NeWater

DEVELOPMENT OF AN INTEGRATED AGRO-ECONOMIC-HYDROLOGICAL MODELLING FRAMEWORK.

Vulnerability analysis and adaptive capacity of different policy options, linking agricultural and water policies

Report of the NeWater project -
New Approaches to Adaptive Water Management under Uncertainty

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Preamble

This report has been completed at the Universidad Politécnica de Madrid (partner nº 38, involved work package 1.7), together with the Stockholm Environmental Institute – Oxford (partner nº 8, involved in work package 2.1), (Thomas E. Downing and Sukaina Bharwani). Some parts of the work (especially the stakeholder meetings) leading to this report have been carried out in close collaboration with other NeWater partners, especially in the framework of the continuous and close collaboration with the Universidad Complutense de Madrid (UCM) and the Geological Survey of Spain (IGME). We gratefully acknowledge their contribution. We would also like to thank all stakeholders who have participated in the process for the time and effort dedicated to this research, especially the Guadiana River Basin Authority and the Irrigation Communities of the La Mancha Aquifer in the Upper Guadiana.

We would also like to gratefully acknowledge the support of the European Commission in providing funds for this research and to the Spanish Ministry of Education and Science for providing complementary funds for this project.

This report is largely based on the paper: Varela-Ortega, C, P. Esteve, S. Bharwani, T.E. Downing (2007): "Public Policies for groundwater conservation: a vulnerability analysis in irrigation agriculture" presented at the CAIWA Conference (International Conference on Adapative and Integrated Water Managemente) to be held in Bassel Switzerland from 12th to 16th November 2007

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Policy Summary

Overview

This report covers the research work carried out in work package WP 1.7 by UPM (in collaboration with SEI, WP 2.1) of the NeWater project. The general objectives of UPM research are the development of a conceptual framework for integrated water resources management and adaptive capacity to the Guadiana river basin in Spain. On this purpose, it investigates, with the involvement of stakeholders, different strategies that can be followed to make management regimes more responsive to changes.

More specifically, deliverable D1.7.6c contributes to task 1.7.6, which comprises the development of an integrated agro-economic-hydrological modelling framework for analyzing policy scenarios, both agricultural policies and water policies linking water and agricultural policies and vulnerability of irrigated farms. This model has been applied to the specific case study of the Upper Guadiana river basin in the central plateau of Spain. A prototype of the agro-economic model was built during the first phase of UPM research in NeWater (see deliverable D1.7.5b). During the last year, further field work has been carried out, extending the area of study to 5 additional irrigation communities. Furthermore, compared to the first modelling structure, the subsequent research developments have permitted a more elaborated analysis focusing on farmers' vulnerability to water conservation policies.

The challenges of water management in the Upper Guadiana

In the Mediterranean basin, irrigation agriculture is a key sector of the economy but it consumes a large proportion of all available water resources, in countries where water is scarce. One example of this situation is the Upper Guadiana Basin, situated in the Spanish southern central plateau. In this region groundwater has been the major driver for developing irrigated agriculture and hence for sustaining thriving rural livelihoods. However, this irrigation development led to the over-exploitation of the Western La Mancha aquifer and the deterioration of the valuable internationally reputed Ramsar-catalogued wetlands of 'Las Tablas de Daimiel'. Regional, National and European policies have been implemented on the purpose of solving these conflicts, but the solution has not been found so far.

In addition, the region is affected by nitrates pollution which makes it necessary to implement a special program for nitrates vulnerable zones, in order to comply with the Nitrates Directive.

Objectives and methodology

The aim of this research is to contribute to explore the potential of establishing a participatory stakeholder-based adaptive water resources management (AWRM) regime in the UGB by focusing on the vulnerability of the private agrarian sector to water use limitations and to the public sector policy enforcement.

For this purpose, the methodology developed (section 3) is based on the combination of qualitative and quantitative methods. The quantitative stage consists on the elaboration of an integrated agro-economic and hydrologic model (section 5). Several policy scenarios have been chosen and simulated, in order to get the impacts that the different policy options would have on the different components of the system. The policies analyzed are: (i) the Water Abstraction Plan (water quotas policy), implemented in the Upper Guadiana Basin to recover the overexploited Western la Mancha Aquifer, and (ii) the Nitrates Directive, included in the environmental Statutory Management Requirements of the Common Agricultural Policy's cross-compliance scheme.

Results from the economic model are one of the inputs for the economic vulnerability analysis (quantitative and qualitative) of different farm types (section 6). Vulnerability is determined through economic indicators which allow building a vulnerable farms classification tree (using the software CART). The tree identifies the main predictive variables for vulnerability. Finally, a qualitative analysis of farmers' decision making process is carried out by using Knowledge Elicitation Tools (KnETs) (section 7).

The different quantitative and qualitative analyses have been supported by a wide empiric work in the area of study (section 4).

Conclusions and recommendations

The present Water Plan of the UGB while responding to the EU WFD objectives will not meet the desired target of ensuring the good ecological status of the aquifer and revert it to its natural recharge level unless new institutional arrangements are put in place. Farmers complying with the water quotas have to face important income losses which make it difficult to comply with this policy.

The analysis of the impact of compliance with the Nitrates Directive in the region of Castilla La Mancha showed that the cost of compliance (measured as income loss) at farm level varies depending on farm types and the adaptive capacity of farmers to face the regulations. However, in every case, water limitations are more restrictive to farming activity than nitrogen restrictions.

The analysis of vulnerability in water resource planning is a key element in robust policy development. Techniques like CART and KnETs combine the drivers of vulnerability in logical rule trees that indicate critical thresholds that result in differential farms' exposure. The results show that the most important explanatory variables for vulnerability are farm size, rate of over pumping and policy enforcement impact index, being the smallest and legal farms the most vulnerable ones. This methodology shows the relevance of considering vulnerability and behavioural responses as core elements of an adaptive water resources management.

The results presented in this report show that there is a need of new institutional arrangements. Enforcing these policies require efficient and socially-accepted instruments as well as a transparent and participatory process of all stakeholders involved. Therefore, participatory adaptive water resource management is essential in the basin and must address the differential vulnerability of stakeholders.

Table of contents

Preamble i
Policy Summary ii
1 Context of the study 1
2 Introduction 2
3 Methodological Framework 4
4 Fieldwork analysis and selection of representative farm types 6
5 The economic model 11
6 Vulnerability Analysis 17
7 Farmers' strategies – the Knowledge Elicitation Tools Application 24
8 Conclusions 27
9 List of references 29
10 Annex I: Contributors to the report 32
11 Annex II: CART Classification tree 33

1 Context of the study

This report is the result of the collaboration of the Polytechnic University of Madrid (UPM) with the Stockholm Environmental Institute – Oxford (SEI - Oxford).

The first stage of this collaboration consisted on the use of the WEAP21 model for the development of a prototype model of the Upper Guadiana river basin, in a workshop held in Madrid, in the School of Agronomy of the Polytechnic University of Madrid, as part of the activities of the Newater project on June 26-30, 2006. This workshop was a first step of a planed cooperation between three teams of the Newater project, SEI (WB2) working in vulnerability and adaptive capacity, Universidad Politécnica de Madrid- UPM, responsible of the socio-economic analysis in the Guadiana basin (WB1) and the Universidad Complutense de Madrid (UCM) , coordinator of the Guadiana basin case study (WB3).

A second step in this collaboration was the Knowledge elicitation tools (KnETs) workshop and the Vulnerability and Validation Roundtable held at the SEI office in Oxford between the 12th and the 23rd of February 2007, with the objective of the application of the KnETs to the analysis of the farmers decision making process and the vulnerability analysis and validation techniques in the Upper Guadiana River Basin.

2 Introduction

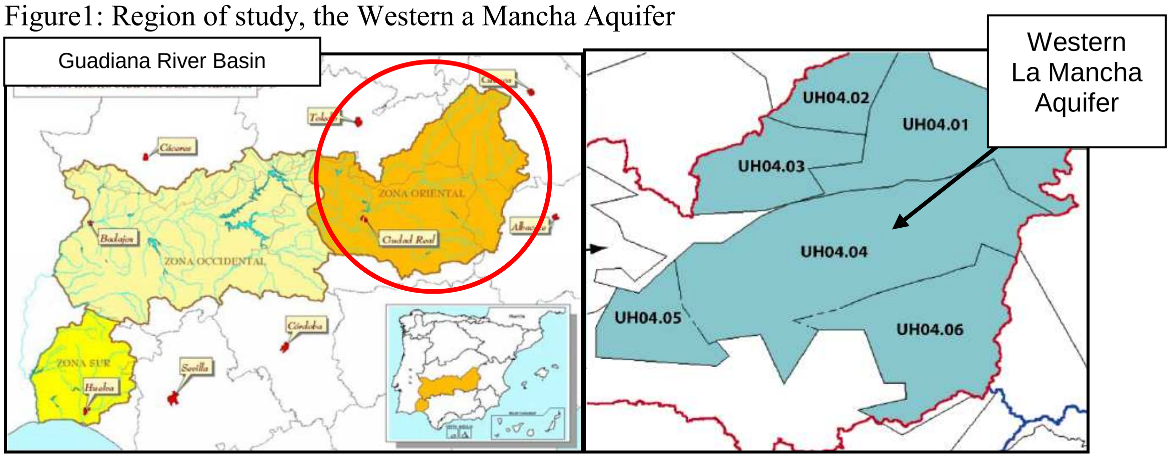
In the Upper Guadiana basin (UGB), situated in Spain's inland southern region of Castilla-La Mancha, groundwater has been the major driver for developing irrigated agriculture and hence for sustaining thriving rural livelihoods. Agricultural policy incentives to intensify production, together with an easy access, low infrastructure costs and high profitability, have encouraged individual farmers to invest in ground water irrigation transformations that have ensued impressive welfare achievements of a former stagnated region (Varela et al., 2007). However, this irrigation development has led to the over-exploitation of the Western La Mancha aquifer (in the Region of Castilla la Mancha) and the deterioration of the valuable internationally reputed Ramsar-catalogued wetlands of 'Las Tablas de Daimiel'.

The Water Management Regime (Water Abstraction Plan) launched in the area during the early 90's to recover the over-drafted aquifer, restricted water extractions and re-defined the previously established water allotment rights of the private irrigators by reducing substantially their entitled water assignments. This compulsory program establishes different annual maximum levels of water consumption depending on farm size, larger farms having the highest water limitations.

The implementation of the Water Abstraction Plan produced serious social conflicts which make it difficult for the Spanish authorities to be capable of fully developing the water use limitation policy, as farmers are not granted any compensation payments for their derived income loss and, hence, the social burden of the policy is supported directly by them.

Next Figure shows the area of study.

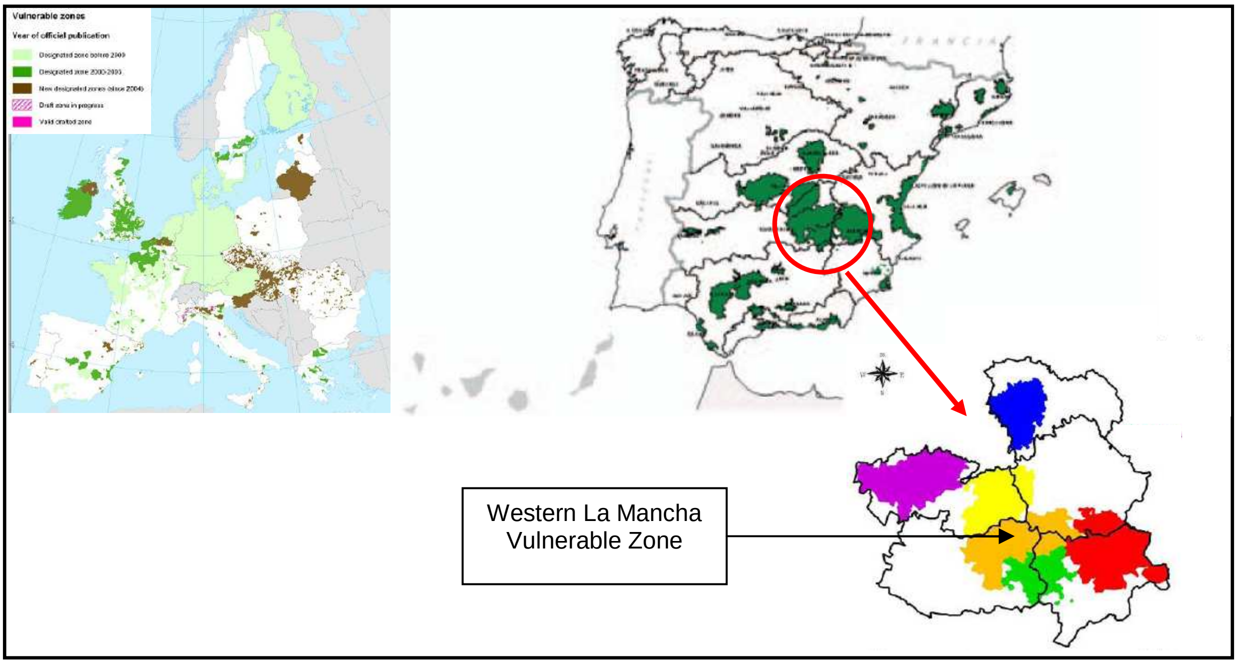
Figure1: Region of study, the Western a Mancha Aquifer



Source: Own elaboration from CHG (2007), Llamas and Martínez-Santos (2005) and IGME (1999)

In addition, the region is affected by nitrates pollution which makes it necessary to implement a special program for nitrates vulnerable zones, in order to comply with the Nitrates Directive. This measure is part of the Common Agricultural Policy Cross-Compliance, and its application is being difficult as farmers maintain that compliance with the Nitrates Directive is producing high income losses. The next figure shows nitrates vulnerable zones under study.

Figure 2: Nitrates vulnerable zones in Europe, Spain and in the Region of Castilla La Mancha

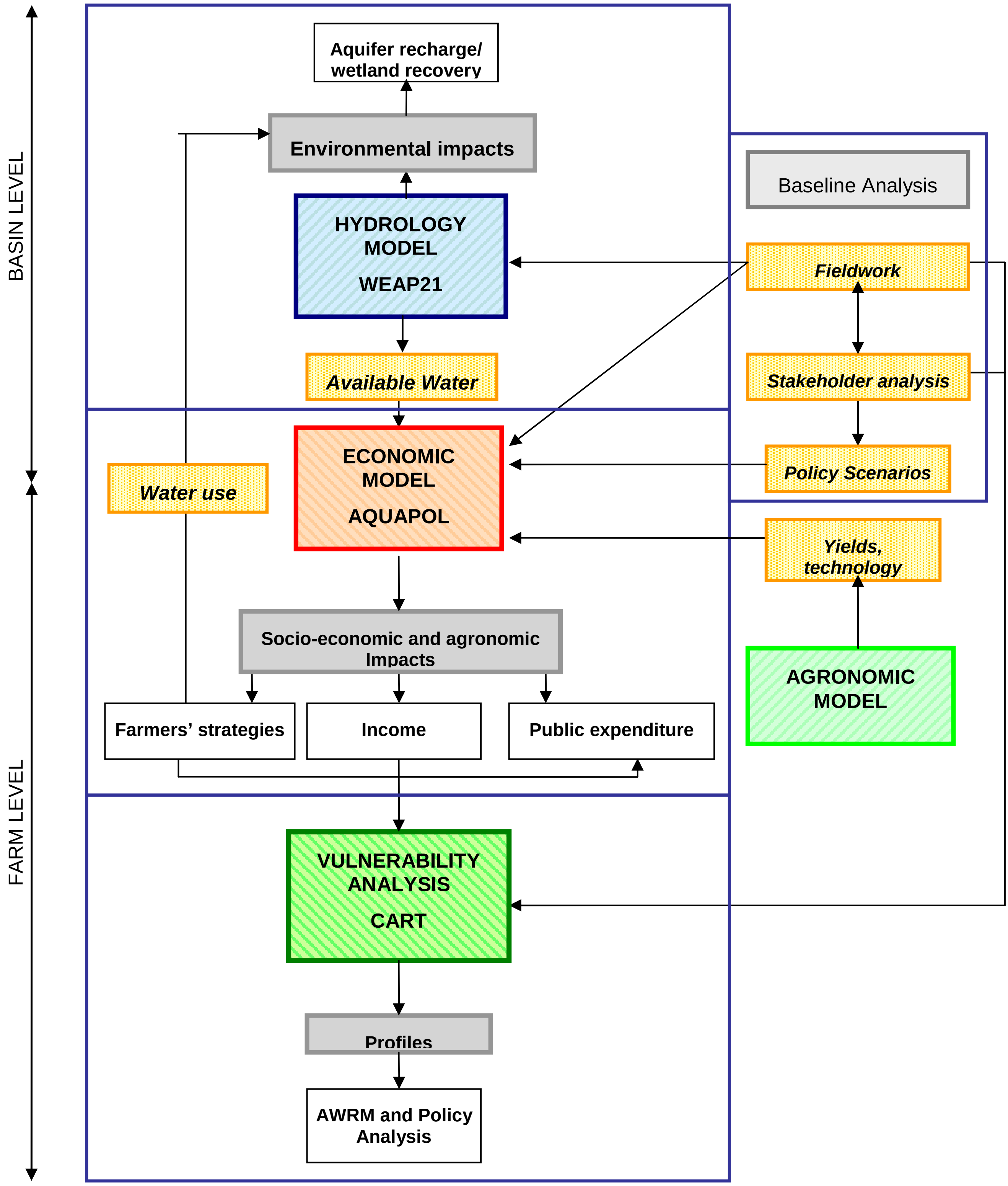


Source: Own elaboration from EEA (2007), MMA (2005) and ITAP (2006)

3 Methodological Framework

In this conflicting environment, the aim of this research is to contribute to explore the potential of establishing a participatory stakeholder-based adaptive water resources management (AWRM) regime in the UGB by focusing on the vulnerability of the private agrarian sector to water use limitations and to the public sector policy enforcement.
The research will focus in the analysis and understanding of how water policies that impose a strict water quota system affect different farmers, farm types, crop mix and technologies. How vulnerable different farmers will be to these policies, how they will cope with them and what will be their capacity to adapt to sharp decreases in water availability as well as to other restrictions in the use of production factors imposed by agricultural polices (i.e. nitrate contamination protection required by the new CAP). How the policy enforcement capacity of the water authority to impose the programmed water quotas will affect the vulnerability of the different types of farmers (legal and illegal drillings) is also one of the main questions in our analysis[1]
The methodology developed for this research is summarized in Figure 3 and is based on the integration of quantitative and qualitative aspects that allows obtaining richer and more ample results as well as deeper insights into the potential of new and adaptive management modes for the UGB.

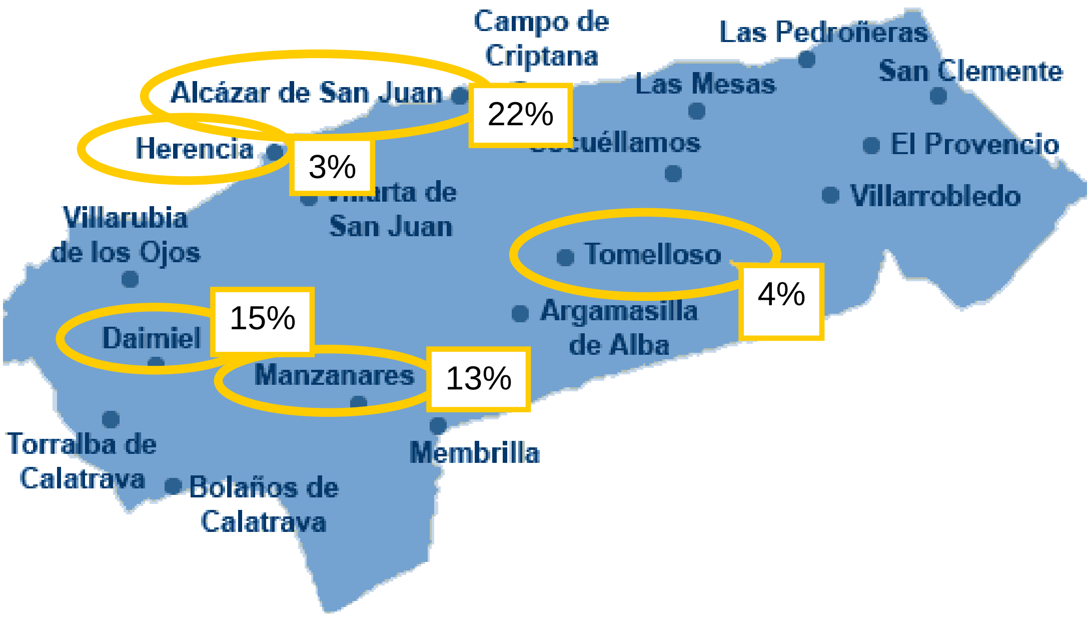
Figure 3: Methodological framework integrating hydrology model, agro-economic model and vulnerability assessment



4 Fieldwork analysis and selection of representative farm types

An ample fieldwork was developed in two phases in 2006 and 2007, in the Upper Guadiana River Basin, in five representative irrigation communities of the Western La Mancha Aquifer. The selected Irrigation Communities correspond to Alcázar de San Juan, Daimiel, Herencia, Manzanares and Tomelloso, which were selected regarding to their importance in the aquifer in terms of surface, and because of the different farm types they represent.

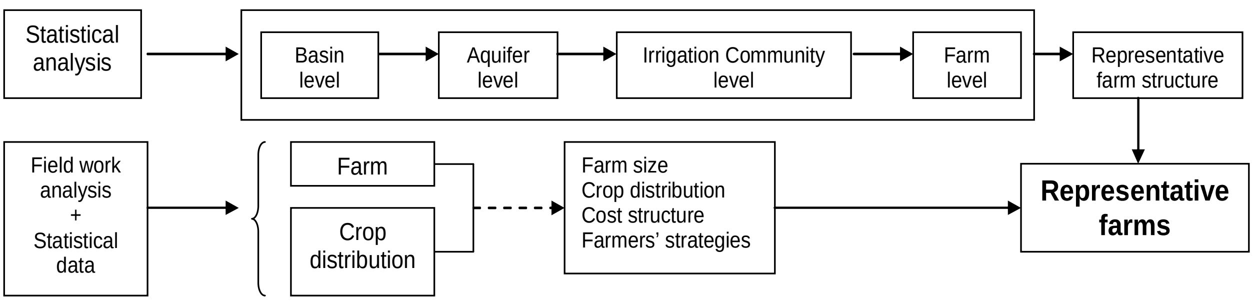
Figure 4: Selected irrigation communities and their relative weight in terms of surface



Source: Own elaboration from www.acuifero23.com

The fieldwork information is the base for the selection of representative farms together with the statistical data analysis. It is also a main input for the development of the economic model as well as for the stakeholder analysis, vulnerability analysis and decision making analysis.

Figure 5: General methodology used to determine representative farm types



The Irrigation Communities (IC) selected for the study are located in the province of Ciudad Real and their farm structure, cropping pattern and input use characterize largely the farming sector of the whole region. Specifically, the IC selected are: Daimiel, Alcázar de San Juan, Herencia, Manzanares and Tomelloso where an ample field work has already been carried out by Varela-Ortega et al. (2007b).

The next level of desegregation is the study of the agronomic zone. The five IC selected for the study belong to the agronomic zone of "Mancha" and its surface distribution has been considered for the definition of the farm types. Several ICs have been selected since there are different farm types' profiles that represent the farm diversity in the Upper Guadiana basin.

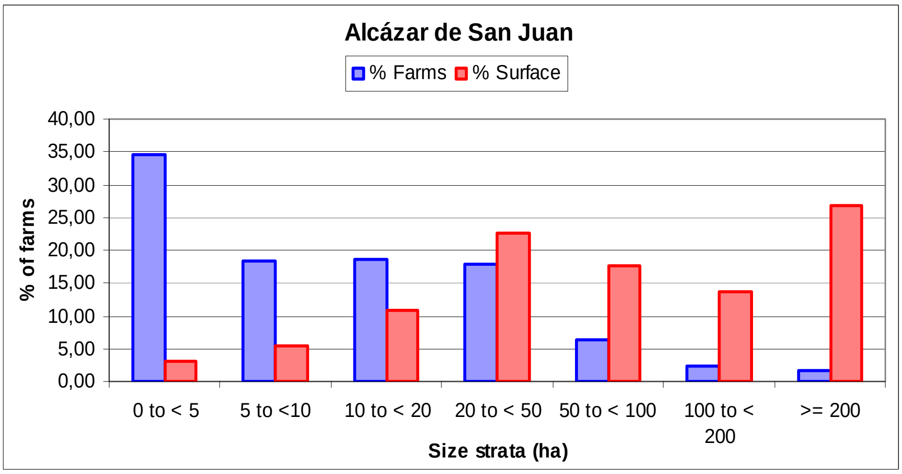
Table 1: Number of farms and surface by farm strata in the agronomic zone "Mancha"

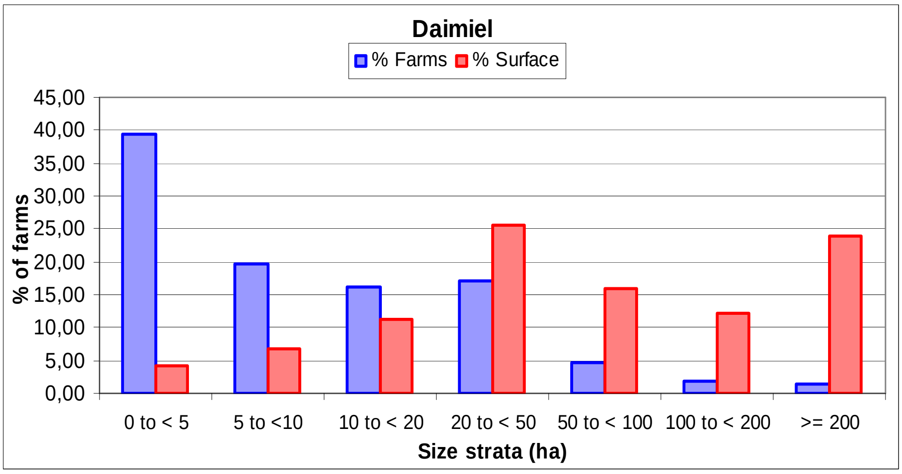
Agronomic zone: "Mancha"					
Farm size	Farm No.	% Farms	Surface (ha)	% Surface	Average surface (ha)
< 5 ha	9697	44,16	21156	5,43	2,18
5 a < 10 ha	4247	19,34	29416	7,55	6,93
10 a < 20 ha	3470	15,80	47556	12,21	13,70
20 a < 50 ha	3028	13,79	90966	23,36	30,04
>= 50 ha	1515	6,90	200373	51,45	132,26
Total	21957	100	389467	100	17,74

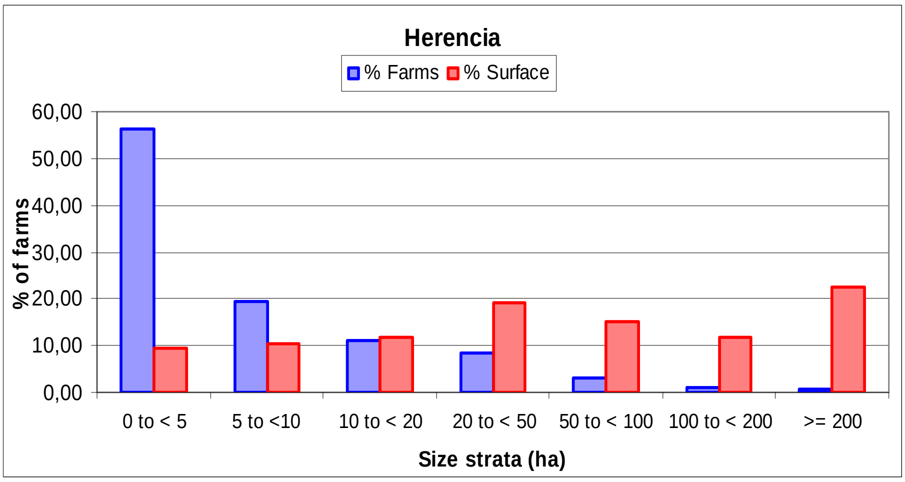
Source: Own elaboration from INE 1999

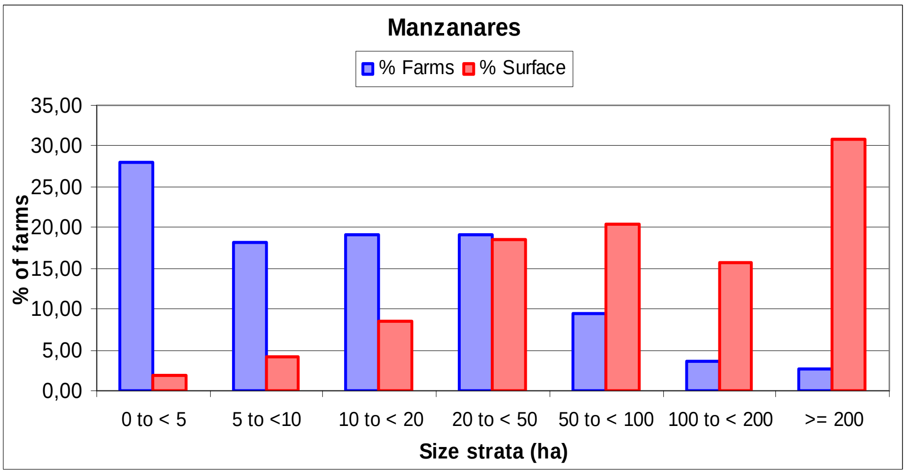
For the selected ICs we have carried out the correspondent analysis of surface and number of farms by farm strata to select the statistically representative farm types. Graphs 1, 2, 3, 4 and 5 summarize the statistical analysis carried out for the selection of farm types.

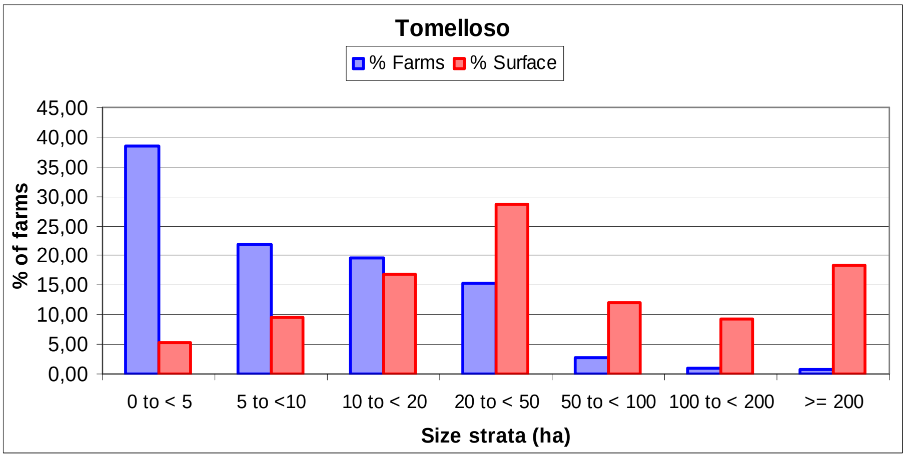
Graphs 1, 2, 3, 4 and 5: Distribution of farms and surface in farm size strata in the ICs of Alcázar de San Juan, Daimiel, Herencia, Manzanares and Tomelloso


Alcázar de San Juan
% Farms
% Surface
% of farms
40,00
35,00
30,00
25,00
20,00
15,00
10,00
5,00
0,00
0 to < 5
5 to <10
10 to < 20
20 to < 50
50 to < 100
100 to < 200
>= 200
Size strata (ha)


Daimiel
% Farms
% Surface
% of farms
45,00
40,00
35,00
30,00
25,00
20,00
15,00
10,00
5,00
0,00
0 to < 5
5 to <10
10 to < 20
20 to < 50
50 to < 100
100 to < 200
>= 200
Size strata (ha)


Herencia
% Farms
% Surface
% of farms
60,00
50,00
40,00
30,00
20,00
10,00
0,00
0 to < 5
5 to <10
10 to < 20
20 to < 50
50 to < 100
100 to < 200
>= 200
Size strata (ha)





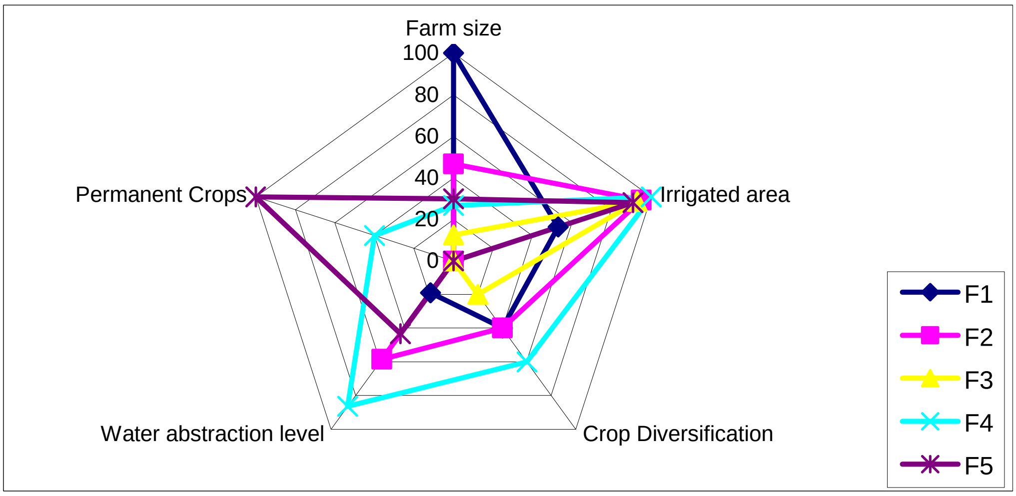
Based on the field work and stakeholder analysis and on the statistical data analysis, a farm typology for the selected five Irrigation Communities (Water User Associations) was constructed to characterize the agricultural systems, modes of production and cropping selection of the area of study. The selected representative farms correspond to five Irrigation Communities of the UGB. Table 2 describes the statistically-based representative farms.

Table 2: Irrigation communities (IC) and selected farm types

Farm	IC	Surface (has)	Level of coverage in the IC (% of area)	Level of coverage in the sub-region of La Mancha (% of area)	Cropping patterns
F1	Alcázar de San Juan	150	40	51	43% Rain fed / 37% Extensive irrigated Crops / 20% Horticulture
F2	Daimiel	70	16	51	10% Rain fed / 57% Extensive irrigated Crops / 33% Horticulture
F3	Herencia	19	22	20	10% Rain fed / 74% Extensive irrigated Crops / 16% Horticulture
F4	Manzanares	40	19	23	5% Rain fed / 24% Extensive irrigated Crops / 31% Horticulture / 40% Vineyard
F5	Tomelloso	45	29	23	11% Rain fed / 89% Vineyard

Based on the data of the representative farms of table 2, graph 6 shows the profiles of the farm types. Profiles are based on the main characteristics of the farms that are relevant for our analysis. These include structural parameters such as farm size, percentage of irrigated land and crop mix and water related parameters such as water use over the Water Abstraction Plan volumes. Profiles show the variety of baseline characteristics of the farms that represent the area of study, and therefore the diversity in the Upper Guadiana region.

Graph 6: Representative farm's profiles



To complement the baseline analysis, we have obtained a set of real farms selected during the experts' fieldwork interviews that best represent the area of study, which is used for the vulnerability analysis.

5 The economic model

For the analysis of the impact of the joint application of water and agricultural policies it was used the economic model developed by Varela et al. (2006a) and largely based on the paper by Varela et al. 2007 "Public Policies for groundwater conservation: a vulnerability analysis in irrigation agriculture",presented at the CAIWA Conference 2007 and Varela et al. (2007c).

5.1 Model structure

The economic model is a mathematical programming model of constrained optimization that includes a risk component that takes into account climate as well as market variability. Constraints in the model include land, water, labor and policy constraints. The technical parameters of the model are based on an ample field work conducted in the area of study as well as on interviews from experts and data from the regional and national administration departments.

The model used is a farm-based non-linear single-period mathematical programming model of constrained optimization, developed by Varela-Ortega et al. (2006a). The model describes the behavior of the representative farmers selected confronted by different policy scenarios. Following previous work in the area of study (Varela-Ortega *et al* 1998, Varela-Ortega *et al*. 2002) the model incorporates new risk parameters and maximizes a utility function (U) subject to technical, economic and policy constraints (g). The utility function is defined by a gross margin (Z) and a risk vector (R) that takes into account climate as well as market prices variability. The model can be summarized as follows:

Maximize U = $f(x)$, $f(x)$ = Z - R

Subject to the following constraints $g(x) \in S_1$,

$x \in S_2$

Where "x" is the vector of the decision-making variables or vector of the activities defined by a given crop-growing area and by an associated production technique, irrigation method and soil type (S). The problem-solving instrument used is GAMS (General Algebraic Modeling System). The technical coefficients and parameters of the model were obtained from field work carried out during 2006 and 2007 (Varela et al., 2007b) in the study area, consisting of surveys and interviews with farmers, irrigation community representatives, technical experts, river basin managers, and regional government officials. The model was duly calibrated and validated, using the risk aversion coefficient as calibration parameter and the comparative data on crop distribution, land and labor parameters in the study area.

The scenarios selected for the simulations of the water policy application corresponds to the original water rights situation (4270 m^3/ha) and a water quotas system, which includes two scenarios: the current situation, in which farmers do not comply fully with the quotas imposed, and the Water Abstraction Plan, in which farmers do comply with the water quotas. The water quotas imposed by the Water Abstraction Plan are summarized in the table 3.

Table 3: Water Abstraction Plan quotas

Farm Size	Water quota (m^3/ha)
0 – 30 ha	2640
30 – 80 ha	2000
> 80 ha	1200
Vineyard	1000

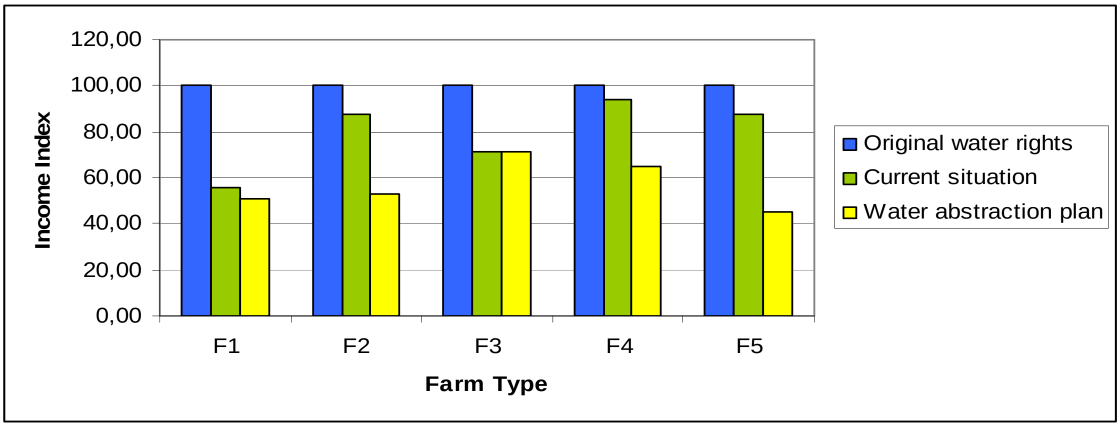
Finally the Nitrates Directive was simulated through the yield decreases produced by the compliance with the Nitrates Directive, from the calibration of the agronomic model CropSyst

5.2 Results of the economic model

- Water policy simulations

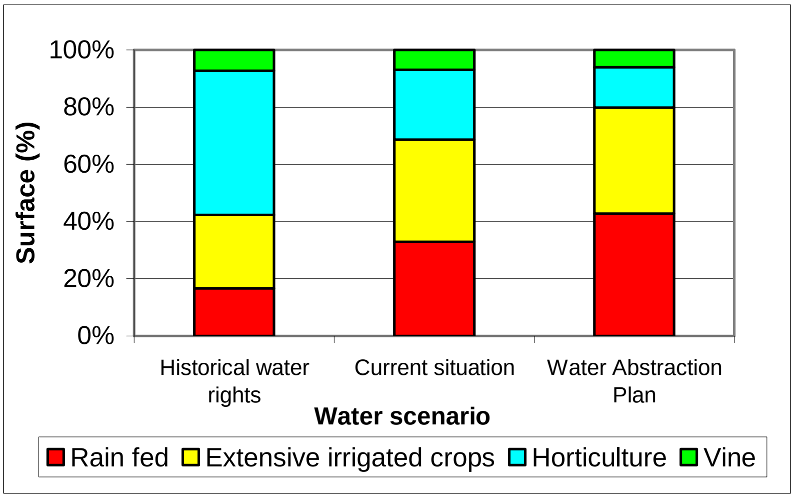
The simulation results for the five farm types are shown in graph 7 that depicts the effects of the application of different water policy scenarios (water quotas). The WAP induces a decrease in water consumption in all farm types relative to de historical water rights and the current situation.
Complying with the WAP provokes substantial **farm income losses** to all farms. However, as shown in graph 7 below, bigger farms with a high percentage of irrigated area face higher income losses (F1), as water quotas are proportionally lower in larger farms. Income loss is especially acute in small non-diversified farms, such as vineyard groves (F5) that have a very small adaptive capacity to water stress conditions. On the contrary, diversified farms tend to loose a lower proportion of their farm income as their short-term adaptive capacity to water scarcity is higher (F3 and F4, especially F3, which grows only annual crops). However comparing total farm income with respect to the minimum survival income level, small farms have a larger income loss and farms that feature a rigid cropping pattern, such as vineyards (F5), are prone to abandon irrigated production.

Graph 7: Effect of the application of Water Policies on farm income across farm types



As graph 8 shows, when water volumes diminish **cropping patterns** are likely to change to less water intensive crops for the area's average farm. Rain fed farming increases progressively as less water is available, extensive irrigation such as barley is maintained and horticulture crops diminish in the average farms, although different responses across farm types are expected according to their adaptive capacity in changing crop mix.

Graph 8: Effect of the water quotas policy on the cropping pattern in the aquifer

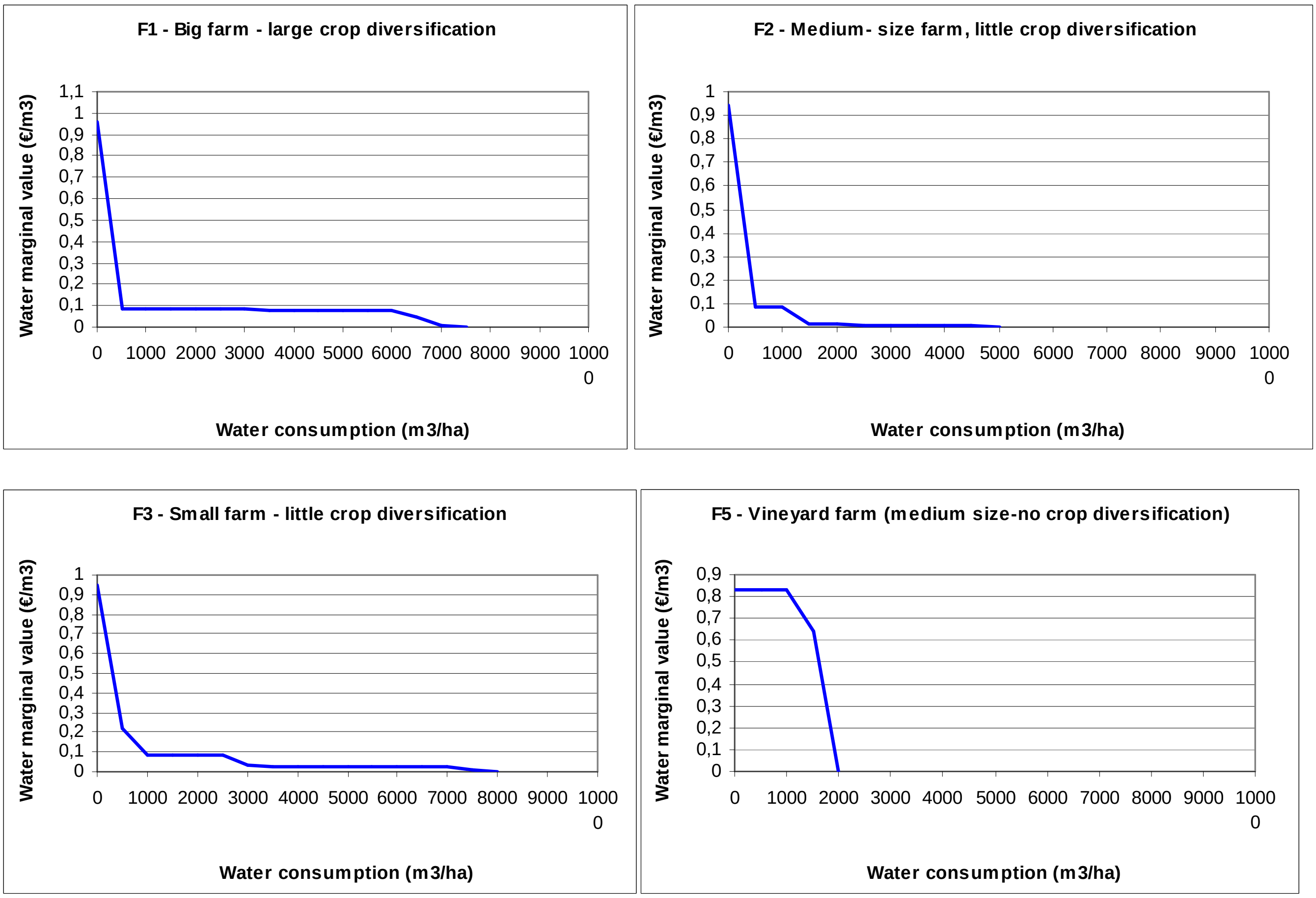


- <u>Adaptive capacity of irrigated farms:</u>

The adaptive capacity that farms have to different volumes of water can be analyzed looking at the **water dual values** (water marginal values) in the model results. Using marginal values of water to assess the impact of water conservation policies has been discussed extensively in the literature as average values can be ambiguous or misleading (Johansson et al, 2002, Turner et al 2004, Hanemann 2006, among others). The value of water for farmers is not constant and increases as less water is supplied because farmers are likely to change their crops and technologies in response to water availability, as shown in the model results where cropping pattern changes according to the available water volumes and to the policy programs

Graph 9 shows the dual values of water for different levels of water availability across farm types obtained in the model simulations. The 'water demand curves' constructed using water shadow prices (dual values) show that farm types have distinctive adaptive capacity to water availability. This is reflected in their comparative ability to adjust their cropping patterns, technologies and farming operations (rain fed farming). When dual values of water are zero, the farm will not be willing to pay for an extra unit of water volume, that is, the farm will be satisfied with the amount of water available. We can see that medium-size farm F2, that grows annual cash crops has a high short-term adaptive capacity as it will operate with 5000 m3 per ha, as compared to its smaller counterpart F4 that, due to size limitations, requires a larger volume of water (7500 m3 per ha) . In contrast, the small vineyard farm F5 is highly adapted to lower water volumes (2000 m3 per ha) due to the use of efficient irrigation technologies such as drip irrigation, widely used in vine groves in the area.

Graph 9 – Dual values of water across farm types from different levels of water availability



- Agricultural Policy Simulations

The two scenarios simulated with the agronomic model are the reference situation, which represents the traditional use of nitrogen fertilizers, and the Nitrates Directive, which corresponds to the full compliance with the directive. The following table shows the results of the simulations for two scenarios by crop and by technique.

Table 4: Effects of the Nitrates Directive on nitrogen application, water consumption and yield.

Crop	Techn.	Nitrogen amount (kg/ha)			Water Consumption (m3/ha)			Yield (kg/ha)		
		Reference situation	Nitrates Directive	Reduction (%)	Reference situation	Nitrates Directive	Reduction (%)	Reference situation	Nitrates Directive	Reduction (%)
BARLEY	RF	49,4	55	0	0	0	0,00	1520	1530	-0,69
	SP1	105,3	110	0	1520	1430	5,92	3402	3191	6,22
	SP2	127,4	110	13,66	1560	1430	8,33	3943	3191	19,08
WHEAT	RF	59,5	55	7,56	0	0	0	2177	2027	6,89
	SP1	126,2	110	12,84	1730	1670	3,47	4985	4479	10,15
	SP2	159,5	110	31,03	1740	1670	4,02	5273	4479	15,06
MAIZE	SP1	275,5	200	27,40	3420	3370	1,46	10866	9877	9,10
	SP2	348	200	42,53	3450	3370	2,32	11022	9877	10,39
SUNFLOWER	RF	39,4	40	0	0	0	0	638	652	-2,19
	SP1	117	80	31,62	2520	2530	-0,40	3102	2522	18,70
	SP2	135	80	40,74	2550	2530	0,78	3159	2522	20,17
SUGARBEET	SP1	213,8	200	6,45	6340	6140	3,15	49402	42646	13,68
	SP2	270	200	25,93	6450	6140	4,81	56100	42646	23,98
PEAS	RF	56,5	20	64,60	0	0	0	980	878	10,44
POTATO	SP2	313,5	120	61,72	3540	3410	3,67	56000	50400	10,00
MELON	DR	188,7	135	28,46	3010	2960	1,66	40000	38600	3,50
PEPPER	DR	202,5	160	20,99	4140	4075	1,57	35220	34060	3,29
GARLIC	SP2	80	80	0	1610	1610	0	7138	6673	6,51
VINE	RF	26,3	50	0	0	0	0	10927	10600	2,99
	DR	158,2	70	55,75	2190	1970	10	25007	23427	6,31

Source: Own elaboration from Azaña, 2007.
RF: rain fed - SP1: extensive sprinkler irrigation - SP2: intensive sprinkler irrigation -
** Maize water requirements are daily ET requirements at maximum water use efficiency, therefore lower than on-field actual irrigation applications.*

Mainly, potato and garlic are the most sensitive crops to nitrogen restrictions in terms of yield (table 4). Sunflower and sugar beet are also very sensitive, and cereals in intensive irrigation are highly affected by changes in nitrogen dosage applied. These results fit with the farmers' perceptions (Varela et al., 2006c) with the expert consultations (INAGRO, S.A.).

Depending on the crop, these reductions in fertilizer costs, water cost and yields will have different impact on the gross margin.

The results of the simulation of the different scenarios where farmers comply or not with the Nitrates Directive are shown in the table 5.

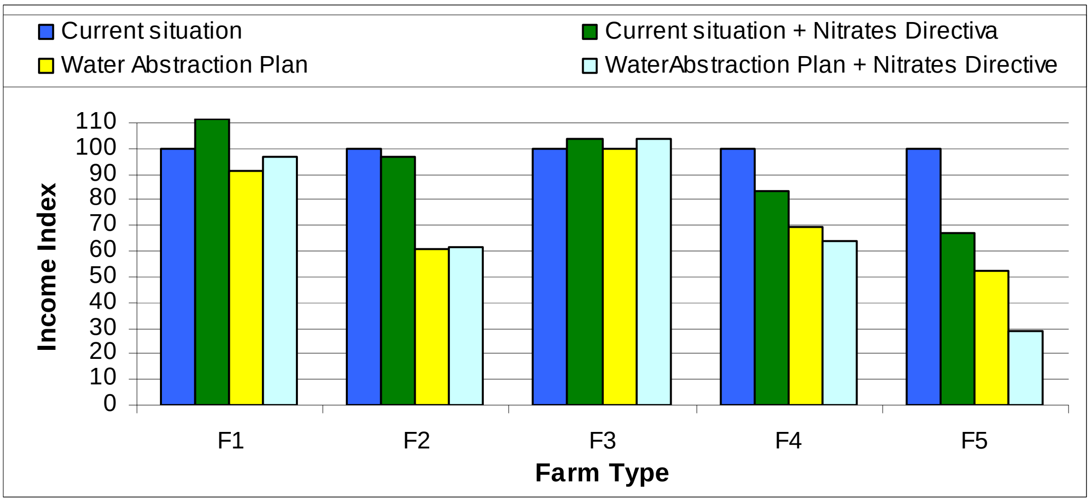
Table 5: Effect of the Nitrates Directive and the Water Abstraction Plan at farm level

Farm Type	Farm Income per hectare (€/ha)				Income Index (%)			
	Reference situation	Nitrates Directive	Water Abstraction Plan	Water Abstraction Plan + Nitrates Directive	Reference situation	Nitrates Directive	Water Abstraction Plan	Water Abstraction Plan + Nitrates Directive
F1	625,32	695,74	573,04	606,89	100	111,26	91,64	97,05
F2	739,44	712,72	447,43	453,63	100	96,39	60,51	61,35
F3	753,59	781,27	753,59	781,27	100	103,67	100	103,67
F4	1039,04	877,59	718,64	676,34	100	84,46	69,16	65,09
F5	829,43	554,17	431,25	239,30	100	66,81	51,99	28,85

Source: Own elaboration

The impact of nitrogen reductions at the farm level change dramatically depending on the cropping pattern. The results of the model show that given the farmer's capacity to adapt them selves to the legislation (switching from one crop to another), changes in the cropping patterns would increase their income. Therefore, farms F1, F2 and F3 do not suffer any income loss because of Nitrates Directive compliance. Farms F4 and F5 have relevant income losses due to the lower adaptation ability because of the permanent crops (vines). Graph 10 summarizes the income variation in the different farm types selected for the different scenarios.

Graph 10: Effect of the Nitrates Directive on farm income



Source: Own elaboration

The results of the model show that farm income is more vulnerable to reductions in water availability than to nitrogen restrictions. The income losses coming from the compliance with the Water Abstraction Plan are very relevant, especially to farms F2, F4 and F5. Farms F1 and F3 are more extensive farms with less horticultural crops surface. However, F2, F4 and F5 are farms that are more intensive and their profitability decreases seriously when water restrictions take place.

It is important to remark that new cropping patterns are very similar between the four farms when they comply with the Nitrates Directive. Melon is the vegetable crop chosen in the four farms F1 to F4; therefore, a dynamic analysis would be necessary to assess the effect of this in the following years when melon prices would probably be lower.

6 Vulnerability Analysis

Based on the paper by Varela et al. 2007 “Public Policies for groundwater conservation: a vulnerability analysis in irrigation agriculture”, presented at the CAIWA Conference 2007.

6.1 Methodology for the vulnerability analysis

The results of the mathematical programming economic model are used as input for the vulnerability assessment, as well as the stakeholder-driven drivers and indicators of vulnerability of the different farm types that were obtained from the stakeholder analysis.

The objective function in the analysis is vulnerability defined by two types of indicators as dependent variables. These vulnerability indicators are defined by two different farm income variables: (i) farm income loss measured as the percent loss of farm income when water availability decreases and (ii) the percent deviation of total income gained in the farm from the minimum income that will allow the farm to continue operating, that is, the threshold for economic viability. These two measurements were considered to capture the relative and absolute income loss that water stress conditions inflict to the different farm types and, hence, their capacity to continue operating in water-scarce policy scenarios. A large farm may have a considerably high percent income loss relative to its total income and still be capable to adapt and continue operating. Conversely, a small farm may have a smaller percent income loss that, in absolute terms, would be sufficiently high as to make the farm fall below the economic viability threshold and be forced to stop operating. The economic viability threshold is defined as ‘minimum survival income’ calculated from Spain’s official data of the ‘minimum inter-professional annual wage rate’2.

Measuring economic vulnerability by means of relative and absolute income loss has been used in the literature mainly in economic analysis, stressing the fact that it is one of the many facets of vulnerability (Coudoutel and Hentschel, 2000). As vulnerability is dependent to access to production inputs, such as land, water , labor and technologies, comparable quantitative measurements, such as income variability, provide relative comparisons aw well as absolute thresholds (sometimes called poverty profiles) that can provide information to policy makers to identify economic viability of the different individuals and their characteristics (Alwang et al. 2001).

The prediction variables include structural parameters such as farm size and irrigated land, agronomic indicators such as crop mix, farming techniques and irrigation technologies, water consumption decisions such as overpumping rate and institutional factors such as policy enforcement capacity. This last indicator reflects the capacity that the Water Authority has to enforce the water abstraction plan in the area and consequently the ability that irrigators will have to engage in free-riding behaviour and pump more water than the permitted volumes.

The two indicators of income loss are used to classify the farms in four vulnerability classes: extreme, very high, high and medium (see table 4). This classification is an input for the farm vulnerability analysis (following Downing et al. 2001, see also Downing et al. 2006) based on the farms’ principal characteristics using the CART method (Classification and Regression Trees, Steinberg and Colla, 2007; see Stephen and Downing 2001 for a review of vulnerability methods including CART).

Table 6: Vulnerability prediction variables

Objective variable	Indicator	Prediction variables
Vulnerability	Rate of Income loss (%) Rate of actual Farm Income to minimum survival income (%)	Farm size (ha.)
		Crops diversification (number of major crops)
		Irrigated Area (%)
		Permanent crops in the farm (yes/no)
		Over pumping (%)
		Water policy enforcement impact (index)

The criteria followed to classify farms into the four vulnerability classes are shown in table 7. The highest class of vulnerability is related to a threshold of economic viability. When farm income is equal or below 50% of the minimum survival income, a farm is considered to be highly vulnerable to diminishing water volumes. The MSI was calculated from the official 2007 minimum inter-professional annual wage rate in Spain that amounts to 7988.4 €/year. As GDP per capita was 23000 € in 2006, 50% over the minimum survival income equals approximately half of per capita GDP and therefore a farmer that reaches an income level lower that the MSI can be considered highly vulnerable to water consumption limitations.

The three lower classes of vulnerability relate to application of the Water Abstraction Plan (WAP). Farms that would lose up to 35% of their farm income with the new allocations are considered to have low vulnerability to water stress conditions and when income loss is in the range of 35% to 50% or above 50%, vulnerability is respectively medium and high.

Table 7: Criteria for the determination of vulnerability levels

Indicator Category	Criteria	Level of vulnerability
Difference from m.s.i.	<= 50%	EXTREME
Income loss	> 50%	VERY HIGH
Income loss	35- 50%	HIGH
Income loss	< 35%	MEDIUM

The last part of the methodological framework is the analysis of the of the vulnerability classification tree based on structural and institutional characteristics in the farms. This analysis elaborates the differential impacts that water conservation policies (i.e. different levels of water quotas with no compensation) as well as the policy enforcement capacity of the river basin authority will have on the irrigation sector of the UGB. Hence, this analysis permits prediction of which farm types will be more responsive to the new Special Plan of the Upper Guadiana basin, which farms will need specific targeted programs and which farms will be more vulnerable to periods of water scarcity, drought spells and other economic stresses.

6.2 Results of the vulnerability analysis

A key explanatory variable for assessing vulnerability is the water policy enforcement impact. This indicator reflects farmers' response to water shortage and illegal behaviour to minimize vulnerability to water stress conditions. Based on the Stakeholder consultations and meetings we can conclude that there is an inverse relationship between the policy enforcement capacity of the water authority to strictly apply the Water Abstraction Plan and the level of vulnerability of the legal irrigated farms. A farm that operates under legal provisions and complies with the granted volumes of the WAP, will be more vulnerable the lower the capacity of the Water Authority to enforce the quota system of the WAP. If the WA is incapable to enforce the WAP quotas, illegal drillings and abstractions will take place and thus legal irrigators will be penalized as they will be granted smaller water volumes in the following periods to recover the exhausted aquifer.

The water policy enforcement index for the vulnerability analysis has been calculated based on the overpumping data and illegal drillings reported in 2006 as shown in table 8.

Table 8: Water policy enforcement rate

Water abstraction (Hm3)*	Total	Policy target	Over pumping	Over pumping rate (%)
	355	214	141	39,72
Number of wells	Total	Legal	Illegal	Rate of illegal wells (%)
	39000	16000	23000	58,97
Average				49,35

Source: Own elaboration from CHG, 2006

The classification of water policy enforcement is the following:

% Overpumping: < 20% → High policy enforcement
20-30% → Medium policy enforcement
30-40% → Low policy enforcement
>40% → Very low policy enforcement

Based on the results of table 8, we can conclude that the policy enforcement level in the UGB can be considered low, as over pumping in the aquifer is close to 40% of total water abstractions (illegal wells are a higher percentage of total wells but these figures are less reliable and vary according to data sources).

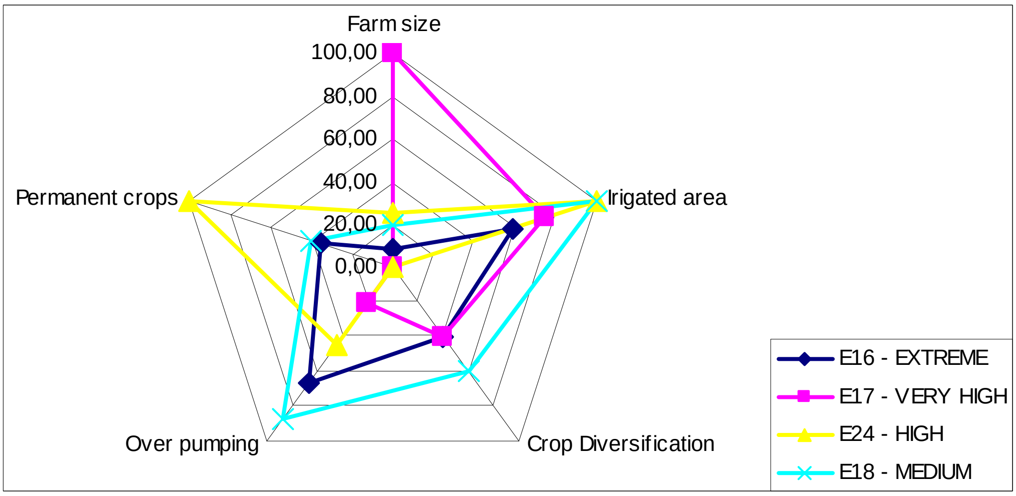
Table 9 shows the indicators for the vulnerability analysis for each of the 25 farms selected in our study region. The first column shows the different farms (denoted by E1 to E25 and by the Irrigation Association), the second column shows the level of vulnerability according to the criteria selected in table 7, and the next two columns show income losses while the remaining columns show the predictive variables defined in table 6.

Table 9: Indicators for the vulnerability analysis

Farm	Vulnerability	% Income loss	Difference from minimum survival income (%)	Farm Size (ha)	Crop diversification	Permanent crops	Irrigated area (%)	Over pumping (%)	Water policy Enforcement Impact
E1_A1	EXTREME	201	13	17	3	YES	29	157	0
E2_A2	VERY HIGH	61	2604	550	5	NO	100	0	3
E3_A3	HIGH	47	976	150	3	NO	91	21	1
E4_A4	HIGH	44	3070	500	4	YES	100	111	0
E5_A5	VERY HIGH	55	1162	242	2	NO	100	0	3
E6_A6	VERY HIGH	57	5024	1200	7	YES	57	0	3
E7_A7	MEDIUM	33	51	19	3	NO	100	14	2
E8_A8	HIGH	47	1587	315	2	NO	84	32	1
E9_D1	HIGH	35	309	73	2	NO	49	65	0
E10_D2	VERY HIGH	55	455	68,5	3	YES	99	0	3
E11_D3	HIGH	45	736	130	6	YES	100	39	1
E12_D4	HIGH	37	510	65	4	YES	100	19	2
E13_H1	VERY HIGH	56	425	64	4	YES	100	0	3
E14_H2	MEDIUM	29	98	21	2	NO	100	0	3
E15_H3	VERY HIGH	50	279	55	4	YES	64	0	3
E16_H4	EXTREME	20	47	17	3	YES	59	75	0
E17_M1	VERY HIGH	52	1565	400	3	NO	75	21	1
E18_M2	MEDIUM	24	260	40	4	YES	100	97	0
E19_M3	HIGH	45	413	68	3	YES	100	1	2
E20_M4	VERY HIGH	48	359	77	1	NO	91	0	3
E21_T1	MEDIUM	22	1143	305	3	YES	34	55	0
E22_T2	HIGH	38	143	45	1	YES	89	48	1
E23_T3	HIGH	40	155	54	2	YES	93	50	1
E24_T4	HIGH	41	150	50	1	YES	100	50	1
E25_T5	HIGH	45	495	85	3	YES	100	8	2

Key: Farms are a sample from the irrigated communes (A, D, H, M and T) noted in Table 1. Vulnerability classes are as derived in Table 5

Graph 11: Real farms' profiles for different vulnerability levels



Graph 11 shows the farm profiles of four of the real farms, each of them with a different level of vulnerability. In this radar plot we can see how the different structural characteristics (farm size and permanent crops) and the different strategies (over pumping, irrigated area and crop diversification) lead to different vulnerability levels. Small farms, with little crop diversification and a low proportion of irrigated surface present extreme vulnerability (real farm E16). Large farms with a low level of over pumping (real farm E17) show a very high vulnerability level. The level of over pumping is a key variable for vulnerability classes. As we can see in the plot, the higher the level of over pumping the lower the vulnerability, except for farm E16, a small vineyard farm with almost null adaptive capacity that is extremely vulnerable.

The dependent variable, farm income loss, has been calculated as the percentage reduction of total income when water allotments are reduced from the initial historical water volumes to the volumes established in the Water Abstraction Plan. As part of the actual water volumes consumed in the farms come, in some cases, by pumping more water than the permitted water volumes, current income has been calculated as a weighted average of two components. One that accounts for the farm income obtained with the official water allotments established in the WAP and the other that accounts for the extra water volumes used in the farm. The weight of each component corresponds to (1- β) and β, where β is the probability of having water consumptions over the permitted quota, and has been estimated by the current over pumping rate in the aquifer.

$$IL = Z_{hr} - Z_T$$
$$Z_T = Z_{WAP} + \beta \cdot Z_{extra}$$
$$Z_T = Z_{WAP} + \beta \cdot (Z_{act} - Z_{WAP})$$
$$Z_T = Z_{WAP} + \beta \cdot Z_{act} - \beta \cdot Z_{WAP}$$
$$Z_T = (1 - \beta) * Z_{WAP} + \beta \cdot Z_{act}$$

Where:

- *IL:* Income loss (€/ha)
- Z_{hr}: Farm income obtained with the historical water rights (€/ha)
- Z_T: Expected farm income in current situation (€/ha)
- Z_{WAP}: Farm income obtained complying with the Water Abstraction Plan (€/ha).

- β: Overpumping coefficient
- Z_{extra}: Farm income obtained using over-pumped water
- Z_{act}: Farm income obtained with actual consumption (€/ha)

Figure A1 (in annex II) shows the CART classification tree of the vulnerability analysis. Farms are classified by vulnerability levels and results show that the most important explanatory variables are farm size, rate of over pumping and policy enforcement impact index. In fact, structural parameters such as farm size play a major role, evidencing that economies of scale are present for some farm strata. Small farms of less than 20 ha are extremely vulnerable to water use limitations as medium-size and larger farms in the range of 20-30 ha have a medium vulnerability and show a greater adaptive capacity to water stress. However, this trend is reverted for larger holdings from 30 to 365 ha that are highly vulnerable farms and farms over 365 ha that present very high vulnerability, and the absence of economies of scales (amply discussed in the specialized literature) is evidenced for this farm strata (see table 10)

In our analysis, farms in the medium-size range (that show a comparative lower vulnerability) that choose to overpump illegally to increase moderately their water volumes are more vulnerable than other farms that extract more water illegally. These farms choose to extract larger volumes of illegal water given the low policy enforcement capacity of the WA in the UGB. If the policy enforcement capacity of the Water authority increases, this tendency is reversed as the risk related to overpumping will be higher, farmers will be more easily caught and penalized and the number of closed unregistered wells will increase.

Table 10: CART Classification of farms in vulnerability levels

Farm size	Over pumping	Water policy enforcement impact	Vulnerability
< =18 has			Extreme (100%)
	<= 1%		Very high (87,5%)
	>1%	0	Medium (75%)
(18-32] has	>1%	1,2, ó 3	Medium (100%)
(32-367] has	>1%	1,2, ó 3	High (100%)
> 367 has	>1%	1,2, ó 3	Very high (100%)

The next table shows the result of the sensitivity analysis to the policy enforcement capacity. This variable has proven to be an important explanatory variable for farm vulnerability and therefore policy enforcement capacity has to increase substantially to efface its impact. Table 11shows the results of the new CART simulations in which overpumping has to fall to less than half (less than 20%) to eliminate its impact on farm vulnerability. That is, when the policy enforcement capacity increases to a level considered ‘high’ in our classification (less than 20% overpumping) then this variable is no longer determinant for explaining farm vulnerability classes.

Table 11: CART farms classification in levels of vulnerability. Increased water policy enforcement.

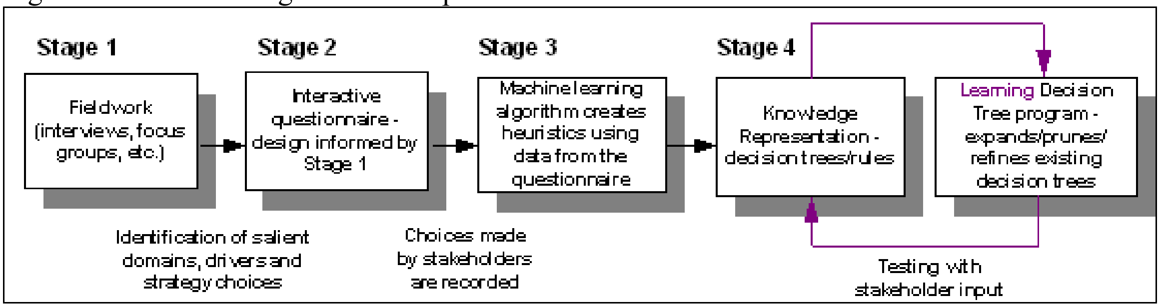
Farm size	Over pumping	Irrigated area	Vulnerability
< =18 has			Extreme (100%)
(18-42,5] has			Medium (87,5%)
> 42,5 has	<= 1%		Very high (75%)
> 42,5 has	>1%	<= 41,87 %	Medium (100%)
(42,5-59,5] has	>1%	> 41,87 %	High (100%)
> 59,5 has	>1%	> 41,87 %	Very high (100%)

7 Farmers' strategies – the Knowledge Elicitation Tools Application

Following Bharwani, farmers' strategies coping with stress conditions can be expressed as follows: "The need to understand the multiple stresses which interact to form complex vulnerabilities has led to the design of tools for knowledge elicitation (KnETs). This interdisciplinary approach integrates methods used in ethnographic fieldwork with classical knowledge engineering techniques from computer science in order to alleviate weaknesses inherent in both methods. This provides a participatory and robust process, from knowledge elicitation to knowledge representation, providing a greater clarity of the ethnographic data and thus possibly a greater understanding of social vulnerability and adaptive behaviour." (p. 1, Bharwani, 2007)

As Bharwani (2006) states, the process of Knowledge Elicitation Tools can be represented in a 4-stage process represented in Figure 3:

Figure 6: The Knowledge Elicitation process



Source: Bharwani, 2006

The interest of the application of the KnETs in the Upper Guadiana arises due to the low effectiveness of the water conservation policies in the Upper Guadiana. The key question in this case is the farmer's decision related to water use (to grow water intensive crops or no water intensive crops, to abstract more or less water, etc), given a policy scenario.

The objective of the questionnaire is to know how the water use would change in different policy scenarios and with different levels of law enforcement.

The possible objectives are:

- Higher water consumption
- Lower water consumption
- Same water consumption

The scenarios correspond to different water and agricultural policies and different policy enforcement levels. The scenarios proposed are:

- Water policies: Water Abstraction Plan
  Agri-environmental Plan with better compensations
  Water rights market
  Subsidies to change the economic activity

- Policy enforcement: High risk of wells and water meters control

Low risk of wells and water meters control

The feasible strategies for farmers' adaptation (involving different water consumption levels) are:

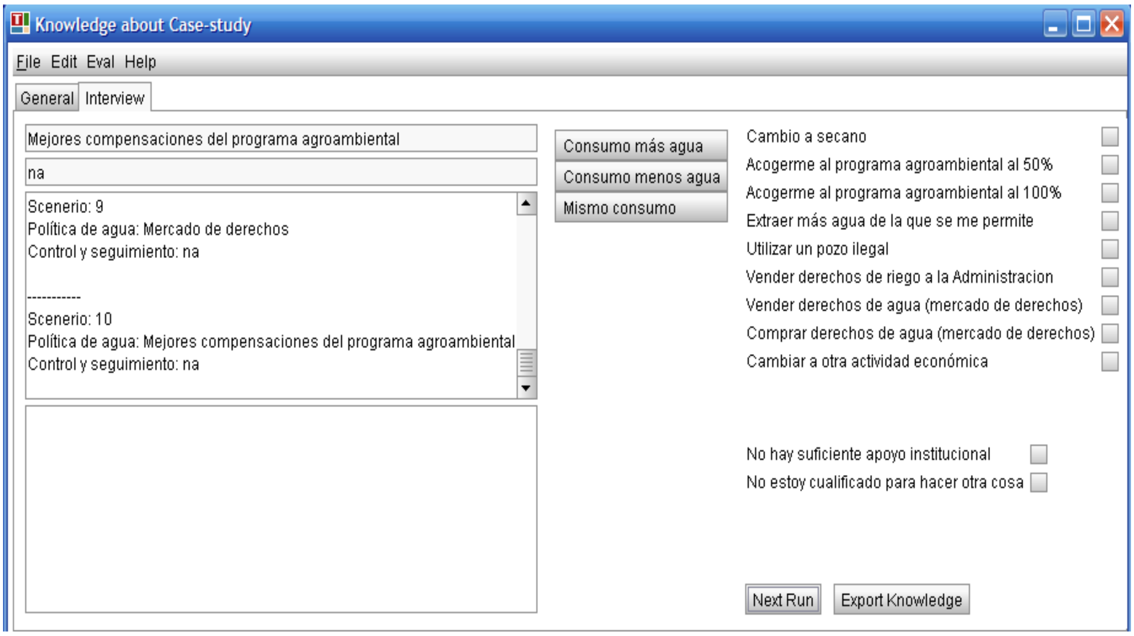
- To switch to rain fed crops
- To take the AEP-50%
- To take the AEP-100%
- To use more water than allowed
- To drill an illegal well
- To sell water rights to the water Administration
- To sell water rights in a water rights market
- To buy water rights in a water rights market
- To change to another economic activity

In addition to this, farmers can justify their choices by one of these options:

- There is no enough institutional support
- I am not qualified for a different activity

The result of the application of the software is the questionnaire that is now ready to use with farmers and experts.

Figure 7: KnETs questionnaire



Once the questionnaire was designed, it was used with farmers and experts in the area of study. In this case the questionnaire was responded by experts and validated by farmers.

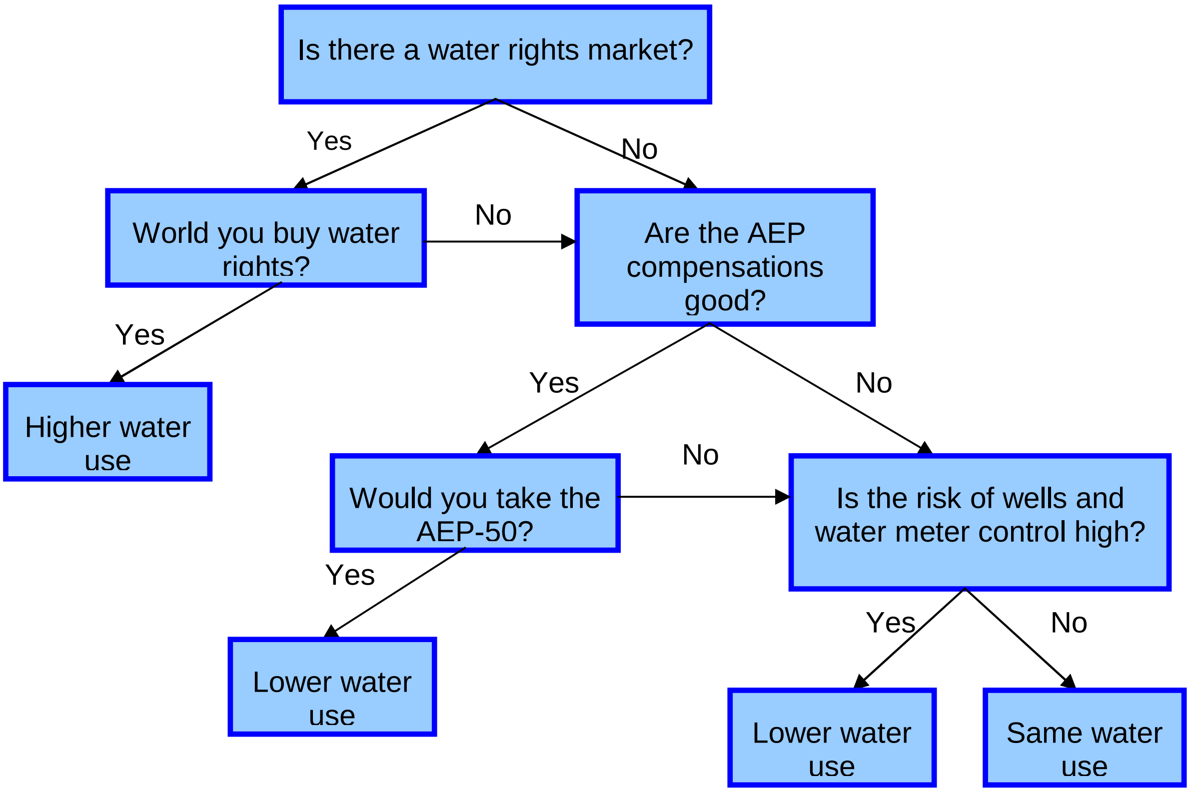
After producing 48 scenarios the algorithm produced the next four rules which are afterwards represented in a decision tree:

- If farmers can buy water rights (water market) then water use is higher
- If there is no possibility to purchase water rights and the Agri-environmental Program (AEP) compensations are good, then farmers will take the AEP and they will use less water
- If there is no possibility to purchase water rights and the Agri-environmental Program (AEP) compensations are not good, if there is a high risk of wells and

water meters control, then farmers will grow less water intensive crops and they will use les water.

- If there is no possibility to purchase water rights and the Agri-environmental Program (AEP) compensations are not good, if the risk of wells and water meters control is not high then farmers will no change their water use.

Figure 8: Decision tree



The decision tree shows that he AEP is a good instrument to reduce water consumption if compensations are good enough. However, good compensations would lead to very high public expenditure. The tree shows that the water rights market could also be a good solution to the aquifer overexploitation, as farmers are willing to buy water rights according to the fieldwork information.

8 Conclusions

- The analysis of vulnerability in water resource planning is one element in robust policy development. It shows two essential progressions in vulnerability assessment:
  - From simple profiles to economic vulnerability. Techniques like CART (and Knets, see Bharwani et al., 2006) combine the drivers of vulnerability in logical rule trees that indicate critical thresholds that result in one farm being more exposed to environmental, economic and policy impacts than another. Such rule trees highlight the relationship between predictor variables and outcomes.
  - From baseline, current vulnerability to behavioural responses. Economic analysis, rule trees, agent-based modelling, and stakeholder role-playing seek to represent how the current configuration of risk might be altered under different environmental stresses, in response to economic shocks, or as a result of policy interventions.

- The starting point for the analysis of water vulnerability in the Upper Guadiana is a thorough description of the baseline vulnerability (not reported in full here), including an analysis of stakeholders (Sorisi 2006, Varela et al. 2006a) and surveys and interviews with farmers throughout the region (Varela et al 2007b). This research presents an innovative analysis that links this baseline vulnerability to a farm-based agro-economic modelling of policy-relevant scenarios. This micro-scale vision is then aggregated to the basin-level by means of a hydrology model (WEAP, SEI 2006) coupled to the economic model by reproducing the same policy scenarios. Differential outcomes are predicted based on indicators of vulnerability combined through a rule tree using CART. This methodology shows the extension of IWRM to consider vulnerability and behavioural responses, core elements of AWRM.

- Looking at water conservation policies currently in force in the Upper Guadiana Basin, we can conclude, from the economic-hydrologic integrated analysis, that these policies will not be able to achieve the recuperation of the Western La Mancha aquifer, even though they will contribute to reduce water consumption in the farms. This situation would worsen in case of droughts.

- The analysis of the impact of compliance with the Nitrates Directive in the region of Castilla La Mancha showed that the cost of compliance (measured as income loss) at farm level varies depending on farm types ad adaptive capacity of farmers to face the regulations. When farmer's adaptation ability is low (i.e. changes in cropping patterns are not easily preformed) the most vulnerable farmers account for income losses around 15%. These results were validated by fieldwork data and interviews to farmers and experts in the area of study. Nevertheless, when farmers adjust the cropping pattern to comply with the ND (by changing to less nitrate-demanding crops and reducing the extended over-fertilizations practices) income loss is low and, in some cases, it may even increase, evidencing a clear benefit of the compliance measure.

- As a general policy recommendation, the present Water Plan of the UGB while responding to the EU WFD objectives will not meet the desired target of ensuring the good ecological status of the aquifer and revert it to to its natural recharge level unless new institutional arrangements are put in place. These will require decisive stakeholder involvement. Enforcing these policies, or any imposed strict water quota system, is a difficult task that will require efficient and socially-accepted instruments as well as a transparent and participatory process of all stakeholders involved, especially irrigation associations, the Water Authority and environmental groups. As the cost of the Water Abstraction Plan is supported largely by the irrigators, there is a need to seek for a more flexible distribution of water allotments among farmers and for complementary measures of rural development that will ensure the maintenance of rural livelihoods in the area. These programs are envisaged in the recently launched Special Plan of the Upper Guadiana (including a water bank) and will need to be targeted specifically to the different types of farm economies in the area. Participatory adaptive water resource management recognising the differential vulnerability of stakeholders is essential.

9 List of references

Alwang, J., Siegel, P.B. y Jorgensen, S.L. (2001). Vulnerability: A view from different disciplines. Social Protection Discussion Paper Series. Social Protection Unit. Human Development Network. World Bank.

Bharwani, S. (2006). "Understanding Complex Behavior and Decision Making Using Ethnographic Knowledge Elicitation Tools (KnETs)." Social Science Computer Review. 24(1): 78-105.

Bharwani, S. (2007). Knowledge Elicitation Tools (KnETs) Workshop, 12^{th} - 23^{rd} February, 2007.

Bharwani, S. Knowledge Elicitation Tools - Guidelines for Use. Stockholm Environment Institute, Stockholm, Sweden. Available on www.sei.se

CHG (Confederación Hidrográfica del Guadiana) (2007) *Plan Especial del Alto Guadiana.* CHG, Ciudad Real, Spain.

Coudouel, A. and J . Hentschel (2000). "Poverty Data and Measurement." Preliminary Draft for A Sourcebook on Poverty Reduction Strategies. The World Bank: Washington, D.C. April.

Dixon, H. J., Doores, J.W., Joshi, L., Sinclair, F.L. (2005). Agroforestry Knowledge Toolkit for Windows: Methodological Guidelines, Computer Software and Manual for AKT5., School of Agricultural and Forest Sciences, University of Wales, Bangor.

Downing, T. E. et al. (2001) Vulnerability indices: Climate change impacts and adaptation. Nairobi: United Nations Environment Programme.

Downing, T.E., Aerts, J., Soussan, J., Barthelemy, O., Bharwani, S., Ionescu, C., Hinkel, J., Klein, R.J.T., Mata, L., Moss, S., Purkey, D. and Ziervogel, G. (2006) Integrating social vulnerability into water management. SEI Working Paper and Newater Working Paper No. 5. Oxford: Stockholm Environment Institute. (November 2005).

EEA (European Environmental Agency) (2007) Nitrate Vulnerable Zones, EU. Available on: www.eea.europa.eu

Gladwin, C. H. (1989). Ethnographic Decision Tree Modelling. Beverly Hills, CA, Sage Publications.

Hanemann, W.H. (2006): The economic conception of water. In: Rogers, P.P., M.R.Llamas and L. Martinez-Cortina (eds): Water Crisis: Myth or Reality. Marcelino Botin Water Forum 2004. London: Taylor and Francis plc.: 61-91

IGME (1999). Unidades hidrogeológicas de España. Mapa y datos básicos. Geological Survey of Spain. Madrid. 34p and maps + CD ROM.

INE (Instituto Nacional de Estadística) (1999). Censo Agrario.

ITAP (Instituto Técnico Agronómico Provincial) (2006). Zonas vulnerables a la contaminación por nitratos. Boletín nº 70.

Johansson, R.C., Y. Tsur, T.L. Roe, R. Doukkali and A. Dinar (2002): Pricing irrigation water: a review of theory and practice. Water Policy, 4: 173-199

Llamas M.R. and P. Martínez-Santos (2005). Report-Baseline Condition Report. Deliverable 3.4.1. Universidad Complutense de Madrid. November, 2005. Newater Project (no 511179) DG Research . EU.Commission, Brussels

MMA (2005). Ministerio de Medio Ambiente. Perfil ambiental de España 2005: Aguas

SEI (Stockholm Environmental Institute) (2005). Water Evaluation and Planning System Tutorial. Boston Center ,Tellus Institute. Available online: http://www.weap21.org/downloads/WEAP_Tutorial.pdf

Sinclair, F. L., Walker, D. H., Joshi, L., Ambrose, B., and Thapa, B. (1993). Use of a Knowledge-Based System Approach in the Improvement of Tree Fodder Resources on Farmland in the Eastern Hills of Nepal., School of Agricultural and Forest sciences, University of Wales, Bangor.

Sorisi, Chiara, 2006, Public Participation and Adaptive Water Management: Assessing the role of System Dynamic Models in the Upper Guadiana Basin in Spain

Stephen, L., and T.E. Downing. (2001). Getting the scale right: A comparison of analytical methods for vulnerability assessment and household level targeting. *Disasters* 25(2): 113-135.

Turner, K., Georgiou, S., Clark, R. Brouwer, R. and Burke, J. (2004) Economic valuation of water resources in agricultura. From the sectoral to a functional perspective of natural resource management. FAO Water reports nº 27. Rome: Food and Agriculture Organization of the United Nations.

Varela C, Maletta E. and Esteve P (2007c). Study of the cost of compliance and its effect on competitiveness. Spanish report. Mediterranean products and farm types: The fruits and vegetables sector and the olive sector in Spain. Cross Compliance Deliverable 13, Facilitating the CAP reform: compliance and competitiveness of European Agriculture. Proyecto CC (nº SSPE-CT-2005-006489) DG Investigación, Comisión Europea. – Universidad Politécnica de Madrid, Madrid

Varela C., P. Esteve, S. Bharwani and T.E. Downing (2007) Public Policies for Groundwater Conservation: a vulnerability analysis in irrigation agriculture. Paper presented at the CAIWA Conference (international Conference in Adaptive and Integrated Water Management). Bassel, Switzerland (12-16 November, 2007).

Varela- Ortega, C. , Sumpsi, J., Garrido, A., Blanco, M. and Iglesias, E. (1998): Water pricing policies, public decision making and farmers response: implications for water policy. *Agricultural Economics*, (special issue of the XXIII Conference of the IAAE, Sacramento, USA, August 10-16 1997). Vol. 19-2: 193-202.

Varela Ortega, C., I. Blanco and P. Esteve (2006b). Economic and Agronomic aspects of water management in the Upper Guadiana Basin. Stakeholder meeting Report. D 1.7.5.b Additional Report (three of four) Newater Project (no 511179) DG Research. EU.Commission, Brussels

Varela Ortega, C., Sumpsi JM and Blanco, M. (2002). Water availability in the Mediterranean region. (Chapter 6) In: Brouwer, F. and Van der Straaten, J. (eds): *Nature and Agriculture Policy in the European Union*. International Library of Ecological Economics. Edward Elgar Publishing Ltd. Cheltenham, UK (pp 117-140).

Varela, C., Blanco, I., Carmona, G. and Esteve, P. (2007b) Field work analysis report in the Upper Guadiana Basin (Spain). Newater WP 1.7 Methods for transition to Adaptive Management. Newater Project (nº 511179-2)-DG Research, EU Comisión., Brussels (*in progress*)

Varela-Ortega C y Simó, A. (2006c): Mandatory standards in 7 EU countries and 3 non-EU countries. Country report: Spain. Cross Compliance Deliverable 5, Facilitating the CAP reform: compliance and competitiveness of European Agriculture. Proyecto

CC (nº SSPE-CT-2005-006489) DG Investigación, Comisión Europea. – Universidad Politécnica de Madrid, Madrid.

Varela-Ortega, C., I. Blanco y G. Carmona (2006a). Agro-economic model for analyzing policy scenarios and cost-effectiveness of policy measures, linking water and agricultural policy. Development of a prototype model. General Report - Newater WP 1.7 Methods for transition to Adaptive Management. Proyecto Newater (nº 511179-2)-DG Investigación, Comisión Europea. – Universidad Politécnica de Madrid, Madrid.

10 Annex I: Contributors to the report

This report is the result of the joint researches of UPM in the NeWater consortium. The following persons have contributed to the whole report:

Consuelo Varela-Ortega, UPM.

Paloma Esteve, UPM.

Thomas E. Downing, SEI – Oxford

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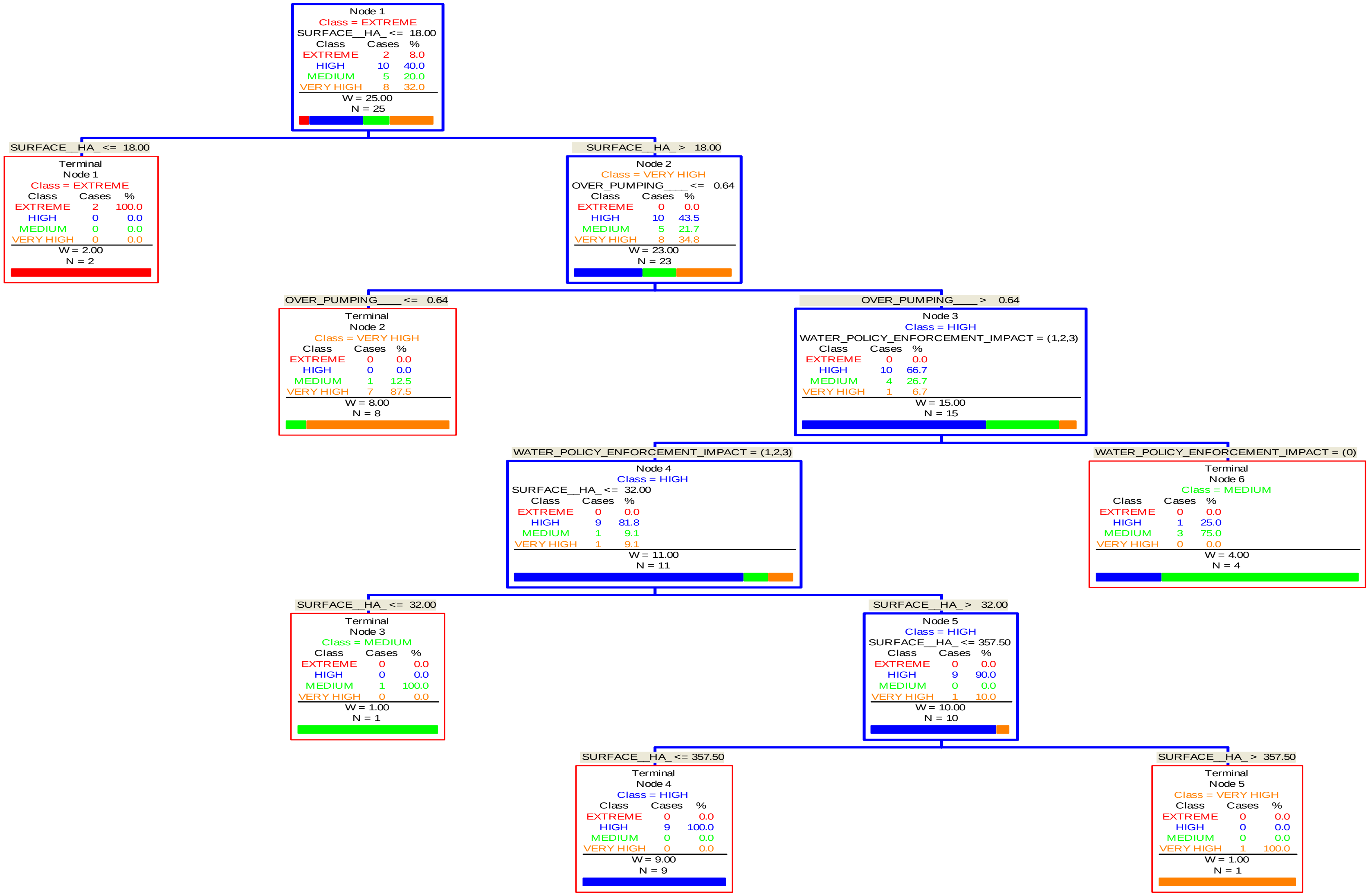
11 Annex II: CART Classification tree



Node 1
Class = EXTREME
SURFACE__HA_ <= 18.00
Class Cases %
EXTREME 2 8.0
HIGH 10 40.0
MEDIUM 5 20.0
VERY HIGH 8 32.0
W = 25.00
N = 25
SURFACE__HA_ <= 18.00
Terminal
Node 1
Class = EXTREME
Class Cases %
EXTREME 2 100.0
HIGH 0 0.0
MEDIUM 0 0.0
VERY HIGH 0 0.0
W = 2.00
N = 2
SURFACE__HA_ > 18.00
Node 2
Class = VERY HIGH
OVER_PUMPING____ <= 0.64
Class Cases %
EXTREME 0 0.0
HIGH 10 43.5
MEDIUM 5 21.7
VERY HIGH 8 34.8
W = 23.00
N = 23
OVER_PUMPING____ <= 0.64
Terminal
Node 2
Class = VERY HIGH
Class Cases %
EXTREME 0 0.0
HIGH 0 0.0
MEDIUM 1 12.5
VERY HIGH 7 87.5
W = 8.00
N = 8
OVER_PUMPING____ > 0.64
Node 3
Class = HIGH
WATER_POLICY_ENFORCEMENT_IMPACT = (1,2,3)
Class Cases %
EXTREME 0 0.0
HIGH 10 66.7
MEDIUM 4 26.7
VERY HIGH 1 6.7
W = 15.00
N = 15
WATER_POLICY_ENFORCEMENT_IMPACT = (1,2,3)
Node 4
Class = HIGH
SURFACE__HA_ <= 32.00
Class Cases %
EXTREME 0 0.0
HIGH 9 81.8
MEDIUM 1 9.1
VERY HIGH 1 9.1
W = 11.00
N = 11
WATER_POLICY_ENFORCEMENT_IMPACT = (0)
Terminal
Node 6
Class = MEDIUM
Class Cases %
EXTREME 0 0.0
HIGH 1 25.0
MEDIUM 3 75.0
VERY HIGH 0 0.0
W = 4.00
N = 4
SURFACE__HA_ <= 32.00
Terminal
Node 3
Class = MEDIUM
Class Cases %
EXTREME 0 0.0
HIGH 0 0.0
MEDIUM 1 100.0
VERY HIGH 0 0.0
W = 1.00
N = 1
SURFACE__HA_ > 32.00
Node 5
Class = HIGH
SURFACE__HA_ <= 357.50
Class Cases %
EXTREME 0 0.0
HIGH 9 90.0
MEDIUM 0 0.0
VERY HIGH 1 10.0
W = 10.00
N = 10
SURFACE__HA_ <= 357.50
Terminal
Node 4
Class = HIGH
Class Cases %
EXTREME 0 0.0
HIGH 9 100.0
MEDIUM 0 0.0
VERY HIGH 0 0.0
W = 9.00
N = 9
SURFACE__HA_ > 357.50
Terminal
Node 5
Class = VERY HIGH
Class Cases %
EXTREME 0 0.0
HIGH 0 0.0
MEDIUM 0 0.0
VERY HIGH 1 100.0
W = 1.00
N = 1