Water Allocation Strategies and their Implications – A Drought in the Limarí Watershed, Chile

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Introduction

Natural risk exposure can be measured by frequency and gravity of natural events and by the degree of the negative impacts or effects on "stakes" or resources. The drought characteristics (e.g. intensity, duration) are depending on physical properties (elevation), hydraulic structures (e.g. conveyance, reservoir) of the area as well as demand in the area under consideration. Therefore it differs among the irrigation sectors. For a similar event, levels of impacts are different and thus the vulnerability associated to each sectors.

The degree of negative impacts can be mitigated by stakeholders capabilities (here farmers and Water Organizations) to confront the event. The risk is determined by the probability to be exposed to an event and by the capabilities to adapt conducts in front of this event. The resources that one can develop in order to protect or mitigate the negative effects can help to determine degree of vulnerability against a drought.

Drought indices facilitate detection of drought conditions and thresholds to activate drought responses. They differ due to the kind of droughts, e.g. meteorological, agricultural, hydrological o social drought. It is important to underline that the vulnerability, and so the risk levels, can change with time and location. Vulnerability is also linked to other technical and organizational aspects. The question now is what other variables could be taken under consideration in order to consider the multidimensional aspect of vulnerability, and, indeed, of risk.

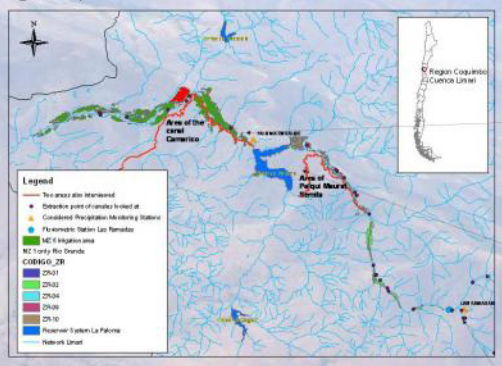
A lot of different indicators or component to evaluate vulnerability has been developed and used in order to characterize the 1993-1997 drought in the Limarí catchment. Here only indicators directly to the exposure to the drought under analysis are being discussed in more detail; these are for example: historical precipitation and discharge data, irrigated area, demand and demand-satisfaction, supply (allocation) system, access to other sources of water (in particular to subterranean water), possibility for participation in the spot water market, the storage capacity – individual as well as organizational – for each analysed sector.

Objectives

- Classify the last severe drought (1993-97) in the historical context, investigate if the drought characteristics differ depending on the location in the catchment and quantify the differences
- Quantify the negative impacts due to the drought in terms of demand satisfaction in the studied areas (comparison upstream and downstream of the reservoir)
- Analyze farmers capabilities of response during this event (private strategies and Water Organizations decisions) in order to characterize the different sectors vulnerability to drought.

Study Area: The main river course of the Limarí watershed

The province of Limarí is located in the semi-arid North of Chile. The normal average annual rainfall does not exceed 120mm and the potential evapotranspiration exceeds 1,000mm. Nevertheless, the main activity in the catchment is irrigated agriculture which is possible through a regulated hydrological and social system known as the "La Paloma System". This technical and social system of water allocation is in operation since 1972. It is physically composed by three reservoirs, storing 1,000MCM, and the associated channel network.
Furthermore the existent legal issue about the properties and differences in water rights are integrated in this analysis, since the spot water market (water volume market, during the growing season) has been an important mitigation possibility at both organizational and individual level.
An important part of the irrigated area dedicates its production to pomiculture for exportation; just a small part is used for annual crops. Nine different private organizations as well as the State are participating in the management of the Paloma System; in this context integrated water management is quite complex.
The study is concentrated only in the main river course, the Rio Grande. The analysis starts In the unregulated area from the first monitoring station (south-eastern part of the map) until the regulated part of the river downstream the reservoir.



Map: The study area under consideration



Pictures: above: Rio Grande downstream the reservoir, middle: Palqui Area; bottom: Las Ramadas

Methods

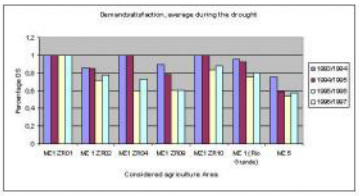
Drought Characterization and probability of occurence	Quantifying the impacts of the 1993-97 drought	Response of the farmers which are the main actors
•Site drought identification /characteristics: **run method by REDIM** software[1] has been used •Two sites has been analyzed (see map): 1. Headwater station Las Ramadas: precipitation records: 1949 – 2006 and discharge records form 1962 – 2007 2. Downstream La Paloma station: only the precipitation records were available •Threshold: preliminary with the median of the samples, afterwards the demand satisfaction of 80% due to the model results of MAGIC[2] has been used. •Indices: Duration (years), Cumulated Deficit (mm/event), Intensity (mm/year) •Return period according to the run method	•Farmers mitigations to the diminishing water availability has been modeled with MAGIC. The lower part of the study area MZ5 has been compared with MZ1 along the Rio Grande (administration of the JVRL: Junta de Vigilancia Rio Limarí) •Real discharge data (in case available) were used, if not, demand was calculated (cultivation, irrigation efficiency etc.) •The results here shown are the results of the base scenario to reflect the demand satisfaction due to •the historical management •economic efficiency of the areas has been compared	•108 Water right owners of different canals have been interviewed •The sample was realized with the canals cadastre. Statistically based, the sampling permits to have a representation of all irrigation sectors and all types of farming systems (multinational fruit exporters, Agrarian Reform farmers, peasants and medium sized entrepreneurs). •Characterization of farming systems •Responses (mitigations) to drought (individual and organizational), post reactive strategies and eventual strategies

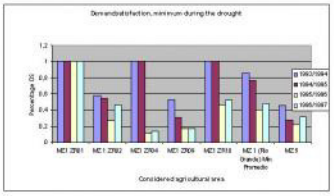
[1] Regional Drought Identification Module (REDIM), Extended Version (2005.3), July 2006 Department of Civil Engineering, University of Catania, Italy

[2] DGA (2005): MAGIC Version V 1.9sp, Direccion General de Agua (DGA), 2005; Copyleft 1996 – 2005

Results: Quantification of the impacts

Region	Characterisation	Max Demand m³/sec	Irrigation area (Ha)	Water source
MZ 1 ZR01	unregulated	0,113	42,14	Rio Grande
MZ 1 ZR02	unregulated	1,770	931,87	Rio Grande
MZ 1 ZR04	unregulated	0,680	658,41	Rio Grande
MZ 1 ZR09	unregulated	0,267	155,77	Rio Grande/Rio Rapel
MZ 1 ZR10	unregulated	0,527	591,03	Rio Grande/Rio Rapel /Rio Ponio
MZ 1 sum	unregulated	3,830	2379,22	
MZ 5	regulated	7,043	6010,13	Rio Grande/La Paloma





It can be seen, that the demand satisfaction (left: average values, right: minimum values during one year) is higher in the upper (unregulated) part, which can be explained by a smaller irrigation area as well as less demand. Furthermore it is quite variable (inter-annual variations also in the regulated part). Interesting also is that in the last drought year the demand satisfaction went up again, possibly due to the rainfall which occured in the second half of the year 1997 and also a result of farmer responses.

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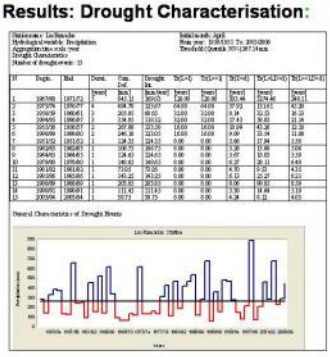
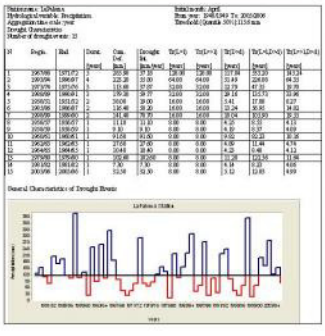
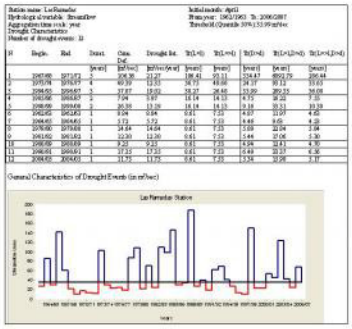
Results: Drought Characterisation:







Tables have been ordered by drought duration, which show that actually the drought from 1994 until 1997 has been the severest since the Paloma System starts operating in 1972. Looking at the second station under evaluation (La Paloma, regulated), the threshold for calculation has been set as well to the median of the samples, which leads to 115.6 mm/year. The results express the characteristics of a hydrological drought. The drought characteristics follow in general the pattern as described before, but started one year earlier (in total four years) than in the upper catchment. Nevertheless the operational model permitted in this year the full assignment of water. The Paloma System regulation effects delayed the hydrological drought impacts. The agricultural drought responses are therefore expected later.

Results: Farmer Responses

•Elasticity of the system: Some farming systems (pasture plantations, vegetable crops, traditional crops as wheat and potatoes) permit to adjust plantation superficies to the annual assignation or let dry plants which represent less value (profitability). 58 % of the interviewed farmers decided and were able to resist to the drought reducing its irrigated surface; this strategy was mainly combined with the strategy of "maintenance irrigation" whose aim is "keep alive" or maintain permanent crops (fruit trees) that represent more investment and added value.

•The participation in the Spot Water market was a punctual strategy to cope with the drought. Most of the farmers who start participating in the "Spot Water Market" during the drought period are still participating today. It is now a permanent strategy, used to increase the irrigated surface and/or to secure the irrigation during the peak period. Many of the new investments done in the Limarí catchment are sustaining their irrigation system on volumes they acquire trough the Spot Water Market.

•These strategies are partially called into question. Due to the economical conditions (less profitability), reducing the irrigated surface would be less sustainable now. The temporary movements of the points of extraction are not contemplated in the Water Code. Some conflicts are questioning these movements. At the end, it is the flexibility of the Paloma System that is called into question. And thus its resistance capability.

• Drilling is considered as a risky strategy: it is impossible to know the real flow and the time it would be still available. Futhermore, energy costs are considerate as strong limit of this strategy.