapala Basin is the first basin in Mexico to operate under a River Basin Council (Wester *et al.*, 2003). Although set up to solve the problems of water management and allocation in the River Basin, the effect it has had on groundwater use can be considered minimal (Wester *et al.*, 2003). Politics and power relations still play very important roles in decisions made over water allocation and distribution in the Basin. This hampers negotiations aimed at optimal and 'fair' solutions to solve the water problem.

Besides, it is imperative that groundwater management gets included in the management discussions of the River Basin Council; conjunctive water management has to replace the present discussions on surface water. At present, there is a lack of interest and political will to work on sustainable groundwater management projects and strategies and most discussions revolve around surface water. Nevertheless groundwater is presumably one of the causes of surface water scarcity in the base flow of rivers and Lake Chapala (Sandoval, Ortega-Guerrero, personal communication).

As seen in Chapter 2, the management of water resources in Mexico is characterized by a strict division of surface and groundwater management. Integrated water resource management (IWRM) at River Basin level has been recognized as a key issue for achieving 'effective water governance' (Orange, v. 2002). Although it poses several challenges and a change in the views on water management that have dominated the development of water resources in Mexico the past century, it is the only way in which long lasting sustainable solutions for water management in the Lerma Chapala Basin can be found.

In 1988, O'Mara recognized the importance of conjunctive water management in the irrigation sector stating that "the issue of efficient conjunctive (water) use is important to the welfare of a majority of the population of the developing world" (p. 15). Scott & Garcés-Restrepo (2001) show the effects surface water irrigation has on aquifers in the DR 011 and urge for more research in conjunctive water management in river basins. Unfortunately little has been done with this scientific evidence. Time and a dwindling high quality water supply might force management and allocation changes in the Lerma Chapala Basin. As groundwater becomes scarcer great pressure is set on agriculture to reallocate high quality groundwater to the domestic, industrial and services sectors. Water transfers and compensation mechanisms will have to be installed to solve the water problems (Wester, 2002).

At present discussions exist about transferring surface water to other uses. Groundwater is readily available if aquifers are stabilized by reducing exploitation. As the agricultural sector is the largest consumer of this source it is also this sector that has to reduce its use the most the coming years. To maintain the highest cropped area possible, more investments are needed for increasing water productivity of groundwater irrigators and in the URDERALES and DR's.

Further research is needed to establish the link that exists between surface and groundwater to set a basis to design technical and social engineering plans that stimulate optimal use of water resources in the Lerma Chapala River Basin in which the environment and the great majority of society optimally benefits from the resources used.

6.5 Wrapping up

Now that I am almost closing this chapter and this thesis I want to come back to the research question that gave form to this thesis to give an answer to it in a couple of paragraphs:

In the groundwater socio-ecology of Guanajuato, which mechanisms and relations determining groundwater irrigation practices and water control are crucial for designing measures aimed at reducing overexploitation of groundwater?

The answer to this question can be found in the study of irrigation practices and of institutional practices. In order to understand which mechanisms are crucial for designing measures aimed at reducing groundwater overexploitation one has to understand what drives the choices of farmers (irrigators) and how these relate to the institutions that implement the different measures. To understand how these institutions relate to the farmers it is crucial to understand how these institutions and its staff operate; what guides their practices and behaviour?

Besides it is crucial to acknowledge that groundwater over-exploitation is an issue of groundwater control. Groundwater control lies at the moment in the hands of the farmers. Their strategies and resources enable them to use groundwater unrestrictedly. This can be attributed to a couple of causes a) energy prices are too low to induce significant reductions on water use practices and, the state has not used this instrument for controlling water use; b) control over extraction/consumption, as established by the law, is not implemented; and c) groundwater sustains thousands of livelihoods and these possess great political power. One measure that could be successful in reducing groundwater exploitation and that affects the institutional practices is:

- *Decentralization of faculties and responsibilities over groundwater management.*

The fact that farmers see themselves as producers and not as aquifer managers implies that they will use their strategies and resources to maximize their production. If this implies using groundwater without restrictions they will do so. This fact brings us to the conclusion that measures aimed at reducing groundwater extractions have to directly or indirectly affect the production rationale of the farmers. Some measures that might be successful at it are:

- *Graded energy pricing.*

Consumption based energy pricing is already used in Mexico but has a minimal impact on farmers irrigation practices. The implementation of a fare based on the energy needed to extract concessioned amounts of groundwater can be a successful mechanism for controlling excessive groundwater extractions.

- *Subsidies:*

Although subsidies are ‘doomed’ by neo-liberal thinking, they offer a great opportunity to direct irrigation practices and production patterns in order to reduce groundwater extraction. The possibilities are numerous; the important thing is that they should revolve around water use and consumption. The subsidies given in the programs of technification of groundwater irrigation systems and soil leveling are good examples of the use of subsidies for reducing groundwater use.

- *Market mechanisms*

Market mechanisms offer another opportunity to reduce water use in the agricultural sector if they create markets for low water consuming crops. In such market mechanisms the government should play an important role. This could be coupled to subsidies.

Beside more investments in the water use sector there has to come a shift in the way water policies operate. Groundwater and surface water have to be integrated. Intra-annual variations in runoff may alleviate or exacerbate water availability in the short-term; however, the medium and long-term effects are clearly significant only for the aquifers. In other words, a condition of low surface water supply can be overcome in just one year of high rainfall and runoff, whereas the accumulated deficit of years of aquifer overexploitation will similarly take years to reverse (Scott & Garcés-Restrepo, 2001). Only through conjunctive water management strategies that slowly reduce groundwater extractions while increasing the productivity of surface water will it be possible to sustain the societies that have developed in Guanajuato and the Lerma Chapala Basin.

6.6 Theoretical implications

This thesis shows how important it is to understand irrigated agriculture as more than just water, it refers to the overall transformation process of growing crops and studying livelihoods that depend on them. It entails the management of information, people and the necessary production inputs. Thus, irrigation has to be studied as an element aimed at agricultural production and, to understand irrigation one has to understand the context in which it takes place. The theoretical approach developed by Mollinga (1997, 1998) on irrigation practices is a very useful tool for analyzing irrigation within the wider framework of agricultural production.

When applied to designing and understanding institutional responses aimed at reducing groundwater exploitation irrigation practices need to be understood. Irrigation practices determine if certain interventions and measures will be effective or not. Nevertheless, when analyzing responses we can not limit ourselves to the study of irrigation practices and have to broaden our analysis to the institutions that implement the measures. Thus institutions can not be treated as a black box.

In the analysis of interventions, *institutional practices* have to studied. The institutions and staff involved in creating and recreating the institutions and the implemented measures need to be included as an object of study in the analysis of groundwater dependent socio-ecologies. In such a study it is important to understand the staff and its practices (what motivates the staff to do its work the way it does?), the culture of the institution, its relation to society, its history, its strategies and resources, its setting and relations to other institutions (in which network does it operate and at what level) and the broader arenas and domains of interaction within their context.

Such an analysis has to focus on the actors within the institution and their mutual relations within the institution. It is through the conglomeration of all the different actors and their behaviour and motivations that an institution is created. As such one has to understand what influences the different actors and how they relate to each other.

The framework established by Mollinga gives us, just as with irrigation practices, a good framework for understanding *institutional practices*. In such a framework *human agency*, *strategies and resources*, *domains and arenas of interaction*, and *rules and regulations*, need to be studied for understanding an institution and its staff. In such an analysis the state can not be taken as outside of society but as part of the greater web that creates and recreates society. As such the dichotomy of the state and civil society is reduced. This gives a better understanding of how these two elements are interlinked and interact with each other in different ways. They create and recreate each other in a continuous reciprocal interaction. In this thesis the CNA and its *institutional practices* where analyzed. This analysis was essential to understand why it has failed to regulate groundwater control and clearly shows why *institutional practices* have to be studied in their context.

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Pictures

Cover and Chapter one: Workers planting onions in a groundwater irrigated field, in the Módulo de Riego de Salamanca. May, 2003, Guanajuato.

Chapter 2: A tube well drilling machine with in the background a broccoli field of a commercial farmer in Laguna Seca. June, 2003, Guanajuato.

Chapter 3: Privately owned modern tube well of a commerical farmer in Valle de Santiago. June, 2003, Guanajuato.

Chapter 4: Pozo oficial No. 18, Módulo de Riego Salamanca. May, 2003, Guanajuato.

Chapter 5: Modern fertigation system control panel in the ranch “El Fuerte”, Salamanca. August, 2003. Guanajuato.

Chapter 6: Flow meter on a private well. August, 2003, Guanajuato.

Annex 1: Operationalization of the research themes in sub-questions

For the operationalization of the research question, the sub-questions where clustered in three themes: hydrology, implemented technical and social programs aimed at reducing groundwater exploitation and finally *irrigation practices*. For each of these themes a set of sub-questions where made to operationalize the different research themes that where chosen, these are presented below.

Hydrology

- *How have groundwater extractions evolved since 1995 in the aquifers of Guanajuato?*
- *What are sustainable extraction levels i.e. what is the annual recharge?*
- *What methodologies are used for the different studies?*

Analysis of the different programs aimed at reducing groundwater extractions

For the different programs (fertirrigación [*fertigation*], uso eficiente de energía eléctrica en operación de pozos [*efficient water and energy use in the operation of wells*], tecnificación del riego en DR [*technification of irrigation in DR*] and nivelación de tierras [*plot leveling*]) the following questions were established to analyze their achievements.

- *achievements in ha (fertirrigación and nivelación de tierras, tecnificación del riego and others) or numbers (uso eficiente de energía eléctrica en operación de pozos)*
- *increased efficiency claimed by different programs (potential water savings)*
- *claimed savings by the different programs*
- *what effects did these programs have on agriculture (see irrigation practices below)?*
- *how is financing and implementation of the different programs organized in Guanajuato?*
- *scope (goals) of these plans for the future*
- *how are savings and increased efficiency measured and quantified by evaluators of the different programs?*
- *what are the main strengths and weaknesses of the different programs?*

Within the analysis of state programs for reducing groundwater exploitation and reaching sustainable management, attention was given to the COTAS (Comités Técnicos de Aguas) in Guanajuato.

- *what have COTAS achieved in Guanajuato since their creation?*
- *how are COTAS organized in Guanajuato in the present?*
- *what are the strengths and weaknesses of the COTAS?*
- *what is their scope for the future?*

Irrigation practices

- *What factors determine (ground) water control in Guanajuato?*
- *Can a rough classification of different irrigation practices be made?*
- *What are the most important human agency factors that determine irrigation practices and how have they responded to state programs for reducing groundwater exploitation?*
- *What are the most important strategies and resources that determine irrigation practices and how have they changed since 1995?*
- *What are the areas or domains of interaction that determine irrigation practices?*
- *What are the rules and routines the determine irrigation practices*?

Annex 2: Detailed list of interviews and activities done during field research in Mexico

This annex is a detailed list of the interviewed people during the fieldwork in Mexico during the period of May to September 200. The interviewed people and events in which I participated are listed below.

- *Semi-structured interviews and informal interviews*

During my stay in Mexico I interviewed 27 farmers of which 11 *ejidatarios*, 13 small property farmers, one *ejidatario* whose well had dried up, and two contract farmers (agro-business) that had access to international markets. Other interviewed institutions and persons are:

- CEAG: Ricardo Sandoval Minero (executive director of the institution) gave us an extensive interview (09-05-03) and opened the doors into the institution. I interviewed several functionaries of the different departments of the institution which contributed important information for this research. Most interviews were in Guanajuato, Guanajuato.
    Isabelle Ollivier, chief of the department of social water management (20-06-03).
    Jose Luis Cruz, director of the area of aquifer studies (19-05-03).
    Jorge Montoya Suarez, general director of the section of social participation (19-05-03).
    Julietta Barrera Mejía, director of stimulation of social participation (20-06-03).
    Vicente Guerrero, ex-executive director of the CEAG, (27-05-03), León, Gto.
- CEH (Consejo Estatal Hidráulico): Ing. Aurelio Navarrete Ramirez (16-05-03), gerente CEH, Irapuato, Guanajuato.
- CNA, state office (gerencia estatal), Celaya, Guanajuato:
    Ing. Francisco Pena de la Vega staff of the groundwater section (29-05-03).
    Ing. Jose Antonio Jaramillo, staff of the program full use of hidroagricultural infrastructure (04-07-2003).
    José Luis Resende, module of transparency (04-07-03).
- COTAS Laja-San Felipe: Alfredo Mancilla Montalvo (26-06-03), responsible for the technical area of the COTAS Laja-San Felipe, San Miguel de Allende, Guanajuato.
- COTAS Celaya: Ing. Francisco Cueva Martinez (04-07-2003), gerente (main responsible) COTAS Celaya, Celaya, Guanajuato.
- FAO-SAGARPA evaluation program, Mexico City: Jonathan Martinez (13-06-03)
- IMTA: Sergio Vargas and Erik Mollard (30-04-03) and when visiting also spoke to other researchers; Jiutepec, Morelos.
- INIFAP: Researcher Ing. Ramón Aguilar (13-05-03), Centro de Investigación del Noreste de Guanajuato (Research Center of the Northeast of Guanajuato), San Luis de la Paz, Guanajuato.
- IWMI Researcher Paula Silva Ochoa, (21-05-03), Guadalajara, Jalisco.
- *Módulos de Riego* of the DR 011:
    Ing. Rubén Vázques Martinez, president of the *Módulo* Cortazar (18-08-2003), Cortazar.
    Different staff members of the *Módulo* Salamanca (12-08-03), Salamanca.
    Different staff members of the *Módulo* Valle de Santiago (18-08-03), Valle de Santiago.
    Different staff members of the *Módulo* Salvatierra (24-08-03), Salvatierra.
    Different staff members of the *Módulo* Jaral del Progreso (24-08-03), Jaral del Progreso.
- SAGARPA in Mexico City: Gabriela Monsalvo present director of the program Manejo Integral de Suelos y Aguas (Integral Management of Water and Soils) and Jonathan Martinez ex-director of the MISA program, one of the main brains behind the programs of Alianza para el Campo and FAO-SAGARPA evaluator .
- SDA/Sub-secretaría del Riego (Sub-secretary of Irrigation): Ing. Miguel Ángel Solis Montemayor, director of the sub-secretary, after an interview (11-06-03) opened the door for us at the SDA. I interviewed the program directors of the different programs aimed at increasing water use efficiency in the irrigation sector in the State of Guanajuato as well as some of the field staff, interviews in Celaya, Guanajuato.
    Ing. Buenaventura Calderón Moreno, coordinator rehabilitation and modernization of DR, (16-06-03).
    Ing. Bernardo Muñoz Hernandez, coordinator plot leveling program (16-06-03).

Ing. Gustavo Magaña, coordinator of the fertigation program (30-06-03).
Ing. Luis Fernando Mendez Torres, coordinator of the program modernization of URDERALES, (04-07-03).

- SRL of the DR 011: Ing. Raymundo Rocha gerente SRL, and Ing. Alfredo Marmolejo Cervantes, chief of operation (jefe de operación) DR 011, (10-06-03), Salamanca, Guanajuato.
- UNAM: Marcos Adrian Ortega, researcher in the area of geo-hydrology in Querétaro, Querétaro, (03-07-03) San Miguel de Allende, Guanajuato.
- Owner and an operator of a well installation company* (02-06-03), Los Rodriguez, Guanajuato.
- Active members of the Comité Pro-Mejora del Agro Mexicano* (18-08-03), Salamanca, Guanajuato.
- Ex-member of the CCLCH, Raul Medina de Wit, (20-05-2003) La Barca, Jalisco.

- *(Participatory) observation*

  During my fieldwork period in Mexico I also assisted to the following events/meeting:
  - Meeting of the CCLCH in Celaya, Guanajuato (04-06-03)
  - Meeting of student researchers in the Lerma-Chapala Basin, organized by Supervisors of IMTA & IRD, 24&25th of June 2003, Valle de Santiago, Guanajuato.
  - XII Congreso Nacional de Irrigación, (XII National Congress on Irrigation), *Hacia la Sustentabilidad de la agricultura de riego, (Towards sustainability in the irrigated agriculture)* Zacatecas, Mexico (13-15 august 2003).
  - Takeover of the Gerencia Estatal (state office) of the CNA by the farmers of the DR 011 and 085 (19-08-03) Celaya, Guanajuato.
  - Extraordinary meeting of the Presidentes de Módulos of DR 011 and 085 with the CNA and SDA, (19-08-03), Celaya, Guanajuato.
  - Meeting of the Presidentes de Módulos of DR 011 and 085 (08-03), Salamanca, Guanajuato.
  - LEAD (Leadership for environment and Development) program in Guanajuato, Mexico (5-7th of May, 2003), Guanajuato, Guanajuato.

* For privacy reasons their names are not mentioned.

Annex 3 Aquifer division discrepancies between institutions in Guanajuato and used methodologies for the aquifer studies

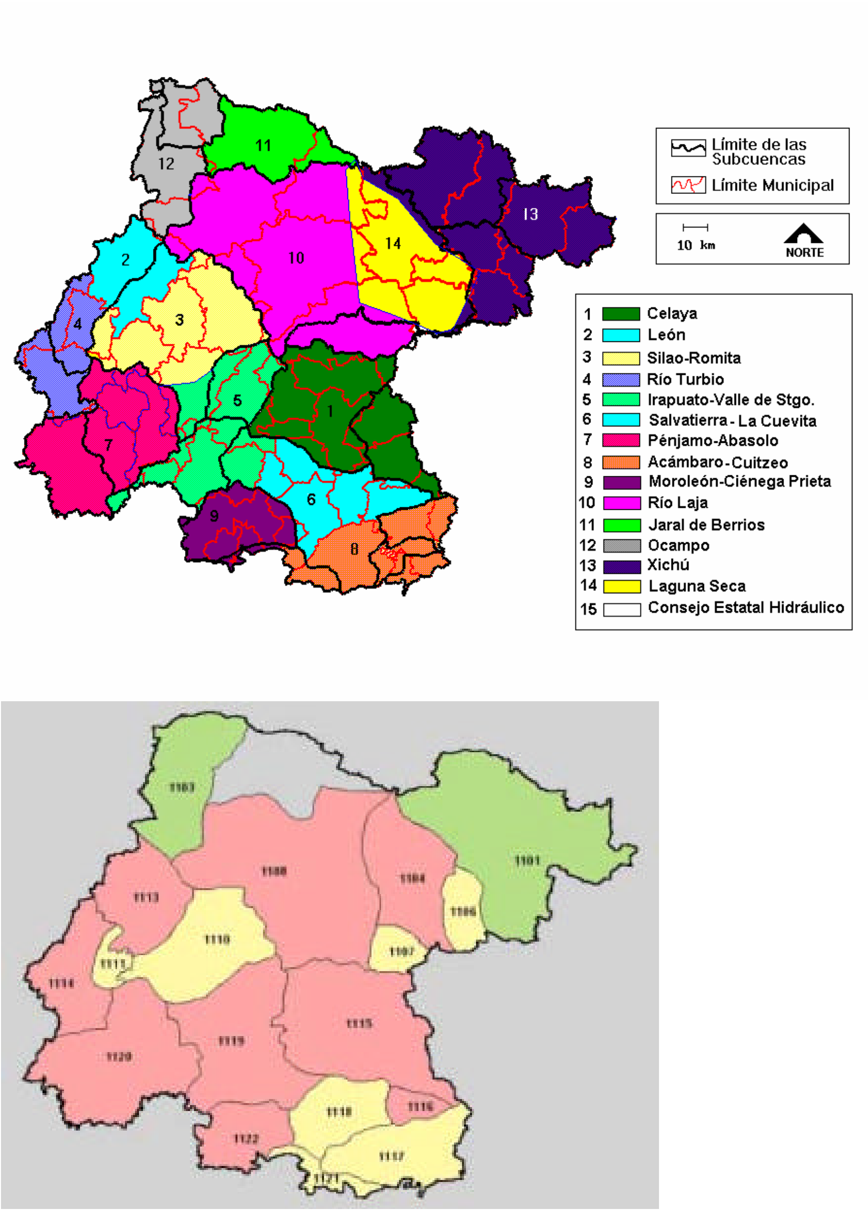

Figure A3.1 Division of aquifer limits of CNA and of CEAG.

Figure A3.1 shows that there exist discrepancies between the aquifer limits used by the CEAG and the CNA. If one looks at figure 3.2 and compares it with the aquifer divisions used by the different institutions it seems that the CNA approximates its limits more to reality.

Methodology of the different studies on aquifer balances

CEAG

The consultancy firms that did the aquifer studies used the methodology described below. The wells in the aquifers were identified through field work and for every well the following characteristics were gathered: localization, owner, static level, discharge in inches, discharge capacity, year of construction, irrigated area, main crops, static and dynamic piezometric levels, ph-temperature-electric conductivity of water and characteristics of the equipment. Some of these surveys were executed as far back as 1995 and some are more recent. The calculations for the different extraction regimes are based on the well database and several assumptions of which the most important are well discharge, average pumping hours per year and the well inventarization.

With the creation of the data base, the mathematical models and the geo-hydrologic characteristics of the aquifers the basic framework to up-date the water balances was made. On basis of this framework, and by a constant monitoring of piezometric levels of aquifers through the control wells (twice a year), studies are actualized every year by CEAG using the following equation:

Recharge = extractions + change in storage

Under recharge the following elements are taken into account: underground recharge from other aquifers, vertical infiltration of rain, irrigation returns, and losses of surface water in irrigation channels. Extractions are determined based on calculated extractions by wells[1], natural springs and evapotranspiration. The change in storage of the aquifers is determined by calculations based on the monitoring system of piezometric control wells that are established by CEAG. In the above situation recharge by vertical infiltration is taken as an unknown and all the other parameters are calculated.

CNA

CNA uses the same equations as the CEAG for the studies of 2000, yet the differences that appear between both studies is that the limits of the aquifers differ and the assumptions that are made differ. The number of wells and their situation in one data base and the other vary for some aquifers. For the studies conducted in 1999 the methodologies used to determine extractions, recharge and deficit are not available but these must have been different as the ones used in 2000 if one looks at the numbers, as these are extremely below all the other figures. The methodology used for the studies of 2000 are described in the NOM-011 (DOF, 2002).

[1] For calculating extractions by tube-wells assumptions are made on average pumping hours of wells coupled to the discharge of these wells and the total number of wells per aquifer (Which is information recorded in the well database of CEAG).

Annex 4: Detailed operation of the Technification of Irrigation Systems Program run by the SDA

The federal and state resources are deposited in the *Fideicomiso* (shared fund) Alianza para el Campo of the state of Guanajuato (FOFAE), which has received 443.7 million Mexican pesos during the period of 1996-2003, of which 249.4 where from the state government and the remaining 197.2 from the federal government. The FOFAE operates these resources based on criteria this instrument defines in accordance to the federal and state norms through the corresponding Technical Committee. The decisions over the authorization of the support to farmers are taken by the Fideicomiso de Ferti-irrigatción (FIDEFER, Shared Fund of the Fertigation Program).

On federal level the normative instance is the SAGARPA through its Sub-secretary of Agriculture (Subsecretaría de Agricultura) which, through the state delegation, is responsible for controlling the operation of the program according to the guidelines indicated in the Operation Rules (Reglas de Operación).

Operation of the programs

The operation of the program is done in a coordinated manner between technicians of the SDA and of the FIRCO. This program operates on a demand basis. This implies that the producers have to take the initiative to apply for the support from the programs. The procedures and processes for getting the support are shown in table A4.1 and the full detailed explanation is given in the Box A4.1.

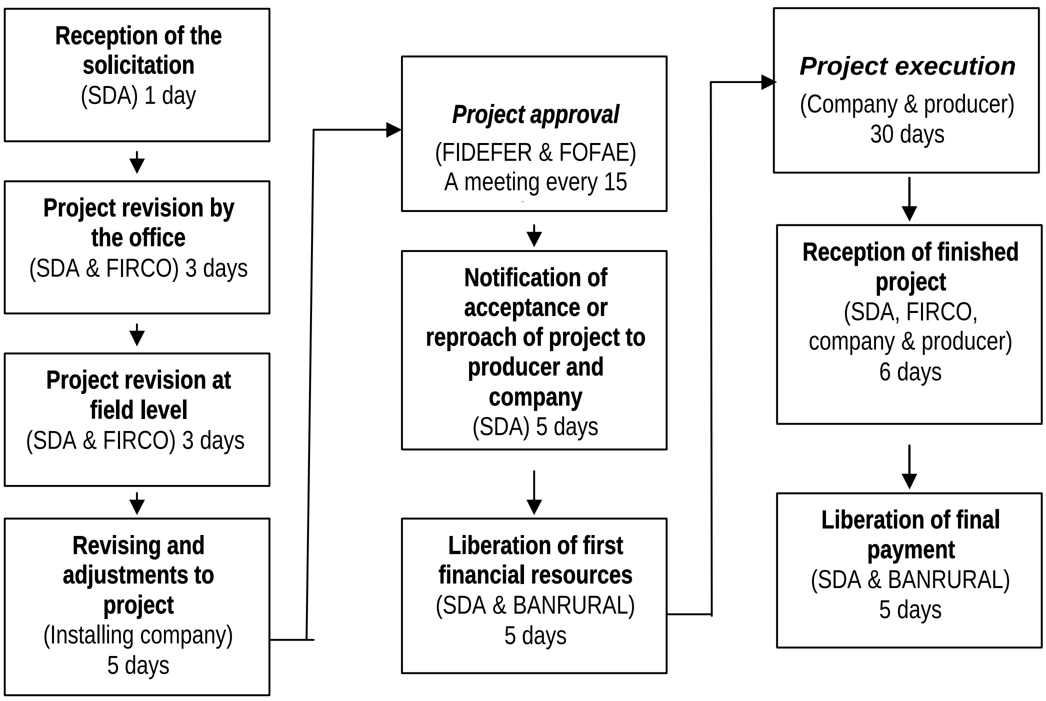

Figure A4.1 Process of operation of the program Tecnificación del Riego (Magaña, 2001)

Box A4.1 A step by step description of the operation of the Technification of Irrigation at Field Level Program (Magaña, 2001)

1. The beneficiary chooses a provider for the Executive Project (which in most cases is the same as the provider of the irrigation system), for the realisation of the project and the needed paper work. If the provider has no capacity for installing the system an installing firm will also be involved.
2. In most cases the beneficiary gives the documents to the provider and it is these providers that negotiate the subsidies for the farmers at the SDA. It is rare that farmers do all the paper work themselves.
3. The SDA, through the Program Direction receives the documents and solicitations of the farmers. The responsible area controls every solicitation before it is accepted to check the paperwork and legal correctness. An entrance file is created for the solicitation.
4. The technical project is presented to the FIRCO (Technical agent), who is responsible for the field control as well as the control of all documents. In case an irregularity is found, it is communicated to the installing company or the producer, which can make corrections.
5. The FIDEFER (Fideicomiso de fertiirrigación) authorises the support for every solicitation once the FIRCO approves the project technically and the area in charge of the program approves the eligibility of the farmer for the program.
6. The FOFAE (Fideicomiso Alianza para el Campo del Estado de Guanajuato) emits the final authorisation and liberates the corresponding financial resources to the FIDEFER.
7. The FIDEFER communicates the authorisation or the negation to the interested producer and to the installing company.
8. The installing company receives financial resources from the SDA and counts with 40 days to install the irrigation system.
9. The SDA controls the physical advance of the project at field level and, if needed, charges the installing companies' fines if the agreed terms are not met due to conditions for which the company is liable.
10. Once the irrigation system is installed the company informs the FIRCO, which verifies the execution of the works and the FIRCO signs an act of delivery and reception with the installing company and the producer.
11. Finally the provider receives the rest of the payment by the SDA.

For an easy functioning of the program the federal and state government have established several institutional frameworks. They have established financing mechanisms for users as well as contracts with the providers. Some of the established schemes are listed below:

A financing scheme has been created to give the beneficiaries of the program credit through the Program for Rational Water Use (PURA, Programa uso racional del agua).

The COTAS and the Módulos de Riego of the DR011 are used as groundwater users' organizations that intercede for the users and facilitate bureaucratic paper work between the SDA and the users.

A list of all the accredited providers is made so beneficiaries can choose a trustworthy company for the elaboration of the executive project and for the installation of it.

A treaty has been signed among all the PVC tube providers to establish maximum prices. At the same time these providers have established a group that represents their interests in front of the SDA and the producers.

Finally once a year the program is evaluated by the FAO-SAGARPA and in these evaluations the overall program is assessed by external evaluators.

Support given (technically what is covered, financially how is it organized for producers)

The program *Tecnificación del Riego* gives support for the acquisition and installation of material for high and low pressure irrigation systems. These can include the rehabilitation or reposition of pumping devices, flow meters, measuring devices, fertigation equipment (tanks, filters, mixers, pumps & injectors) as well as the formulation of the project and technical assistance to the producers as long as these elements form part of the installation of a complete irrigation system. There are basically three types of irrigation systems that get installed in Guanajuato: sprinkler irrigation, drip irrigation and low pressure conduction systems (*riego por compuertas*).

The support extended for the installation of the irrigation systems is given by the federal and state government in a stratified manner (pro-poor) according to the classification given in tables A4.1 and A4.2 for the years 2002 and 2003 (this stratification is evaluated and reestablished every year):

Table A4.2 Stratified % of support given to producers by Alianza para el Campo, 2002 (SDA, 2002)

Benefited area per producer (ha)	Support of Alianza para el Campo (%), 2002
< 3.5	85
3.6-5.0	80
5.1-10	70
10.1-20	65
>20	50

Table A4.2 Stratified % of support given to producers by Alianza Contigo, 2003 (Interview, 30-06-03)

Benefited area per producer (ha)	Support of Alianza para el Campo (%), 2003
< 10	70
10-20	60
> 20	50

The percentages shown in the table above is with respect to the total costs of reference, which will be the same if the price is lower than the standard taken by the SDA. This standard sets the maximum limit of support per hectare as seen in the table A4.3 (for the year 2002 and 2003, and these are also evaluated every year).

Table A4.3 Limit of costs per hectare for which Alianza Contigo gives support in 2002 and 2003 (SDA, 2002, Magaña,interview 30-06-03)

Type of irrigation system	Limit support costs per hectare (mexican pesos)	
Year	**2002**	**2003**
Low-pressure	5.000	7.000
Sprinkler	9.000	11.000
Drip	14.000	18.000

Technical assistance is given to producers benefited by this program for the installation of irrigation systems. The support is given according to the same division in cost sharing shown in table A4.2 and with a maximum cost, in 2002, of (Mexican pesos) $258.50/ha for specialized technicians.

Until recently it was not possible to get support for technification of the same parcel twice. Now the policies have changed and farmers can get support from the SDA if they want to change their irrigation form a low pressure irrigation system to a high pressure (sprinkler or drip) system. In these cases the support that was given in the past gets subtracted from the new financial support that is extended. It is not allowed for producers to change from one high pressure system (sprinkler) to another (drip).

Furthermore the support of the program is only for the initial installation of the irrigation system. O&M costs are not covered and once the system is installed the farmers become fully responsible for reposition and updating of the irrigation system (especially important for the high pressure systems). Box A4.2 contains a list with the requirements needed for being applicable for the program. And Box 4.3 shows the personnel working in the execution of the program since June 2000.

Box A4.2 Requirements to enter the support programs for improving irrigation technology (Magaña, 2001)

- Title or solicitation of a water concession by the CNA
- Copy of the receipts of the CFE of the energy consumption of the last 3 years
- Copy of the papers of ownership of the area (plot) to be benefited
- Executive project that includes
  - Description, objectives of the project
  - Topographic study of the area
  - Agronomic study of the area
  - Hydraulic design of the irrigation network

Box A4.3 Resources set aside for the program of Technification of Irrigation Systems at field level (SDA, 2003).

The program has for its operation, since June 2000, the following human resources (personnel):

- One Program Director
- One Coordinator
- One engineer to receive and control the documents for solicitations
- Eight engineers for controlling the solicitations and receiving the executive projects at field level as well as for receiving the concluded works
- Two engineers devoted at controlling the installation work at field level

  Beside the abovementioned human resources the SDA makes use of GPS systems for monitoring and evaluation, and a flexible database that is actualized to control and manage the data as efficiently as possible.

Annex 5: Detailed explanation of the program Modernization of URDERALES

The main problem with most of the URDERALES and the cause of the deterioration of the infrastructure is a lack of organization of the users. For this reason the SDA's first requisites to give support is that the URDERAL is legally constituted in an association of users. The process of organization is guided by the SDA and starts with meetings in which the users are slowly convinced of the benefits of organization.

The first step the SDA takes, when executing an intervention is to update the users lists (padrón de usuarios). With this, an evaluation is made of the amount of money the association can get from the water rights. Sometimes they even have to check if the users have to pay water use rights at all. Most of the URDERALES work on basis of a contribution that the users establish themselves. Once a users association is formed, the SDA, with the association sets a *cuota de riego* (irrigation fee) for the users. The irrigation fees in URDERALES at this moment lie between the 50-150 pesos per irrigation turn/ha (against 260-340 pesos in DR).

Once the irrigation cuota is established an assessment of the URDERAL is made, the capacity of the dam is established, and the hidroagricultural infrastructure for irrigation is assessed. Some of these studies are done in conjunction with the CNA and the Colegio de Posgraduados. In the assessment socioeconomic aspects of the URDERAL are included.

After the assessment is made an executive project for improving infrastructure is prepared. This executive project is presented to the general assembly which has to approve the project. At this general assembly meeting, the SDA explains how the financing structures work and which role the different actors play within it. There are two ways in which the works are done:

1. Directly between the SDA and the users. Here the SDA pays 60% of the total costs and the users 40%. In some cases the municipal government pays part of the 40% the users have to pay. Sometimes the municipality pays 20% so 50% of the total the users have to pay.
2. With support of the federal government through the CNA. In such cases the CNA pays 50%, SDA 25% and the users 25%.

In the projects where the investments are the highest the support of the CNA is asked for. Small works of one to two million pesos are financed directly by the SDA and the users. For work of eight to ten million pesos the support of CNA is asked for (see Figure 5.1). The works that are done vary but there are generally three types of interventions.

- The installation of conduction pipes of PVC and iron of the whole irrigation area with hydrants for each parcel that is to be irrigated (a completely modern conduction system is installed).
- Only the channels are improved and duck bill flow meters are installed.
- A combination of the two abovementioned. In some cases pumps are installed to create pressure to feed some of the low pressure conduction systems.

Once the SDA enters into an URDERAL for work it becomes the 'advisor'. The SDA intervenes on all levels: organization, operation, maintenance, irrigation and operation practices are taught, in some cases even technical support with regards to the crops the users cultivate is given. Most of the URDERALES produce maize, wheat and sorghum. Some start with the production of vegetables and horticulture but this is in the most advanced URDERALES where new irrigation systems are installed and support has been given. With the saved water through new works, the possibility of producing another crop or to have a security if the rains fail is given to the producers.