AGRICULTURAL WATER QUALITY AND WATER USE: DEVELOPING INDICATORS FOR POLICY ANALYSES

Analysis of the Irrigation Status and Agricultural Water Uses for Sustainable Development in Northwest Mexico

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The key parts of the Report are as follows:

Recommendations and Summary of Discussion

1. **Plenary Opening Presentations**
2. **Plenary Session 1: Water Quality Indicators**
3. **Plenary Session 2: Water Use Indicators**
4. **Field Trip Guide to Miryang Dam and Bakdal Reservoir**

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ANALYSIS OF THE IRRIGATION STATUS AND AGRICULTURAL WATER USES FOR SUSTAINABLE DEVELOPMENT IN NORTHWEST MEXICO

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Abstract

In northwest México, an adequate supply of clean water is the most important pre-condition for sustaining life and for achieving sustainable agriculture. Despite the important role water plays in the development of Mexico, the commodity has an uneven distribution. in time, quantity, and quality. The unfair distribution has resulted in many areas in the region, experiencing water shortages. The situation became worse by the fact that many regions in Mexico have started experiencing water scarcity, specifically in the arid zones. Predictions are that by 2010 most of semiarid zones of Mexico will experience water scarcity. The lack of water will severely affect the society and economic development. Primarily, competing users within northwest México include industry, tourism, agriculture and domestic supply. However, about 90 per cent of water is destined to agriculture. The high demand for water for agricultural use is a consequence of the increasing population, leading to over exploitation of water, both, for agriculture and domestic use. Predictions are that demand for water will increase dramatically. Feeding this population will place large demands for irrigated agriculture, but sustaining this expansion will become difficult. The focus must, therefore be based on a sustainable use of water in irrigation. There is some evidence that an appropriate organization will guide the society towards a sustainable use of water, an example here, being the Irrigation District No. 66, of the Sto. Domingo Valley. In this irrigated area the users of available water are voluntarily organized in a private association of groundwater well holders. A conclusion is that organizations of consumers and producers within the hydrological unit will hold the key for sustainability.

Key words : Northwest México, water availability, consumptive use, water depletion, arid zones.

Introduction

In northwest México as in the rest of the world, human survival depends on water. Therefore, adequate supply of clean water is the most important pre-condition for sustaining life, maintaining ecological systems to support that life and for achieving sustainable development. Despite the important role water plays in the development of Latin-American countries, the commodity has an uneven distribution in time, space, quantity, and quality. The unfair distribution has resulted in many areas in the region, experiencing water shortages, while majority of the population pay increasingly high price for water or the lack of it.

The situation is made worse by the fact that many Latin-American countries have started experiencing water-stress or scarcity conditions, specifically in the arid zones where the population cannot be long last sustained with the available water resources. Predictions are that by 2010 more than 10 Central and South American countries will experience water scarcity. The lack of water will severely affect more than 200 million of the population within this region; constrain food production, environmental protection and economic development. In view of the water situation in our countries, we cannot therefore fail to recognize the important role water plays in sustainable national development in every country. Lack of sustainable water use will therefore result in, socio-economic development that is restricted over the long term, socio-economic and political conflict, due to a lack of or scarce resources and therefore hunger and poverty; particularly in areas that lack water. Sustainable use of our water resources plays a crucial role in development of various sectors of our economy.

Study site

Climate

Climate in Baja California Sur is dry, with a rainy season in summer; precipitations from August to September are due to the effects of tropical storms by the Pacific side of Mexico (Díaz *et al*. 1994). The expression of aridity is highly evident for some seven months, from January to July (Troyo-Diéguez *et al*. 1990). The weather data (temperature, evaporation and precipitation) used in this study for La Paz an the other municipalities of B.C.S. (México) were obtained from the División Hidrométrica de Baja California Sur, of the Comisión Nacional del Agua (CNA 2000). In its turn, CNA collects this information from the available weather stations (García 1981). Similar sets of data for Guerrero Negro, in the Mulege County, were obtained from the historical reports of the weather station in the 'Agricultural Project', in Guerrero Negro B.C.S. (México), 650 km north La Paz City. Other international data bases were consulted (NOAA 1997a,b).

Water resources

Water is the key resource to Northwest México development. On a regional scale, the commodity is abundant in some places but very scarce in others, but it has an uneven distribution by nature. At a continental scale, northwest México is significantly disadvantaged in comparison with the other regions of Central-America with regard to its endowment of water resources. Therefore, the lack of water represents a severely constraining factor of development for this region, where the economy depends largely on agriculture. The lack or regularity of water resource management in northwest Mexico has therefore resulted in desertification, soil degradation, salinity, growing poverty and rural exodus. A situation that has kept several rural zones in northwest México in a state of socio-economic instability and therefore reinforced México's dependence in some way on more developed countries. The management of the resource has become one of México's highest priorities.

The geography of the region predicates a variable climate, with extremes of precipitation and temperatures and considerable variability. The region covers an area, which includes both desert and tropical weather conditions. Precipitation in this region occurs in terms of the distance away from the equator. This varies over North and Central America from near 1500 mm/year at the southern States of México to just around 150 mm/yr in the northwestern Mexican region (Budyko 1974). There is an extreme climate variation especially away from the equator, with a large portion of the country consisting of semi-arid and arid zones, with 200-800 mm/yr, mostly experienced in a single rainy season (Bailey 1979). In the specific case of Baja California Sur, the mean annual renewable water resources totals about 88 million $m^3 \cdot yr^{-1}$ of which about 90 per cent is ground water. The aridity in this State reaches a high degree from March to July.

There are however, four water sources in the region: Rainfall, the seasonal stream or river basin systems, groundwater and the fresh water available in dams. Most of the water originates from rainfall, which in most cases is erratic and unreliable. Most of the seasonal streams flow from the Sierra de La Laguna mountainous chain. Baja California Sur, one of the most critical states in Mexico from the hydrological viewpoint, has no permanent rivers but only one, the Mulege River. In this State the surface hydrology is described by seasonal streams with catchments accounting for some 10,000 km^2. These flow out of the highlands in the upper portions of the basins towards the agricultural valleys and plains. Because of some seasonal tropical storms the region also has short-term streams located around the region, of which, most of them are lost unto the sea. These streams play an important role in the groundwater recharge. But with over 50 major water basins exploited by agriculture, most of the water in is shared by many kinds of producers with very few and mostly unknown agreements on equitable use, technological development or environmental protection. There is some evidence that an appropriate organization will guide the society towards a sustainable use of water, an example here, being the Irrigation District No. 66, of the Sto. Domingo Valley. In this irrigation district the users of available water are voluntarily organized in a private association of groundwater well holders.

Groundwater resources

Groundwater resources in the region are widespread but with very limited possibilities to increase. A large percentage of the population uses groundwater as their main sources of supply. However, the importance of groundwater in the region is still underestimated, since aquifers buffer rainfall variability has continued to provide reliable sources of potable supplies. Substantial renewable ground water reserves are limited to sedimentary aquifers along the major hydrological basins and in coastal deltas and plains. However there is a real need to better understand and manage the groundwater resources since their development could be the main key to managing rainfall variability and drought in some parts of the region. However, northwest México's water resources endowment is particularly difficult to manage effectively, leading to a dimension of complexity. The endowment needs to be adequately managed and therefore adding a special challenge (Gill 1991). Though some limited surface water resources may be appearing to be attractive to certain degree for reservoir developments, there are difficulties, and which some of them appear to be the following:

(1) High rates of evaporation, **(2)** environmental constraints in some areas, **(3)** large capital investments needed, **(4)** management of water resources is in some way dependent on political decisions and implications, tension and, interference, and **(5)** over governance is a common feature within these States, in terms of accountability, rule of law, and transparency.

Water resources development difficulties are also prevalent and in most cases are to do with, poor quality in many of the localities, due to saline intrusion and chemical pollution. An evident danger of depleting non-renewable resources (mining), large number of boreholes needed and low success rates in striking water. As demands for water increases, wastewater re-use is another source that will have to be studied, and where the return flows may either be recycled as a conventional source. The use of recycled sewage water is now accepted and promoted in tourist regions, such as Los Cabos, in Baja California Sur State, and San Carlos, in Sonora State. Several localities within this region that are short of water will have to shift largely from fresh or recycled water for agricultural purposes early this new century.

Socio-economical and environmental reasons to manage water in Northwest México

Water is a vital resource as human survival depends on it. Conservation and careful management of the water resource is a matter of necessity and great importance. At present, many people in some disperse rural areas in the study region have no access to safe drinking water. Majority of these people are the rural poor-paying gradually more for water services, while suffering the most in terms of health and economic opportunities.

Water is a commodity of strategic importance in the arid zones of northwest México. The availability of the commodity for both household consumption and other economic uses is closely associated with poverty reduction and food security. Therefore limitation of water availability to the majority in the region, will severely disrupt both socio-economic and health status of the population. The increasing population in northern México, estimated at 2.4 per cent annually, will further put greater demand on water, with industry, agriculture, energy and municipalities competing for the same resource. Agriculture will require more water for irrigation to achieve food security. Yet, water stress and access, have been already experienced in many areas in the region, with the predictions that the imbalance in demand and supply will place about 40 million Mexicans in areas of water scarcity. Because of the increasing demands, rising costs and diminishing water supplies, developing sound water resource management will be crucial to the region's socio-economic and environmental goals to benefit present and future generation. New options, such as desalinizing systems, will have the highest priority for research and development.

Currently, there is a generalized lack of awareness of the state of water resources in terms of quality, availability and demand. Furthermore, the users underestimate its economic, social and environmental value. In this sense, it is clear that the management aspect of water has not been emphasized enough. Most people have taken the resource for a granted or subsided good, unaware that water is a finite resource, with supply constraints, and scarcity value, and that therefore they should pay for.

Water users and conflicts

Primarily, competing users within northwest México include industry, agriculture, tourism and domestic supply. However, about 90 per cent of water is demanded by irrigated agriculture. The high demand for water for agricultural use is a consequence of the increasing population that demands for more food production, leading to over exploitation of the water resources, both, for agriculture and domestic use. Predictions are that demand for water will increase dramatically. Feeding this population will place large demands for irrigated agriculture. Sustaining this expansion will become difficult. On the other hand, the noticeable development of tourism will increase the water demand for this activity. The focus must, therefore be based on efficient and sustainable use of water in existing irrigation systems in order to reduce the water requirements.

Methods

Socio-economical survey and estimators were applied in order to estimate and measure some of the main parameters about the irrigation status and the agricultural water uses in Baja California Sur, in northwest México; also, relevant data was obtained from gubernamental offices. The methodology used to calculate the water resources of the region varied from locality to locality, according to the different activities in response to the microclimate variations.

In general, according to the available information, the water resources balances were estimated mainly on the basis of groundwater extraction, data from weather stations and some surface water flows measured at hydrometric stations. In this semiarid region, withdrawal for agriculture and other uses usually represents a significant percentage of the total water resources, as the difference between recharge and extraction is in many micro-regions highly creditable. This is the case in several arid and semi-arid zones where such withdrawals average an important part of the renewable water resources. In general, the information collected shows that the water resources balances take into account groundwater resources and frequently refer to exploitable water resources and evidently to the annual recharge. Additionally, the validity of estimated groundwater recharge, in some of the micro-regions, based on a global infiltration coefficient applied to the average annual precipitation, is variable. The hydrological regions of the Baja California Sur State are shown in Figure 1.

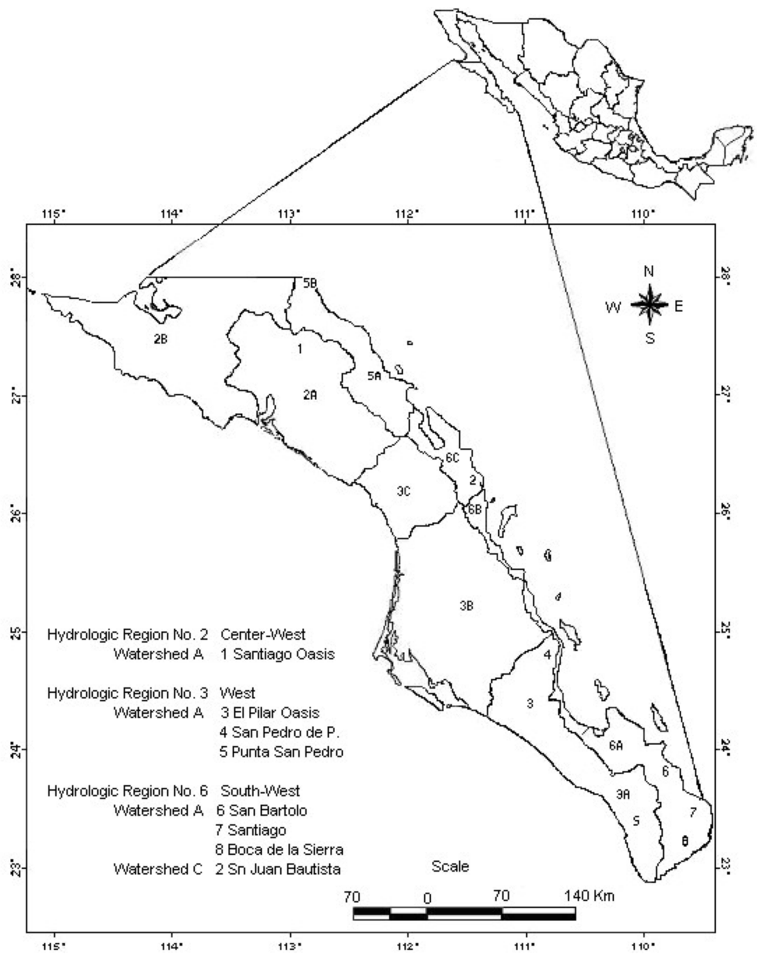

Fig. 1. Hydrological regions within the Mexican State of Baja California Sur, México

The wide range of micro-climates encountered in the region generates a spatial variety of hydrological regimes. As a result, the region shows an uneven distribution in precipitation, water resources and water use conditions. In the sub-humid areas, by the southern portion of the Baja California Peninsula, water management has always been directed toward the oportune use of seasonal streams, and also for flood control and protection. On the other hand, in the arid areas, by the middle portion of the mentioned Peninsula, the hydrological studies have been oriented much more towards water resources assessment. The methodology of the consistent hydrological balance was applied in estimates of hydrological contributions and demands potentials of the use of water (Hiriart and Monobe, 1980). This estimates were based on the area of the reception basin, which was considered with base in the topographical maps 1:50,000 (INEGI 1996), annual precipitation (obtained of the nearest climatological stations), and socio-economic factors, in accordance with Hiriart and Monobe, 1980. With the obtained data, the average net available volume of water was calculated. The calculated demand was compared with the estimate of the contributions, with the objective of carrying out the hydrological balance; this fundamental hydrological information was obtained to evaluate if the volume of water contributed to the reception basin is in hydrological balance or in over-exploition.

Results and discussion

The climatic characteristics of the region generate strong inter-seasonal and inter-annual differences in water resources. Meteorological phenomena such as *El Niño* or tropical storms and hurricanes along the Pacific coast of México (Nicholls 1985), specifically afecting the southern portion of the Baja California Peninsula, alternate with lengthy drought periods, not only in the arid or semi-arid areas but also in the sub-humid zones. As a consequence, the annual or monthly average estimates of water resources seem to be generally poor indicators of the water resources availability (James & Burges 1982). The use of aridity indexes seems to be a reliable method to assess the climate variations in arid zones (Stadler 1987), specifically to prevent droughts in advance.

In terms of the regional water resources, the region is characterized by a high percentage of water resources destined to the agricultural producers, for extensive and intensive production systems, more than two thirds of the total water resources of the region. The computation of water resources was complex in the case of the many rural villages spread all over the region, situation that is common in other rural arid zones (Hiriart & Monobe 1980). In some micro-regions, large inconsistencies were observed in terms of runoff data of seasonal streams crossing different localities. Overall, this region in northwest México is obviously not well endowed with water resources for the different socio-economic activities and consequently can not ensure sustainability in this arid zone.

About the difussion and promotion of irrigation technologies

In order to save water for other activities different to agriculture, the Mexican Government has design financial programs to support the improvement of irrigation infraestructure. Despite the efforts that the government has been doing in relation the the transfer of irrigation thecnology, yet there is much to do to improve the difussion to a majority. In Figure 2 it can be observed that the efforts oriented through meetings with authorities and the direct communication among the producers themselves are the most efficient way of difussion of the new technologies for improving irrigation and water use.

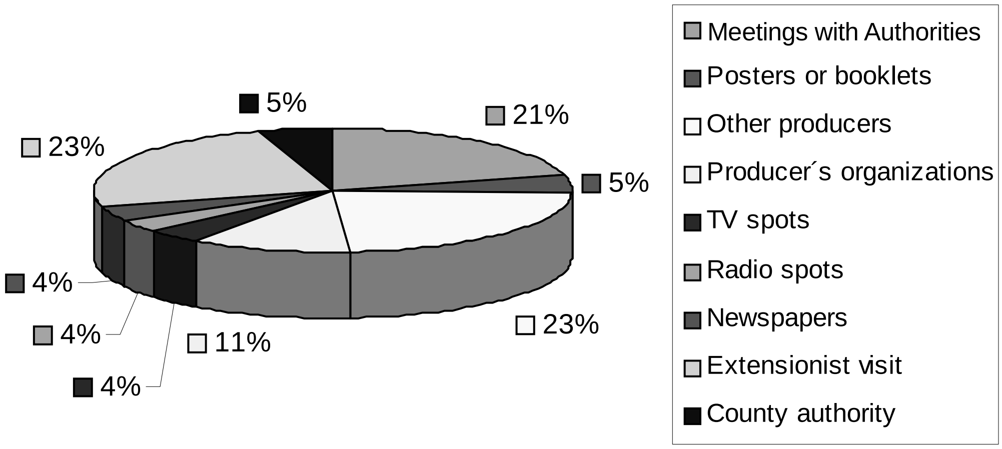

Fig. 2. Participatory efforts in the mechanisms of diffusion and promotion of irrigation and water related technology, Baja California Sur, México

Data about the water use in the Baja California Peninsula are observed in Table 1 and Figure 2; it can be observed in Table 1 and Figure 2 the distribution of the different types of water use. Traditional agriculture consisting in extensive crops, grains and forages, is the main cause of the significant amount of water required by this activity.

Table 1. Synopsis of the water use in the Baja California Peninsula and related States, according to the consumptive use Unit : Mm^3/yr

Water use	Baja California	Baja California Sur	Peninsula (total)
Agriculture	1830227	6450	1836677
Domestic	74	1914	1988
Multiple (industries)	164	425	589
Livestock	809	2403	3212
Urban (public)	146640	421	147061
Services (county)	28	129	157
Total	1977942	11742	1989684

Source : Oficial Data Base Of Repda And Additional Information From The Administrative Office Of Grpbc.

In Table 2, an approximation of the hydrological balance in terms of the estimated internal renewable water resources is presented. It can be noticed the extremely low availability of water for the Mexican State of Baja California.

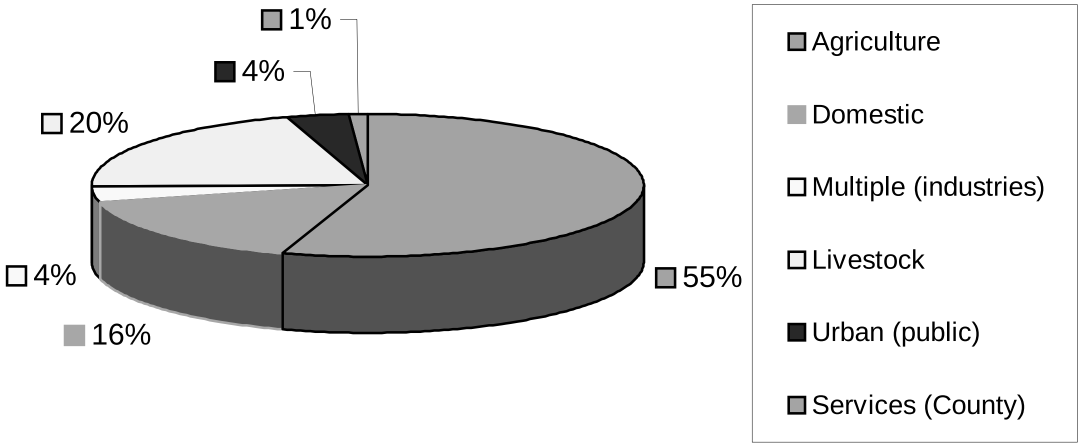

Fig. 3. Water uses in Baja California Sur, México

Table 2. Regional distribution of internal renewable water resources in Baja California Sur as compared to the regional parameters

Region	Mean annual		Internal renewable water resources/yr	
	mm	Km^3	Km^3	M^3 per inhabitant/yr (2000)
Baja California Sur	130	9.36	3.10	35
México	772	1,512	409	4,338
Central América	2,395	1,194	6,889	20,370

Conclusions

According to the observed hydrological and socioeconomic evidences, water resources generated from endogenous precipitation (surface runoff or groundwater recharge) should not be used as water availability indicators because they do not consider trans-boundary flows, and available estimates do not consider water consumed by natural vegetation (forests, range lands, bush lands) which may by huge amounts in some micro-regions and localities of the study region. the actual renewable water resources was used here as an approximation of the sum of the internal renewable water resources plus naturally incoming trans-boundary flows minus naturally outgoing trans-boundary flows. However, the actual renewable water resources also should not commonly be used as a water availability indicator because it does not consider evapotranspiration from natural vegetation (if exists).

Irrigation potentiality and limitations

The irrigation potential for the region is estimated at 60,000 ha, taking into account only the micro-regions for which data were available. Sixty-six percent of this regional irrigation potential is located in four irrigation districts: Sto. Domingo, La Paz-Carrizal, El Vizcaíno, and Los Cabos. The methods used to estimate the irrigation potential vary from locality to locality, which makes comparisons difficult. These methods usually take into account the climatic conditions, as well as the land irrigation suitability. Studies where water resources, surface and groundwater availability, as well as efficiencies according to irrigation techniques, are considered scarce. Additionally, only in some micro-regions, the economic, social and environment characteristics are considered for the assessment of irrigation potential. In some cases, additional facts were found in factibility studies or in projects, which gave a more realistic idea of possible irrigation expansion on a short to medium term basis. Outstanding is the low irrigation potential in relation to the total area of the La Paz and Mulegé counties.

Irrigation development

In most micro-regions and localities within the region, irrigation development occurred during the last century, particularly from the 1950s. Although the increase was steady from 1961 to 1997, a regional recession was observed from the mid 1970s to late 1980s, which contrasts with the high increment ratios of the 1960’s. At a bigger scales, the causes of stagnation during the 1970s are similar to some countries such as Argentina, Chile or Mexico. Only Brazil registered a continued increment of the area under irrigation during that same period. Baja California Sur had a similar tendency to that one of northern México. In the majority of the productive micro-regions within the region, irrigation is seen not only as an important means to increment productivity and intensify and foment crop diversification, but esentially the only one, hence became a focal objective of most agricultural policies of all the government scales in the region. About the scarce surface waters, different dependences related with the hydraulic sector have carried out efforts to take advantage of this source of water, represented by oases. However, this works have not been enough, in number and space distribution, to avoid the drastic depression in the availability of the hydrological resource, due to the droughts of the last years and to the increase in the demand of the water. In rural villages, the oases sustain agricultural activities, although through a restrictive use, because of the low availability of water. According to the features mentioned above, changes should be promoted in the pattern of cultivations by those of smaller consumption of water and those which allow the use of treated residual waters.

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