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Human Development Report **2006**

Human Development Report Office
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Water Subsidies and Aquifer depletion in Mexico's Arid Regions

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2006/23

Human Development Report 2006

Water for Human Development

Case Study: Water Subsidies and Aquifer depletion in Mexico's arid regions

Alejandro Guevara-Sanginés

Farmers in middle and high income industrialized countries tend to be heavily subsidized by their governments thanks to their important political weight. Mexican farmers are not the exception. Even after the structural reforms of the 1990s in which the country scrapped policies like guaranteed prices and privatized fertilizer firms, farmers in Mexico still receive hundreds of millions of dollars per year in transfers. Some of them take the form of matching grants to buy inputs or equipment, through a program called *Alianza para el Campo*. Those producing corn receive a direct transfer per ton sold as "commercialization support"; while other important export crops such as coffee and sugar are the objects of specific support programs with generous budgets. Across the board support takes the form of a zero VAT rate that all the agrochemicals enjoy, and, at the center of our argument, a subsidy of more than 2/3 the cost of electricity for those irrigating with groundwater, all this on top of a zero price for water itself.

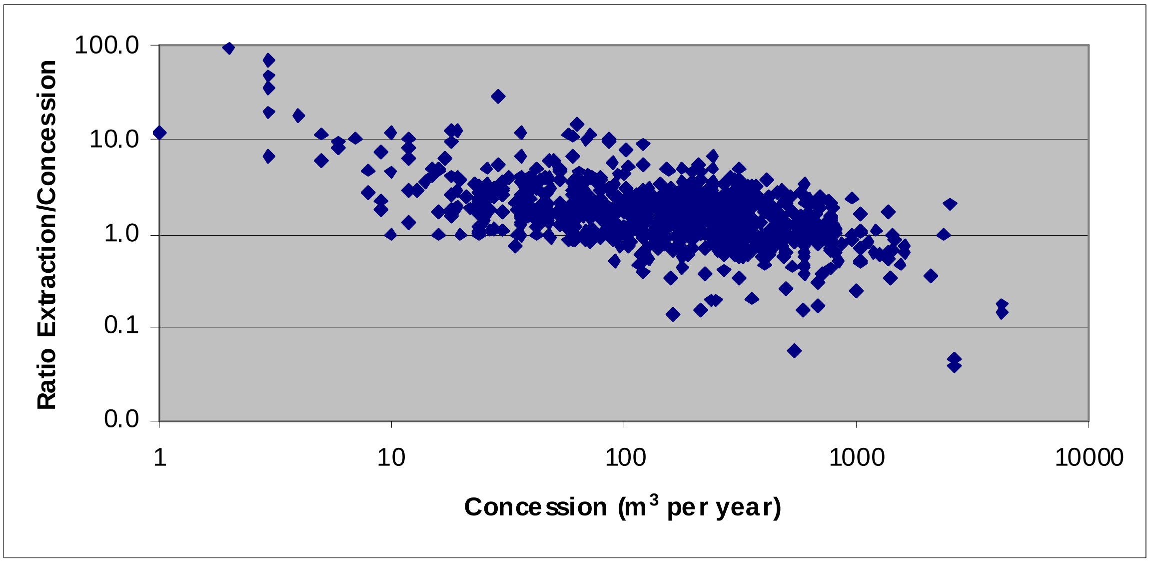
The fact that nearly 80% of all water in Mexico is used by agriculture makes the pumping subsidy have important effects in the rest of the economy, especially where population, industry or the service sector are growing fast and compete for the scarce resource. In Mexico, a country with extensive arid regions and where the largest population centers are located in watersheds with medium to low levels of rain, irrigation has a large economic and ecological footprint. The economic importance is clear by comparing acreage with productivity. Representing only the 25% of total farmland, irrigators produce 53% of all crops and take credit for 70% of agricultural exports. The environmental impacts can be related to two main issues: saline water intrusion or arsenic and heavy metal pollution caused by overexploitation of aquifers, and reduction in water supply to wetlands. Both issues will be explored in more detail through two cases which illustrate in a very clear way how the tradeoffs between conservation and economic growth goals can be made worse by the wrong policy choices.

It is important to look first at the institutional context. To manage irrigation water, Mexico has a system of concessions handled by the federal government whose stated aim is to limit the total sum of extraction to the maximum sustainable yield of each aquifer. The agency in charge of determining, granting and enforcing concessions is the National Water Commission (*Comisión Nacional* *del Agua:* CNA), also responsible for delivering water to local governments and firms obtaining water directly from the federal waterways. This system faces three key problems:

1. The first problem is that a large share, approximately 26% of farmers, extracts water without actually having a concession. Their status is classified as "in process of regularization", to soften the fact that what they do is illegal extraction and bring them gradually into the fold. That process is complicated by what is problem number two:
2. In many aquifers, the volume of water that corresponds to the concessions given already is greater than the total sustainable yield of the aquifer, a problem labeled as "overconcession". Caused either by miscalculation or corruption over the previous decades, the excess groundwater concessions leave the National Water Commission with little room to maneuver to both legalize the illegal users and to decide how to reduce extraction to the correct level in the aquifers in worst shape.
3. On top of that, there is a third major problem. Even when a farmer does have a concession, he or she not always respects the maximum level of extraction allocated. This is just the result of the limited enforcement capacity of the CNA which makes farmers face a low probability of being caught and fined.

Not all is lost; Ávila, Muñoz and Jaramillo (2004) find evidence that, within its enforcement limitations, CNA is still using its resources in the most efficient way. Figure 1 shows the ratio of extraction to concession volumes for a sample of irrigation farmers whose information on real extraction levels was obtained through indirect calculations on usage questions. Notice that the ratio is nearer to the band between zero and 1 (extraction equal or lower than concession) the larger the concession volume. Small irrigators are the ones who cheat more frequently and by a larger margin, extracting on average five times their concession levels. The resulting pattern corresponds to one that would be generated by an agency closely watching large users while letting smaller, but numerous, fry escape. If there is a fixed cost for monitoring each water user, then the agency is following the most effective strategy given a fixed budget.

Figure 1: Ratio of actual extraction to legal concession



Source: INE (2005) using data from *Colegio de Posgraduados* (Colpos 2001) Survey of Irrigators.

In this context, the electricity subsidy is giving incentives for farmers to extract more water, whether or not they are currently extracting below their concession levels, and even if they have no concession at all. If the aquifer is already or close to being overexploited, the subsidy causes an excess demand relative to the maximum sustainable yield. Even if the aquifer still has room for additional sustainable extraction, the electricity subsidy causes a social waste of resources: it induces an economically inefficient use of water because the additional quantity of water it allows to extract is actually yielding agricultural products whose market value is less than its total costs of production if the real cost of electricity was taken into account. It is an overall loss of social welfare despite the gains of welfare to farmers. That water would be more productive if used by industry, households, either present or future ones.

Table 1 shows the types of agricultural users and their electricity tariffs applicable to them. The general code that identifies the electricity tariff paid by irrigation farmers is 09. In its standard form it has several blocks of increasing rates and is applied to all those farmers that have either have no concession or have not applied to get the lower tariffs. The lower tariffs have actually a single price for all levels of consumption, and are identified as tariff 9CU for day use, and tariff 9N for night time use.

The average cost of generating electricity is 0.63 pesos while average transmission costs are estimated to be 0.81 pesos. The difference between the total cost of producing and delivering electricity (an average of Mx$1.44) and the fees paid by farmers, times their total electricity consumption, amounts to an annual implicit subsidy of US$ 700 million dollars. The recipients are approximately one hundred thousand irrigation farmers, the better off segment of the rural population. Approximately US$560 million are handed down each year to those farmers with groundwater concessions, while US$140 million are given to “irregular” farmers.

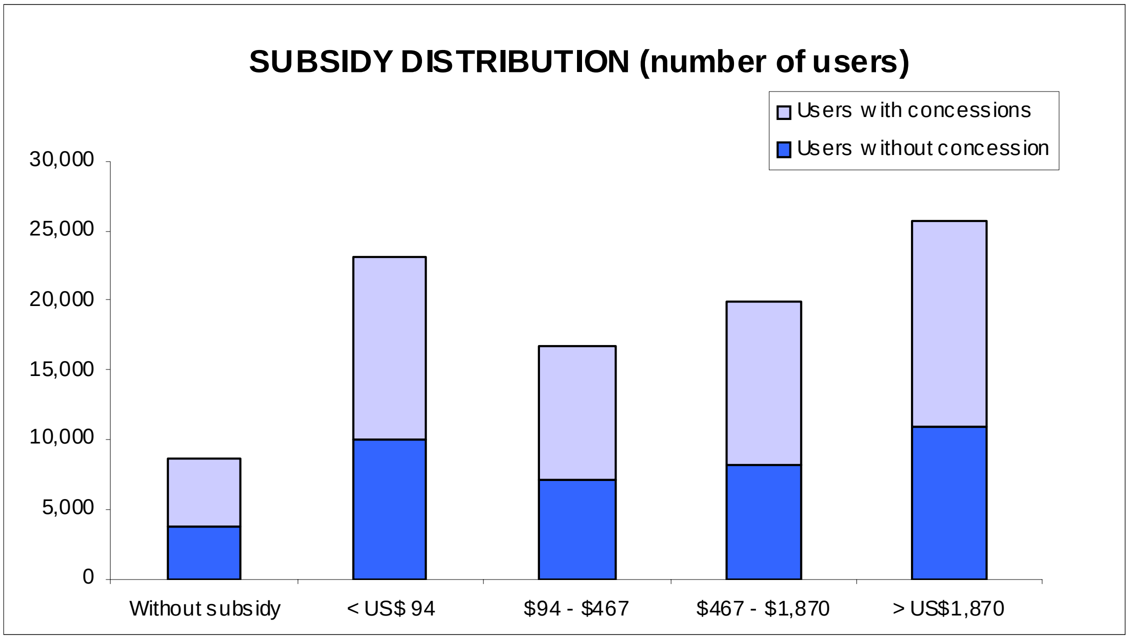
Table 1: Agricultural Tariff structure

Type of agricultural users or use	**Code**	**Tariffs** *(pesos/kWh)*	**# Users** *(thousands)*	**Consumption** *(million MWh/ year)*	**Subsidy** *(million US$/ year)*
No concession	09	0.55 ... 0.74	27.6	1.5	$140
With Concession (day rate)	9-CU	0.34	54.2	3.2	$560
With Concession (night rate)	9-N	0.17	22.9	2.2	
Total			**104.7**	**6.9**	**$700**

Source: Federal Electricity Commission, August 2004

Not only there is a regressive distribution of income by favoring irrigation farmers vs. those owning only rainfed land. As it happens with most input subsidies, the largest farms receive the largest transfers. By looking figure 2 we can get a sense of the inequality of the distribution of the subsidy. The top 25 thousand users receive transfers of more than US$ 18 hundred dollars per year, while the 25 thousand least privileged irrigators receive less than US$ 94 per year. A more precise measure of inequality, the Gini coefficient, is estimated to be 0.91 for the electricity subsidy, very close to 1, the maximum level of inequality. The Lorenz Curve, a graphical depiction of inequality linked to the Gini coefficient is presented in figure 3.

Figure 2.-



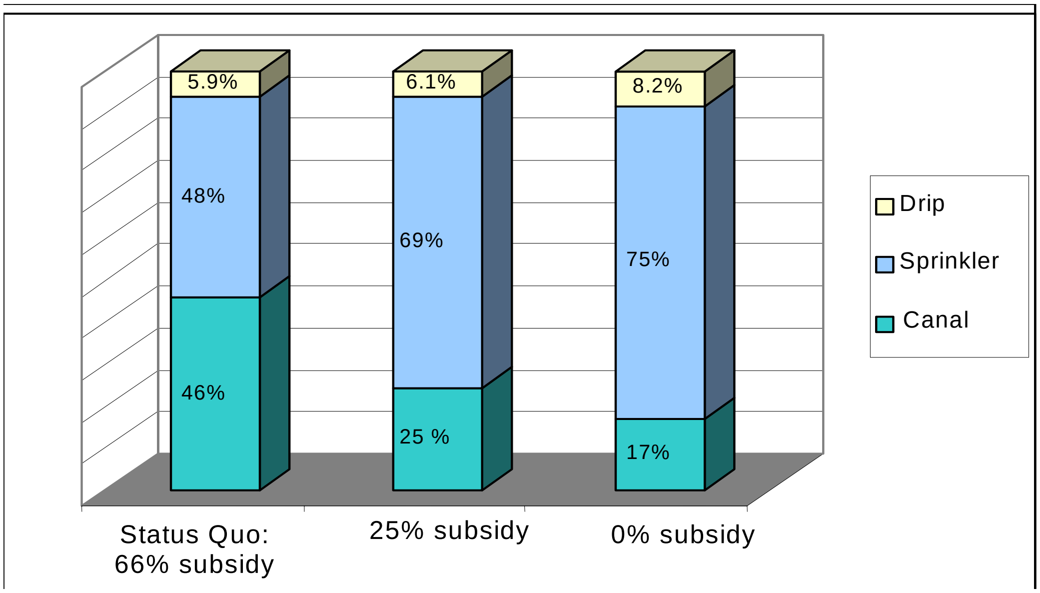
The subsidy as a perverse incentive that causes overdraft aquifers

The pumping subsidy prevents the adoption of water-saving technologies because water is made artificially cheap, so otherwise profitable investments in sprinkler or drip irrigation equipment are rendered useless to the farmer. Figure 4 compares the status quo of technology choices of a sample of farmers in aquifers that have particular low water tables with the predicted choices they would make if the subsidy was reduced to 25% of total cost or if it was completely eliminated.

The results of subsidy removal or decoupling are dramatic. For example, 46% of the farmers in the sample had canal irrigation, the least efficient technology where two fifths of the water is lost to evaporation or percolation before reaching the crops. The econometric predictions show that if the total subsidy was reduced from the current 66%, to just 25% of the real cost, then nearly half of those currently using canals would switch to sprinkler irrigation. If the subsidy was completely removed then three quarters of all irrigators would adopt the use of sprinklers, and 2% of them would even go beyond sprinklers and adopt drip irrigation, raising the use of this technology to 8%, a rate of adoption readily seen in richer countries where high value crops are grown in arid environments, which is where Mexico grows most of its irrigated crops. Water savings of this induced technological change would be significant because sprinklers improve average efficiency of 75% and drip irrigation reaches 95%.

Figure 4.

Distribution of irrigation technologies within COLPOS sample under different scenarios of subsidy decoupling



These predictions are based on observed behavior. An empirical study carried out by INE and UIA (Muñoz, *et al.*) looked at the natural experiment of farmers in Mexico extracting water at different depths in the different aquifers of the country. Each farmer's choices, both in irrigation technology as well as total water extraction, respond to the implicit prices paid for water through the electricity bill. These "shadow prices" are indeed higher the lower the water table, even if they are all subsidized. So, through the use of econometrics, one can predict the change in behavior a farmer would have if facing a higher price of electricity (or water) just by looking at the choices of a similar farmer located where water is already more costly to extract.

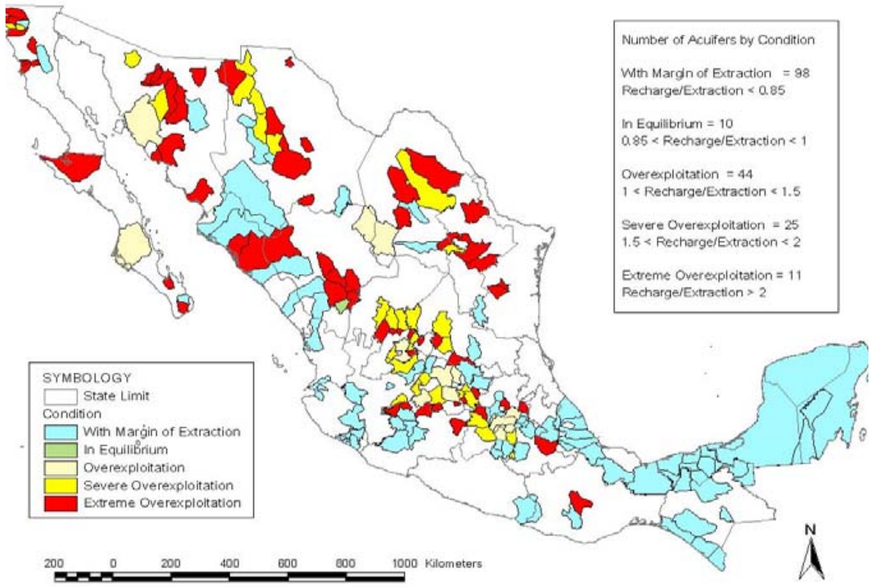
There are other possible reactions to an electricity price increase besides adoption of more efficient technologies. For example, some farmers could switch to crops that use less water. Some others would change the timing of irrigation towards dawn or dusk, where there would have less evaporation. There are multiple minor repairs to infrastructure that could prove to be cost-effective actions to save smaller but still important quantities of water. In marginal lands, where crops had little profit margin and were only cultivated because of the subsidy, some farmers could reduce the total area planted and even a few of them would be closing their operations altogether. Adding all these effects to that of technology change, the INE-UIA study estimates that in the long term, once all desired adaptations are undertaken, the net saving of water of doubling the price of electricity, and thus reducing the subsidy to just 1/3 of total cost, would bring a 19% reduction in water extraction. Despite this inelastic demand for water, the reaction to the decoupling of the subsidy would be enough to bring some aquifers back into equilibrium and buy time for the rest.

Not all types of farmers respond in the same way. The overall effect is the sum of the actions taken by all the different type of producers. The INE-UIA analysis shows that larger farmers tend to adapt more rapidly than smaller ones when facing a higher price of water. Size, measured in terms of value of the total output of the farm) does have an effect. We do not know if this is due to economies of scale or because larger farmers have more access to credit to pay for what is a profitable switch in technologies for any farmer in their circumstances. In any case, if the subsidy was reduced to one quarter of the cost of electricity, then each of the farmers that belong to the group that includes the 20% largest ones would adopt technology and modify practices in order to save on average 33% of the water each one consumes. In contrast, those that belong to the smallest quintile of farmers would only undertake actions that would make them save 5% of their water and, if the reason is credit constraints and not economies of scale, clearly loosing potential profits through missing opportunities to improve water efficiency. This disparity in the capacity to adapt can be dealt with specific credit and training support to smaller farmers, but it also highlights the importance of having neutral transfers that are part of the decoupling process, an issue that will be discussed later.

A clearly unsustainable pattern of groundwater use

In nearly 100 of Mexico's most important aquifers, the aggregate result of the perverse incentives generated by the electricity subsidy and the lack of enforcement of the current system of concessions is an excess extraction of groundwater from its most important users, above of what nature recharges each year. Figure 5 shows the pattern of overexploitation of aquifers in Mexico. All the aquifers where large cities are surrounded by irrigation agriculture are heavily overexploited. So are most of those aquifers in dry areas close to the highway system that connect them to these cities, the US border or large ports. In the 11 of them in worst shape, extraction rates go from 200% of natural recharge all the way up to 800%. These levels of extraction cannot be sustained for long.

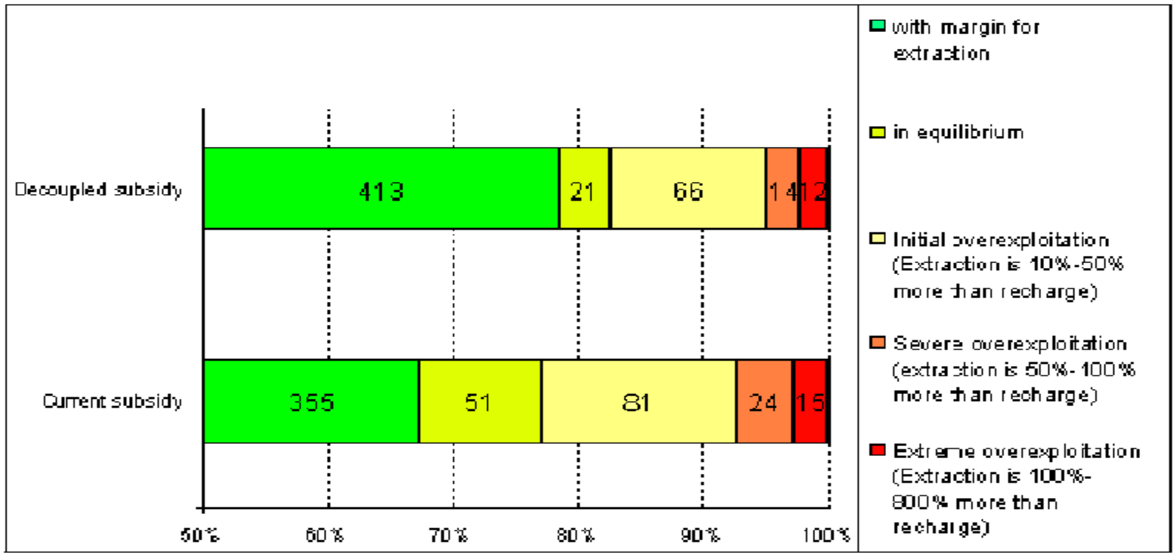
Figure 5: The 188 Most Important Aquifers and their Levels of Exploitation



Source: INE, based on CNA "Water Statistics in Mexico" 2005 edition

Figure 5 compares the current status of all aquifers in Mexico with the predictions of aggregate extraction once the subsidy is reduced by ½. Notice here how 58 aquifers[a] would pass from being at the brink or already overexploited to a situation where there would be a margin for expansion, either of future industrial or household consumption, or a surplus that would replenish the stock and raise the water table again. The patterns of extraction of 28 overexploited aquifers would now become sustainable, and although only 3 extremely overexploited aquifers would pass to the next best category, for all of them time would have been gained. Time is important, both to avoid facing a crisis unprepared, but also to find other policies to reduce overextraction even more, such as subsidizing better technologies or actually negotiate the registering and enforcing of concessions.

[a] There is a small, but yet unmeasured, dampening effect, due to the reduced induced recharge



Decoupling, not eliminating, the subsidy

Decoupling or reengineering subsidies is a term used by organizations such as the OECD and the World Trade Organization to identify the policy measures that switch the support to a specific economic sector from one that causes price distortions to one that provides neutral transfers. The best examples of neutral transfers are cash payments, allocated using a registry of eligible farms or households, and paid either per hectare or per household. The basic idea is that by avoiding distortions to market prices better (in the welfare generating sense) decisions will be taken.

A decoupled subsidy still provides support to the groups that legislators, public opinion or the executive recognizes as deserving, or to those interest groups that lobbied to become beneficiaries. The fact is that a neutral transfer does not distort markets and society gains from this. From an environmental point of view, the gains are rooted in the same idea; there is no use of natural resources beyond that where true net welfare is generated. In the Mexican case, without the subsidy more water would be saved and more aquifers would be used in a sustainable way, while the neutral transfer would leave farmers as well-off as before.

Where would the budget for the neutral transfers come from? It would come from the additional revenues generated by the price increase. It is not just making the money go from farmers to the government and back again. The price signals have now changed and the incentives to save water (or the input whose support is being decoupled) are now in place. The transfer in any case would make it easier for the farmer to undertake the investment in new equipment that now does look profitable.

Because we know that smaller farms would react less than larger farmers, then we would observe the former absorbing most of the electricity cost increment. This makes the handling and timing of the neutral transfer all the more important. Having them receive the transfer and later paying it back almost entirely to the government would not ruin the effect of the decoupling; it is the aggregate effect that one is after, not the same reaction from all farmers.

Delivering a decoupled subsidy is more complex that providing one through input prices. It requires a payment vehicle which is stable, objective and minimizes the risk of fraud. An *ex-professo* list was created to deliver a payment per hectare under a program called PROCAMPO, as part of the policy to decouple all the guaranteed prices in agriculture in the face of NAFTA. PROCAMPO was more progressive than the output price policy because it paid the same per hectare to all farmers no matter what their productivity was, thus benefiting the poorest and less input intensive producers. However, it still needed to put a cap on transfers per household to avoid following the same distribution as land ownership.

Which payment vehicle would work best for the case of decoupling the irrigation subsidy? It could be land, as in the output decoupling case, but it is difficult to measure without fraud how much land were the owners irrigating. It could be the amount of water stated in the concession itself. That would make more sense and would actually be punishing those cheating and extracting more water than their concession. For those irrigating with no concession at all it would provide no relief. This is a major political feasibility weakness because of the large share that these two groups represent. The decoupling program could be patched by creating a transition payment per hectare for those in the “regularization” process, and by providing extra funds for the smaller irrigations, which we know are the ones that cheat the most.

Equity is indeed a key point for the political feasibility of the decoupling of the irrigation subsidy. More equity actually worked well for the output subsidy decoupling. Enough poor peasants saw it as better for them, and their representatives supported the measure. The largest farmers were chastised for not being competitive in front of an inevitable NAFTA process, and were asked to move to export crops instead. However in the case of water it is not clear it would work in the same way. If it is a single payment per m^3 of water in concession, with the fixed budget coming form the additional electricity revenues, then those in the most overexploited aquifers will loose. They spend more electricity to extract every m^3 than those that have land where the water table is higher. There could be some regional differentiation, but too much would be vulnerable to criticism of unequal treatment of “equal” farmers.

An additional challenge for the decoupling proposal comes from what any policy maker would perceive as a desirable attribute of any subsidy: transparency. A transparent subsidy is a vulnerable subsidy, even more if there is a clear -and difficult to justify- disparity between the already richer irrigation farmers and the much larger and poorer group of farmers with rainfed lands. Such a transparent decoupled subsidy could attract public opinion outcries, legislator challenges and protests from the rest of the farmers, because of its inherent inequality. A price-of-input subsidy instead has the advantage for the privileged group that it hides these transfers, making it appear as a matter of justice that the government should not "price to high" the inputs it provides to farmers. The money is allocated through the budget assigned to the public utilities, not handed openly to irrigators. Those irrigators opposed to a net gains decoupled subsidy are thinking in the looks in the face of their peers when they receive in the open a check for US$5,000, just for being lucky enough to have a (also free) water concession, instead of receiving the same subsidy hidden in their quarterly electricity bill.

These political feasibility challenges need to be met, most likely by a policy entrepreneur willing to absorb the political costs of antagonizing the most privileged of farmers under the status quo, with the goal in sight of saving from collapse the aquifers that maintain most of the population and the industrial and service sector part of the economy.

CASE STUDIES

A summary of two case studies will be presented to illustrate the consequences of aquifer overexploitation caused by the aforementioned policy failures. In the case of the aquifer of Hermosillo, Sonora, the costs of overexploitation are loss of prime agricultural land because of the induced saline intrusion. In the second case, the threatened aquifer of Cuatrociénegas, Coahuila supports endemic species of immense value to science in an area where alfalfa fields are expanding.

Tragedy of the commons in Hermosillo, Sonora

Agriculture in the dry climate state of Sonora in Mexico's Northwest depends almost exclusively on groundwater. The coastal region, well connected to the highway system that links Mexico to the U.S. market, is a major producer of corn, tomatoes and other high value vegetable crops. In the 1960s the water could be extracted at a depth of 11 m. and farmers treated it as an endless supply. However, by the 1980s water table levels were dropping fast, while the economy of the area kept growing. Corn productivity was among the highest in the country, and tomato became the most important cash crop. The liberalization of international markets, first with GATT and next by NAFTA, further increased demand. This is the time when the water policy failures exacerbated a crisis that should have just been a story of successful growth, increased relative scarcity and the following investment to increase water productivity. A response that market signals could have solved in a simple, direct way, was now in the realm of a vicious circle in which farmers facing increasing pumping costs asked for more subsidies, especially in electricity; the government responded, and thus new entrants to the tomato business were happy, while incumbents were kept content, but the aquifer kept being drawn down.

All this would have found a limit in any other aquifer, once the electricity subsidies became too outrageous or were stopped by the requirement to offer the same treatment to all regions. However, in a coastal aquifer such as the Hermosillo one, the overexploitation crossed a threshold that changed the direction of the water flows, normally going from the land to the ocean. In the late 1990s water had to be pumped from 135 m. from the ground, and the Hermosillo aquifer was now 58 m. below sea level. Saline intrusion began, first in the areas nearer to the coast, with accumulated effects that eventually rendered those fields unusable. As it progressed further into the land it sounded high an alarm to those farmers in the vicinity. Their fields, already connected by the road infrastructure that had been built thanks to the wealth they were generating, were going to be lost in timeframes measured in years, not decades.

The National Water Commission had the same imperfect enforcement capacity as it had nationwide, but now it was bolstered by a concerned State government and the farmers that were coming to realize that the free rider situation that all enjoyed was really a tragedy of the commons in the making. One of the very clear lines of reaction to the crisis was to have CNA prohibit the opening of new wells and begin to close down some of the existing ones. Some were closed by nature, the salinization process still advanced relentless, but the rest needed to be closed by decree. Needless to say, there would have been no need to close any wells if extraction limits could be actually strictly enforced, and there was a way to reduce the concessions in a proportional way.

Collective action for farmers to support the agency was made easier by the formation of an aquifer-level association. In that way it was easier for farmers themselves to negotiate who would close down and who would still produce. Agribusiness firms posed no problem; they were actually closing down their rental contracts in the most affected areas and renting new land further away from the coast. The water markets opened by the new Water Law began to operate more and more, as a way to cope with scarcity. Some traded the right to salinized water for wells farther away from the land, avoiding personal losses but not contributing to the solution really.

Central to the actions to solve the crisis is the issue of compensation. If a farmer had to choose between closing a well now and having saline intrusion closing it in 5 years, there was no question of what she would do. A few years more of production, even with diminishing profits, was better than zero. Compensating losers is a sound economic proposition for the rest of farmers: the present value of their gains is greater than the foregone profits of those closing their wells. In the end, the federal agencies provided the public good of compensating some farmers that closed their operations, giving a net transfer (using taxpayers' money) to those who had been responsible for the crisis they now faced.

The situation at the Hermosillo aquifer is not sustainable yet. The city still grows and without expansion of the supply apparently collapse was averted, but the low water table implies that only the richest farmers, with more powerful pumps, have access to the still heavily subsidized water

The case of *Cuatrociénegas*, Coahuila

The dryland valleys of north-central Mexico contain some of the most diverse desert ecosystems in the world. Even among this diversity the desert wetlands of *Cuatrociénegas* stand out. The ancient aquifer emerges as a series of desert springs, streams and ponds where freshwater bacteria, mollusks and fish have existed in relative isolation from other large bodies of water for thousands of miles and for several million years, giving place to what are now a fair number of endemic species. The research value of such a natural experiment of oasis evolution is enormous, as is its bequest value for future generations. Even if the springs have been isolated from lagoons, rivers and oceans for very long periods of time, they might not be isolated from neighboring aquifers –or so believe scientists like Valeria Souza, who has analyzed the genes of bacteria and archea in the area- thus making them indirectly vulnerable to the overexploitation of groundwater taking place by the surrounding agricultural activities. However, there is more than one scientific opinion on this matter. For the *Instituto Mexicano de Tecnología del Agua* (IMTA), a government research center specialized in water issues, geohidrological tests show no sign of current physical link between the *Cuatrociénegas* aquifer and any of the neighboring ones used for irrigation agriculture.

In recent years the political stakes of this scientific debate have been raised by the actions taken by a group of alfalfa growers in order to expand their operations in the neighboring *Valle del Hundido* valley. Alfalfa is grown in the Mexican drylands because the most common practice is to allow cattle to browse free in the rangeland during rainy season while supplementing food the rest of the year. The market for alfalfa in the central Coahuila region had been growing over the years due to the greater demand for meat in the dynamic urban centers of the region and a more open trade in cattle with the US after NAFTA. Additionally, the arsenic and heavy metal pollution crisis of some of the large aquifers in the region, brought about by their overexploitation like in the case of *La Laguna*, has also put pressure in moving production to the minor aquifers in the periphery. Importing alfalfa into the region is not cost effective, because transportation costs are high relative to their value per kilogram, so there is pressure to produce as locally as possible. All this economic forces combined with the artificial economic feasibility of opening new wells brought about by the electricity subsidy explain the current potential threat on a Mexican hotspot of biodiversity.

The area is not without protection, and the favorable outcome of the latest clash of interests between biodiversity conservation and expansion of cattle ranching activities is certainly due to the constituency formed around the objective of preservation of the area. Thanks to the national and international scientific community who drew attention to Cuatrociénegas' uniqueness, it was declared a Natural Protected Area in 1994, under the federal system of protected areas. This gave the possibility to the Federal Attorney for the Environment (PROFEPA), the enforcement agency of the Ministry of the Environment and Natural Resources, to step in when complaints were filed about the opening of more than 100 new wells in *Valle del Hundido*. The farmers, and their local and State government supporters, argued that there was no proof of connection between the Cuatrociénegas and Valle del Hundido aquifers, and that this was enough to continue with the expansion plans of more than ten thousand hectares of alfalfa fields. The research undertaken by IMTA brought further support to their argument, and weakened the federal case. There was an unclear situation to add to the issue though, because the alfalfa growers held recent groundwater concessions granted by the National Water Commission, and these are supposed not to be issued when aquifers, like the *Valle del Hundido* one, are considered at risk from overexploitation. However, the case for conservation had solid but partial gains thanks to an error made by some alfalfa growers when they cleared the land and opened the wells without filing a request for land use change, a request that must include an Environmental Impact Assessment. Their counterargument that there was no valuable biodiversity in their lands was easily turned down because the diversity of cacti of the area was well known. Those farmers had to stop the construction of new wells, restore the desert vegetation, and forget about the new alfalfa fields.

The *Cuatrociénegas* case clearly illustrates the difficult choices that have to be made when scientific knowledge about the connectedness of aquifers is still incomplete. On the one hand, the increase in demand brought about by economic growth and trade puts pressure to open new irrigation fields as soon as possible, proceeding without delay especially if there is no evident connection between aquifers. On the other hand, the precautionary principle would dictate that any decision regarding the authorization of additional extraction should wait until more information is generated. Mexico is dedicating resources to research through institutions like INE, IMTA and the SEMARNAT - National Council for Science and Technology (CONACYT) research fund, so information should be becoming available with time. Nevertheless, a larger budget dedicated to these critical issues would certainly help shorten the wait. However, common sense and the search for economic efficiency are the best way out of the conundrum. In the first place, if electricity was priced at its real production and distribution costs then fewer wells would be profitable, and a decoupled subsidy could be used to increase efficiency in the current ones. Finally, if the policy was not to let any aquifer become overexploited, then there would be economic benefits to current and future users as a group while society is assured that no damage is done to any biodiversity-valuable conservation aquifer in case they are connected. True natural resource scarcity needs to be taken into account by firms and consumers to bring about the changes in behavior and tap into human ingenuity so growth will bring more welfare to the people without compromising the future generation's capacity to do the same.