AVEC

Integrated Assessment of Vulnerable Ecosystems under Global Change

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WUNDERBAR

Water Use Nation D'Espaňa Regulated By Adaptive Responses

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1. Introduction

1.1. Study Area

Spain covers over 505, 000 km² and had a population of more than 43 million (INE, 2005) in 2004, which leads to a population density of 85 persons per km². The GDP in 2003 was about $780 million euros (current price). Spain has one of the most diverse terrestrial ecosystems in Europe spanning four biogeographical regions including Atlantic, Mediterranean, Alpine and Macaronesian. These regions are exposed to a great natural climatic variability with prominent gradients in land use and water availability.

There are large north-south differences in annual mean temperatures (Figure 1) ranging from less than 2°C in the Pyrenees to more than 20°C along the southern coast. Differences in altitude also give rise to large annual temperature differences. There are three broad zones of rainfall across Spain, rainy Spain (> 800 mm), semi-arid Spain (300-800 mm), and dry Spain (<300 mm) as shown in Figure 2. A gradient of decreasing precipitation can be found from north-west Spain to the south-east of the country.

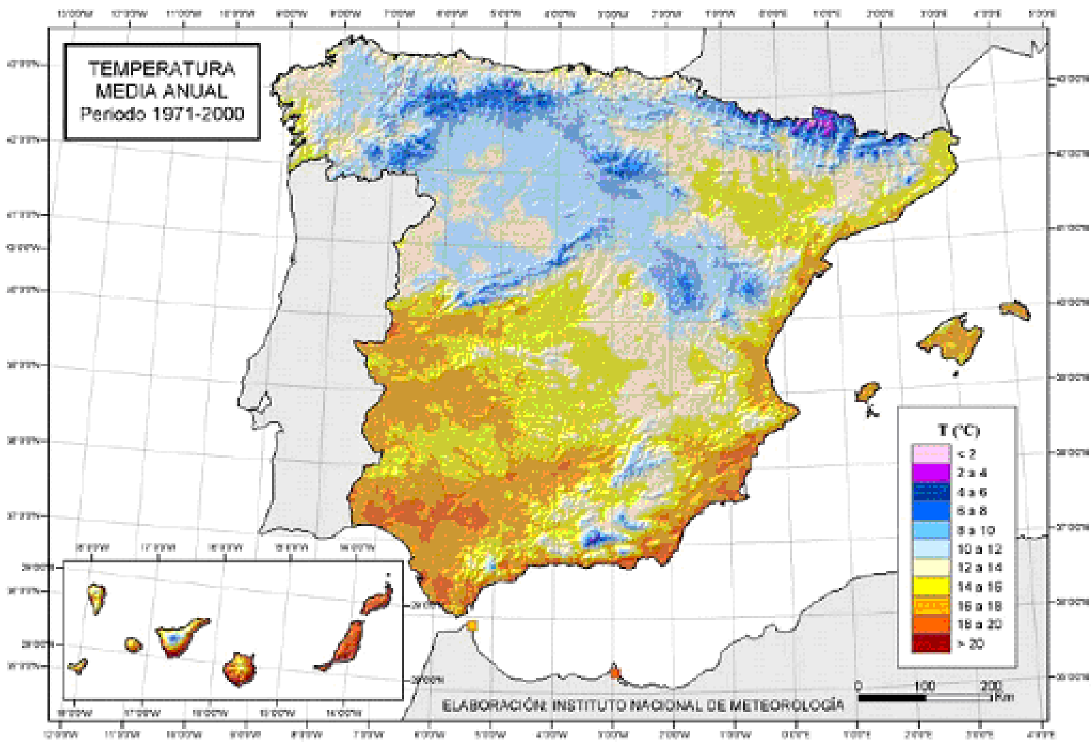

Figure 1: Medium annual temperature in Spain from 1971 to 2000.

As is the case in most European countries, the Spanish services sector (including tourism) has grown steadily since the Second World War and now dominates the economy, accounting for 60.5% of GDP in 2004 (INE, 2005). This expansion has come largely at the expense of the agriculture, forestry and fisheries sector. In 2003 about 4% of the national GDP was formed by agriculture. However, it accounts for 12.1% of the European Union's total production. Around 15 million hectares are covered by forests with timber productivity of 1.2 billion Euros per year. Since Spain is one of the world's top tourism destinations (around 50 million visitors per year), and plays an important role in the Spanish economy contributing 12% of GDP and employing 12.5% of the population.

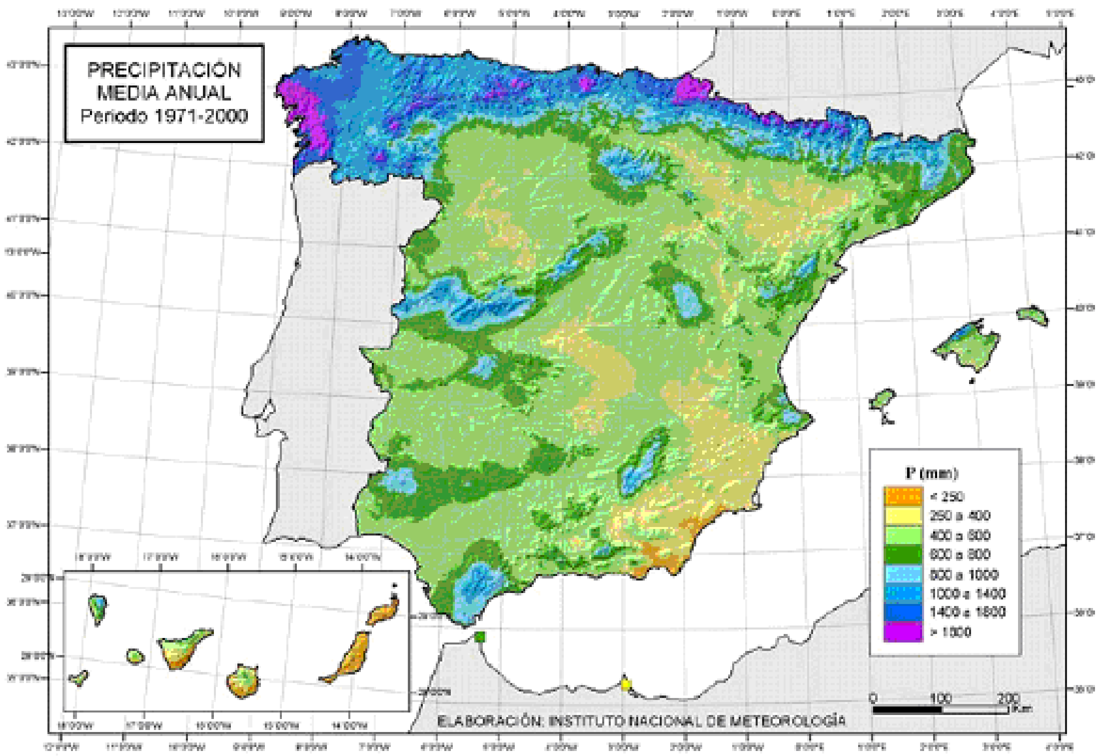

Figure 2: Mean annual precipitation in Spain from 1971 to 2000.

1.2. Project Objectives

Water is a very valuable resource e.g. as drinking water, for irrigation, and for the natural environment. As a result of the high spatial and temporal variability of precipitation across Spain, water plays a crucial role in every aspect of Spanish life. Therefore, many conflicts arise between competing sectors for this resource. Several studies (IPCC 2001, Schröter et al. 2005, Moreno 2005) show that with climate change water shortages are likely to increase, and as a result, more conflicts for this resource can be expected. Today, water is the number one environmental hot topic in Spain.

The aim of this study is to assess the vulnerability of three sectors, namely agriculture, tourism and forestry, from the potential water availability pressures derived from climatic change. More specifically, the study compares the present water stress situation with future scenarios based on trends and climate change models. Together with the adaptive capacity of each sector, the project gives an insight into how present conflicts might be exacerbated or improved in the future.

1.3. Sectors

This study focuses on three water dependent sectors of the Spanish economy, namely agriculture, tourism and forestry (which includes natural ecosystems). While forests systems, natural ecosystems and non-irrigated agriculture receive their allocation of water directly from precipitation, irrigated agriculture and tourism compete for the remaining water in the form of run-off. In the following below, the sectors, their linkages and the corresponding stakeholders are described.

1.3.1. Agriculture

The Mediterranean has been identified as one of the most vulnerable regions in Europe, where projected climate changes may cause some areas to become too hot and/or too dry to support agriculture for many crop types. Approximately 21 million ha (40%) of the national territory of Spain is farmed or used for pastures. Nearly one fourth of this area is irrigatable, whereas more than half is actually irrigated (Moreno 2005). About 50% of the national agriculture production is provided by crop sectors - fruit and vegetables, vineyards, olive groves and cereals. The remaining production is mainly formed by livestock.

Changes in the Common Agricultural Policy (CAP) are already showing some effects. Certain irrigated crops (maize, cotton, rice and alfalfa) are being heavily subsidised resulting in the over use of water resources. While in the past high subsidies did not always promote sustainable land use e.g. in terms of crop choices in relation to climate and soil, new agro-environmental measures seem to structure land use in a more environmentally sound way.

Different IPCC reports (IPCC 2001a, 2001b) indicate strong impacts of climate change on agriculture. Here, three factors play a major role, namely the likely increment in the CO_2 concentration and the temperature, and the decrease of precipitation. While the first factor will lead to a greater productivity and water-use efficiency, the latter factors will have the opposite effect. A rise of the temperature could also promote different diseases to crops as well as to animals. Extreme temperatures and low precipitation could necessitate reduced irrigation in regions where present rainfall is sufficient. Shifts in land-use could follow.

1.3.2. Tourism

Spain's excellent climate and natural landscape makes it a very popular country for tourists. Large sandy beaches and the reliable number of sunny days, together with low rainfall, make coastal areas of Spain a 'Mecca' for tourists from all over Europe. In the last two decades, however, another type of tourism has been developed based on the natural and cultural heritage of the countryside, and mountainous areas. Tourism provides benefits to the country in the form of revenue and employment, providing around 2 million jobs. However, the effects of tourism exacerbate the existing water conflicts. Water consumption in tourist areas is noticeably higher (about 500 litres per tourist and day) than in domestic households (about 160 litres per day). Furthermore, 56% of the influx of tourism is concentrated around the months of June, July, August, and September when water is scarce. Within these months the pressure on water resources is even greater not only due to the numbers of tourists, but also due to the fact that these are the months when precipitation is naturally low.

Present water scarcity could increase with climate change since precipitation is likely to decline (Moreno 2005). Climate models predict more extreme temperatures events, which could make some resorts less attractive to tourists. Higher temperatures can also lead to increased cardio-vascular problems. Additionally, the higher probability of forest fires, and its high media profile, can lead to a climate of insecurity amongst tourists. Recently burned areas, as well as the process of desertification, may lead to the loss of the aesthetic function of the Spanish landscape.

1.3.3. Forestry

About 50% of total Spain is covered by forests, which can be divided into dense forests (30%) with more than five percent foliage projective cover (FPC) and open woodlands (20%) with less than five percent FPC. The dense forests consist of different species types, namely conifers, broadleaved and a mixture of both. Several ecosystem goods and services are provided by forests, such as water regulation, timber provisioning, erosion prevention, carbon storage, and biodiversity.

Forests are subject to different threats caused by changes in land use and the climate. Meanwhile, timber logging promotes the erosion of the soil which prevents the establishment of new seedlings on these sites. Hot dry summers increase the probability of fire, and at present more than 20,000 forest fires occur per year with more than 150,000 ha being affected. This risk as well as the risk of forest pests and diseases is likely to increase under future climate conditions. The sensitivity of adult trees to environmental stress is relatively low. However, seedlings are more sensitive to low rainfall or soil erosion which makes forest regeneration sensitive to the described exposures. Moreover, the genetic variability of forests has decreased due to fragmentation. Since forest succession takes several decades or even centuries, its adaptive capacity is relatively low, particularly if changes are fast.

1.4. Stakeholders

In assessing the relevant water dependent stakeholders, the study focused on institutions, business and interest groups at the national level. Multi-stakeholder meetings were set up that looked at the varying concerns associated with water usage. Additionally, we also sought to increase the applicability of the study by engaging them in the early stages of the research. Stakeholders and their concerns are given in Table 1.

Table 1: Stakeholders and their concerns.

Stakeholders	Aspirations	Fears
Farmers Union	Productivity, employment	Water usage pressures, unemployment, reduced crop yields
Tourist Operators	Revenue, employment, suitable climate	Water usage pressures, reduction in tourist numbers, unemployment
Environment Agency	Biodiversity, landscapes water regulation	Loss of biodiversity and landscapes, excessive pollution, land degradation
Timber Associations	Productivity	Increased forest fires, competition from global markets
Water Authorities	Reliable water quality, availability and distribution	Poor water quality due to nitrogen leaching, deforestation and pollution, loss of water reserves due to decreased precipitation

2. Methodology

2.1. Conceptual Framework

The methodology in this study is based on historical trends, stakeholder input, and some potential future scenarios, to explore the vulnerability of Spanish water resources to changes in climatic conditions. This approach leads to the conceptualisation of water availability in terms of two drivers. Firstly, climatic factors determine the water availability in terms of precipitation and run-off. Secondly, national policy and local institutions shape water availability and distribution among the different land uses and related sectors. This study explores the exposure of the human-environmental system to a change on the climatic conditions and the effect that subsequent adaptive actions, both in the form of policy and stakeholders' actions, can have on the vulnerability of the system via the changes on the services provided by the different sectors - agriculture, tourism and forestry.

Vulnerability

This study adopted the definition of vulnerability as "the likelihood of a specific human-environment system to experience harm due to exposure to perturbations, accounting for the process of adaptation" (Schröter et al. 2004) which is commonly expressed as a function of three overlapping elements: exposure (E), sensitivity (S), and adaptive capacity (AC) (Turner et. al 2003).

$$\mathbf{V} = f(\mathbf{E},\mathbf{S},\mathbf{AC})$$

The characteristics of the exposure (**E**) are simulated through scenarios (i.e., policy and climate) that link changes in the drivers of water availability to the stressors, in this case a decrease in water availability for a particular sector. The degree to which the sectors are sensitive to a shortage of water availability is expressed in terms of water stress (**S**), which accounts for the differential water dependency of each sector. However, operators in these sectors have the possibility to buffer negative effects of water stress in different ways. This additional adaptive capacity (**AC**) has to be considered in assessing the vulnerability to changes in water availability.

Exposure
This study analysed the impacts of climate change on the already water-stressed sectors from present time to 2050. An increase in temperature or decrease in precipitation will have negative impacts due to increased water stress across the region, while opening opportunities for alternative development in selected areas. However, further water stress will undoubtedly lead to further conflict between the competing sectors. Since different water stress aspects (e.g. drought frequency, minimum reliable water supply) are relevant to the different stakeholders, the potential exposures were discussed and defined within the stakeholder dialogue.

Sensitivity
The sensitivity of the system was described in terms of water stress. Water stress across the region was measured by looking at the potential supply, or reserves, of water from run-off (groundwater run-off and surface run-off). This subsequent run-off was calculated using a simple hydrological model. Tourism and irrigated agriculture are counted together assuming that humans are managing the distribution of water to these sectors. In contrast, forests and non-irrigated agricultural lands fulfill their water demand from the incoming precipitation, which is not managed by human infrastructures. Overall, the combination of exposure (climate change) and sensitivity (water stress) results in the potential impact on the relevant sector.

Adaptive Capacity
Adaptive capacity or the ability to implement adaptation strategies is a major factor determining the differential degrees of vulnerability across Spain and between sectors. Vulnerabilities may exist across Spain in differing levels and some regions may be more vulnerable than others. How sectors within those regions are able to adapt to the potential impacts of water stress will very much depend on the prospective *autonomous* adaptiveness of each sector (or individual stakeholder) or the way in which national or regional policy can provide some form of *planned* adaptiveness. Autonomous adaption (Parry and Carter 1998) can be described in a number of ways. Autonomous adaption could be described as natural adaption i.e. an unconscious biophysical adjustment (e.g. increased growth in plants due to CO_2 increases). Routine adaption is based on more conscious adjustments and can be seen as a response taken at an instinctive level (e.g. shifting of a sowing date based on soil moisture conditions). Finally, tactical adjustments represent a pronounced response over and above an instinctive reaction (e.g. a change in crop type). For all our stakeholders, how they react in an autonomous way to changing climatic conditions and the impact on water stress will be dependent on an individual's or sector's potential adaptive capacity.
In our study we focused primarily on strategic (*planned)* adaption initiated by policies of national government. However, we made some initial judgments on the *autonomous* adaptive capacity of each sector before any *planned* adaption had taken place. The adaptive capacity of each sector was defined in 'meetings' between the affected stakeholder(s), resulting in a stimulating discussion between competing sectors. By making qualitative assumptions on the effects of adaptive capacity on the potential impacts, the approach of our vulnerability assessment combined a quantitative process with a qualitative process.

2.2. Vulnerability Assessment

The vulnerability assessment of this study consisted of two parts, (1) the evaluation of exposure, sensitivity and adaptive capacity of the sectors, and (2) their integration into a qualitative vulnerability assessment.

We first mapped our sectors to land uses which resulted in two groups, differentiated by their water intake source, irrigated agriculture and tourism (run-off dependent) and forests or non-irrigated areas (direct precipitation dependent). Their exposure to a decrease in water availability resulting from a scenario of environmental change was calculated out of land use data and a simple hydrological balance model. Run-off was estimated based on a simple function of precipitation in continental Spain (Schulze pers. comm.) as shown in Figure 4.

Once the water availability to the different land uses was determined, the current condition respectively the sensitivity of each sector to a simulated water shortage was estimated in form of water stress by land-use type and sector. Next, we estimated the potential impacts to each sector specific service by developing a potential impact matrix (Figure 10). This matrix relates varying degrees of water stress to potential changes in the services based on stakeholders' input and expert knowledge. Subsequently, a map of the current condition (water stress level) of the land-use type based on current water availability, and a map of the potential impact for a climate change scenario were created. These maps of the potential impact were afterwards shown to the stakeholders participating in the study. The stakeholders indicated their probable adaptive capacity and their reactions to possible policy changes. Their input was used to derive an adaptive capacity matrix (Figure 11) which was used in conjunction with the potential impact matrix (Figure 10) to estimate vulnerability.

Figure 3 shows the application of the conceptual framework for assessing water stress sensitivities for Spain. The involvement of the stakeholders during the working progress improved the maps of potential impacts, provided important information about adaptive capacity, stimulated discussion between competing sectors, and established valuable feedbacks to politicians.

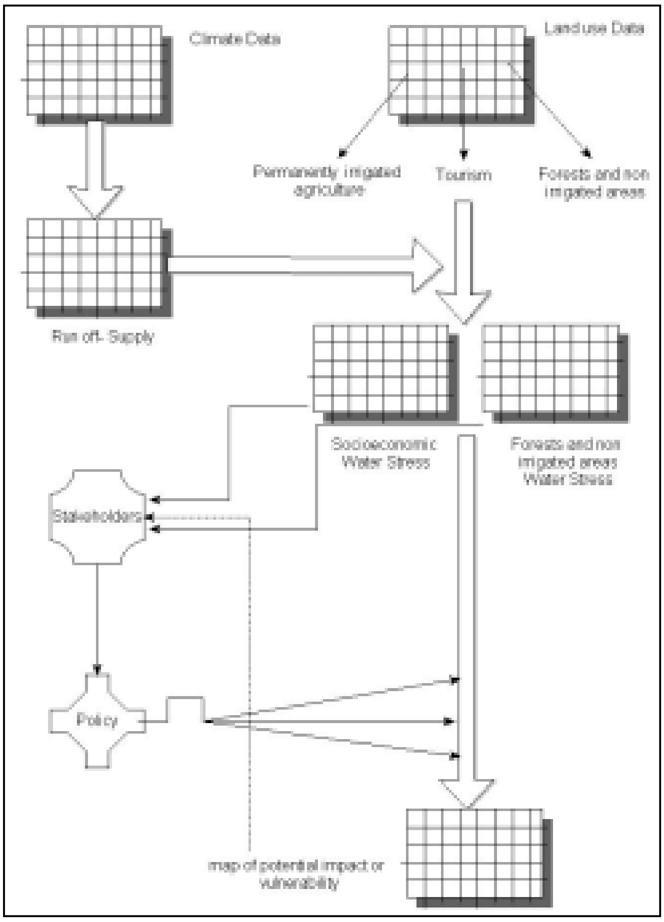

Figure 3: Application of the conceptual framework based on the WUNDERBAR model and the integration of Stakeholders and Policy makers.

2.3. Input data

The study recognised the need to address vulnerability in terms of scales, dynamics of pressures and coupled system interactions. Data and time was limited. However, a nation wide grid of land use (Corine - 250 m resolution) was used together with climate data with a 10 minute resolution for monthly precipitation and temperature (ATEAM 2005). The spatial units were based on a 50 x 50 km grid, and all calculations were derived within this grid, including:

- percentage of land use by sector
- mean annual precipitation
- mean summer precipitation and temperature

These inputs were used in the WUNDERBAR model to calculate water stress within each 50 x 50 km grid, as described below.

2.4. The WUNDERBAR Model - parsimonious spatially explicit water stress model

The WUNDERBAR model approach assesses the sensitivity of each target-sector to the water demand to supply ratio. For this purpose, a simple water balance model was developed. The model first calculates the annual amount of water received from precipitation, and then the demand of the irrigated agriculture and tourist sector per grid cell. Each grid cell is characterized by an incoming amount of water calculated as mean annual precipitation multiplied by the total area of the grid. The volume of water that can be managed equals the run-off (i.e. run-off = precipitation - evapotranspiration) and is multiplied by the infrastructure's efficiency to capture water. The variation of run-off as a function of the incoming precipitation is illustrated in Figure 4. This amount of water constitutes the supply for each target grid cell (50x50 km).

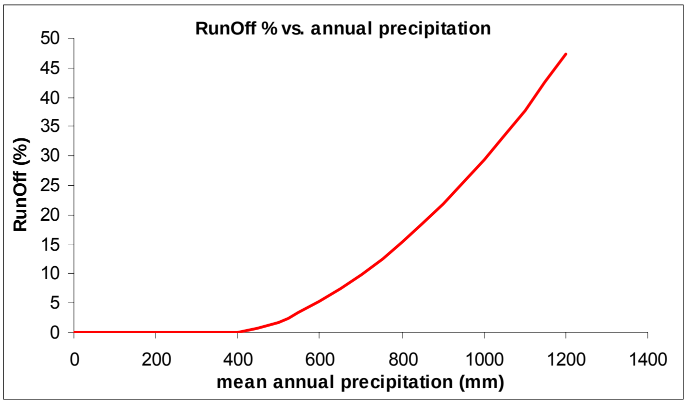

Figure 4: Annual run-off vs. mean annual precipitation

The percentage of each land-use type (except tourism) for each 50km by 50km cell was calculated by aggregating Corine data. The percentage area for tourism was estimated by assuming that tourism existed along the coast of Spain and inland by 10 km. Urban areas were also included as tourist areas, whereas mountain tourism areas where estimated as those occurring above 1600 m and suitable for skiing. The water stress for each grid cell was then calculated based on the demand and percentage of each land use occurring within the cell. Figure 5 shows the simple equations that were used in the model. Explanations of these variables and the parameters that were used for our scenarios are given in Table 2.

Supply = RunOff(%) x AnnuaPrecipitation x CellArea x infEfficiency

WSsocecon = (TouristicDemand + IrrigatedAgricultureDemand) / Supply

TouristicDemand = Tourperiodlenght x Tourmeancons x Numoftourists

IrrigatedAgricultureDemand = IrrAgrArea x Irrigcoef x AnnuaPrecipitation

WSnatveg =1 **-** Sqrt(Min(0.1 * SummerPrecipitation / (2 * SummerTemperature), 1))

Figure 5: Basic equations from the WUNDERBAR model

Table 2: Input parameters and scenario assumptions for the "parsimonious" water balance model.

Sector	Parameter	Explanations	Scenarios			Units
			Current [2]	*Climate Change*[3]	*Climate Change with Policy*[4]	
Tourism	numoftourists	Tourist density: mean number of tourists visiting a region	200	200	200	ind/km²
	tourmeancons	Mean water consumption per tourist per day	500	500	current -20%	Lt/day
	tourperiodlength	Mean duration of stay	10	10	10	days
Irrigated agriculture	Irrigcoef	Amount of water compared to natural precipitation which is available after irrigation	2	2	Current -25% and +10% efficiency	-
Forests and non-irrigated agriculture	Summer-Temperature[1]	Mean summer temperature	see map	current +1		°C
	Summer-Precipitation[1]	Mean summer precipitation	see map	current -10%		mm

[1] The ratio (prec/2*temp) expresses a measure of the drought severity for the summer month (Moreno 2005).
[2] See section 2.4.1, [3] see section 2.4.2, [4] see section 2.4.3

2.4.1. Current situation (potential impact)

Historic and future perspectives are key to a better understanding of the vulnerability of a region. Therefore, we first estimated the current condition of our system in an attempt to capture the historic dimensions of our study. This condition was expressed in terms of the current water stress level (sensitivity) of the different sectors using climatic (exposure) and land use data from the ATEAM database. The remaining parameters, outlined in Table 2, were based on a short literature review. In our case, the current situation represents the potential impact, which is a function of "sensitivity" and "exposure" (PI = f(S,E)).

2.4.2. Future trend - adding Climate Change (no policy)

A temperature increase of 1°C and a precipitation decrease of 10% were used to simulate a change in climatic conditions (exposure). These changes were applied to each cell. We are aware, that precipitation and temperature changes are not likely to be equally distributed across Spain, therefore, errors may occur due to these simplified assumptions. Following this scenario the "socio-economic" parameters were kept constant, assuming no policy derived response.

2.4.3. Adding Adaptive Capacity (with policy)

To simulate a planned adaptive capacity three national government policy drivers were recommended:

1. An increase in the water price can have several impacts on the parameters.
2. The water use efficiency can be increased due to reduction of leaks and better reservoir management.
3. The consumption of tourists per day can be decreased, by public awareness campaigns. The irrigation factor can be decreased as well, since a shift to less water demanding crops can take place.

3. Results

In order to validate our model we compared the run-off output of WUNDERBAR for current climatic conditions with the run-off of the ATEAM project. These two maps are illustrated to Figure 6.

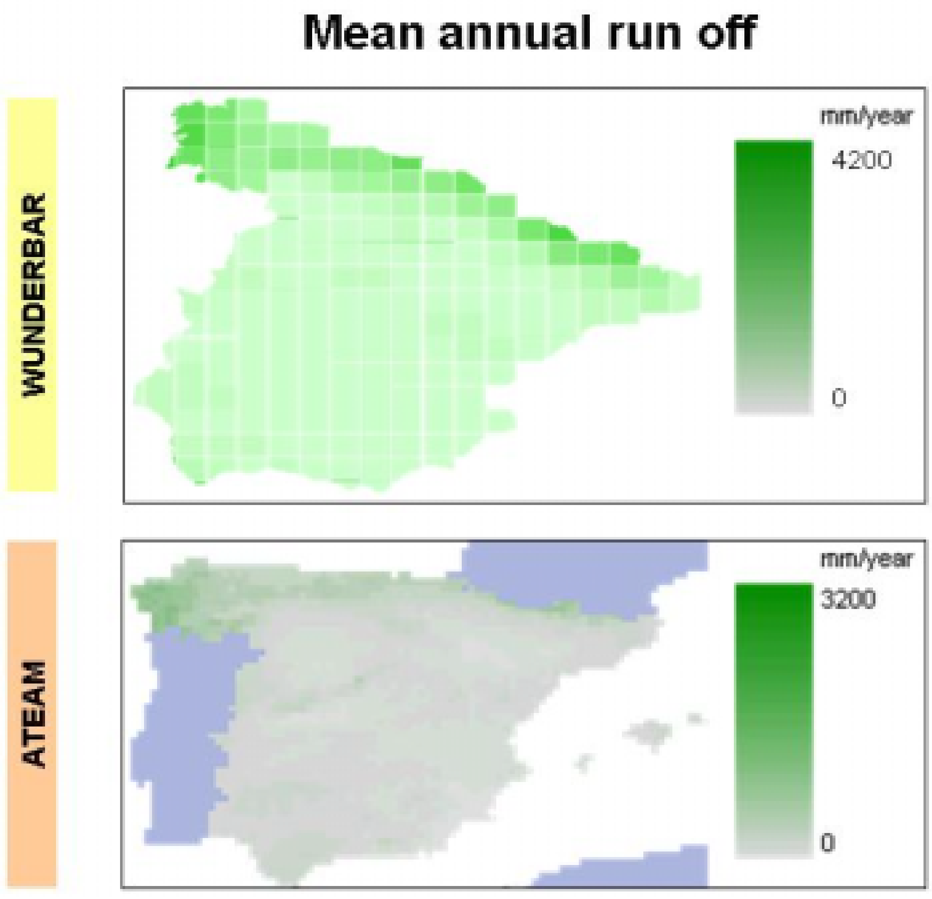

Figure 6: Comparison between the annual mean run-off from the WUNBERBAR model and the ATEAM model

The maximum simulated annual run-off reaches a higher value than the ATEAM maximum. This could be an effect of the smaller resolution of our grid. Nevertheless the spatial distribution is well captured and there are strong similarities between both model results.

3.1. Current situation

Water availability and distribution is already an important issue in Spain. As illustrated in Figure 7a and 7b a significant area of Spain is currently under medium or high water stress status. These areas can mainly be found in the southern part where there is greater tourism development in conjunction with the presence of irrigated agriculture and reduced rainfall. Water stress on forest and non-irrigated agriculture is high along the southern coast and medium in the southeastern part of Spain where there is already little forest and agricultural area because of the dry conditions.

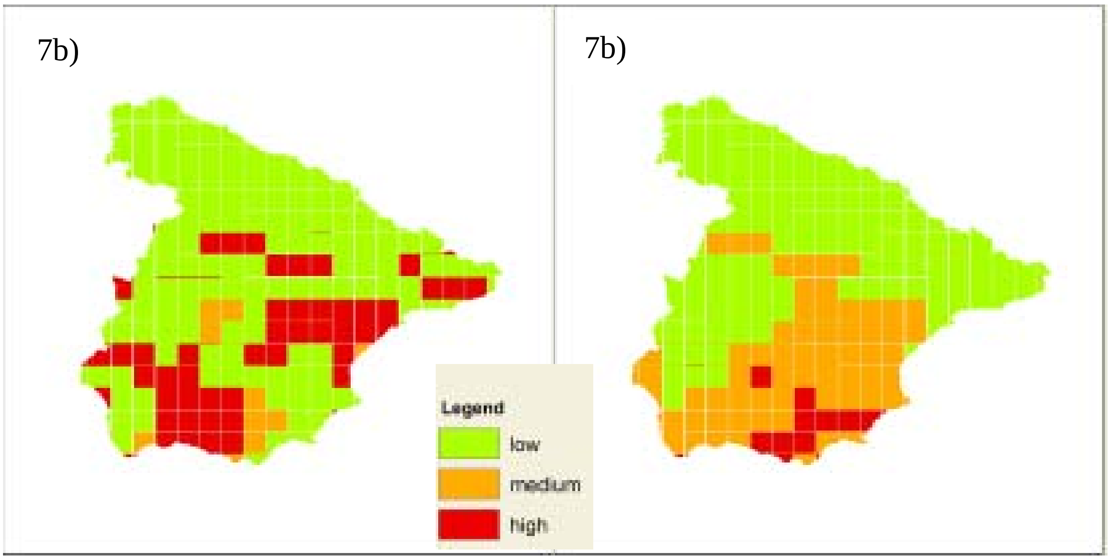

Figure 7a and 7b: Current water stress based on current climate conditions for a) tourism and irrigated agriculture sectors and b) forest and non-irrigated land

3.2. Future trend - adding Climate Change (no policy)

WUNDERBAR results indicate that enhanced dryness due to climate change increases the areas of high and medium water stress considerably (Figure 8). This pattern clearly points to a high sensitivity of water availability to climate change and, therefore, suggests that water, and linked sectors, are potentially very vulnerable.

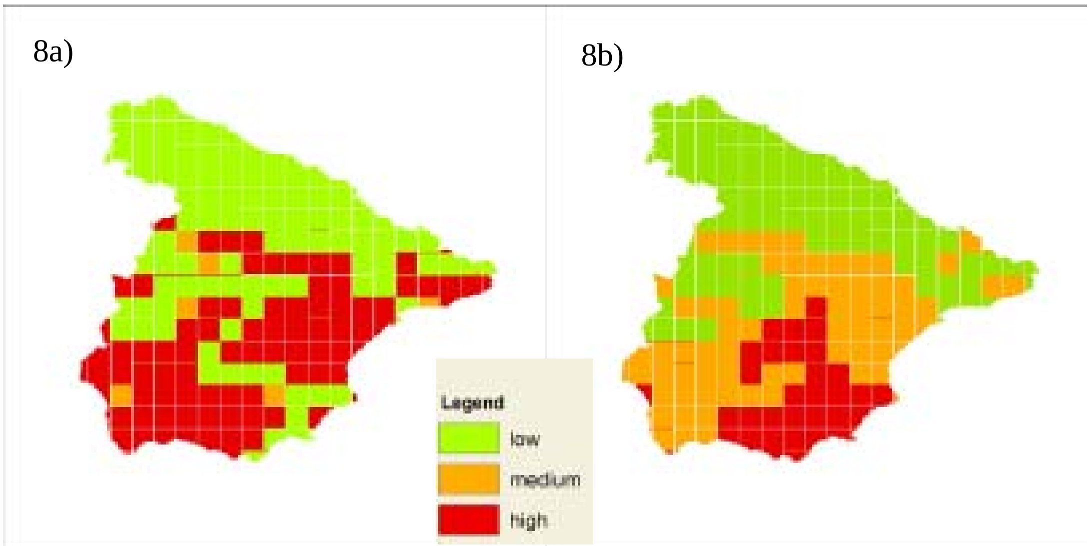

Figure 8a and 8b: Water stress after adding climate change for a) tourism and irrigated agriculture sectors and b) forest and non-irrigated land

3.3. Adding Adaptive Capacity (with policy)

Adaptive responses due to increased water use efficiency of the infrastructure, changing to less demanding agricultural crops, and increasing the price of drinking water, could decrease water stress in some areas. However, the overall picture (Figure 9b) does not change significantly indicating that the adaptive capacity within the tourism and irrigated agriculture sectors is low. If WUNDERBAR results prove to be valid, Spain's water sector and hence economy is very vulnerable to climate change given that its high sensitivity in conjunction with expected exposures cannot be compensated by simple adaptive responses/adaptation measures.

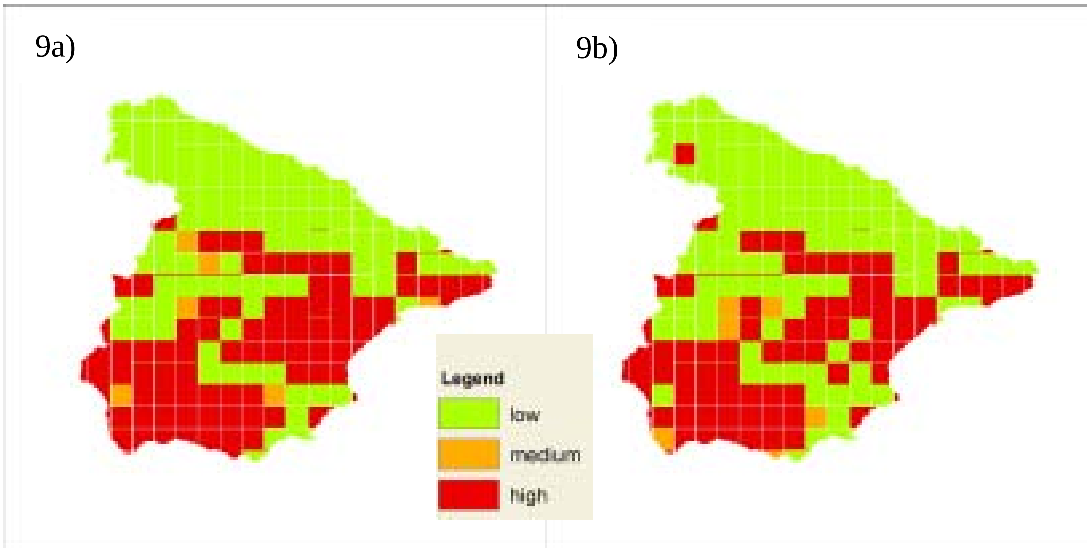

Figure 9a and 9b: Water stress by changing policy showing a) tourism and irrigated agriculture sectors before policy change and b) tourism and irrigated agriculture sectors after policy change

3.4. Potential Impact matrix

The following matrix was the basis to assess the potential impacts to the services and sectors in relation to their water stress. This process involved high stakeholder participation.

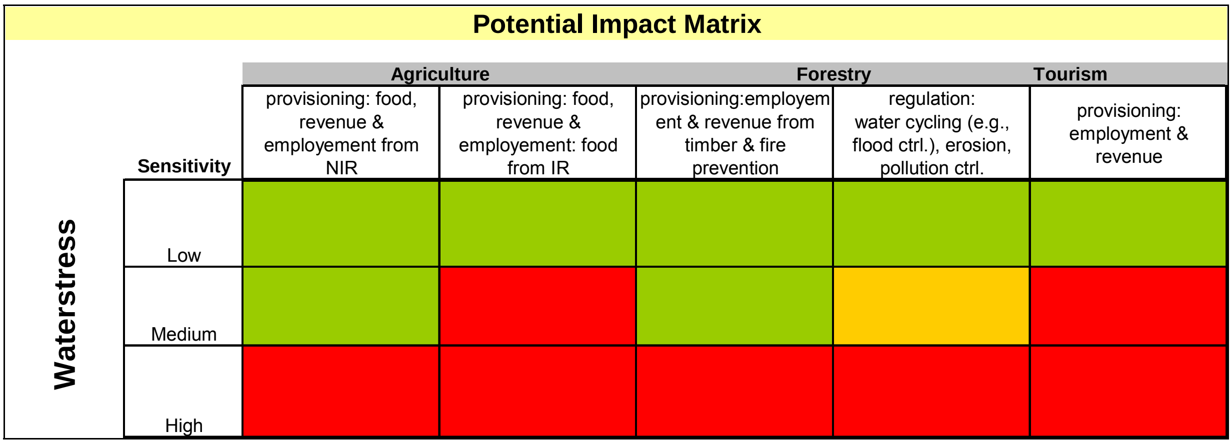

Figure 10: Potential Impact Matrix. Levels of potential impact are indicated by the colours with green = slight, orange = moderate and red = high.

The specific level of water stress for each cell (low, medium and high) and how it affects each sectors (or sub-sectors) is represented by three levels of potential impact - slight, moderate or high. Each sector felt that high water stress in their area would lead to a high impact and pointed to negative impacts within their sector. Low water stress was not seen as an issue.

3.5. Adaptice Capacity matrix

Together with the stakeholders, an adaptive capacity matrix was developed (Figure 11). It was developed based on stakeholder input examining their adaptation strategies and perceived capacity to deal with varying degrees of water stress. The agricultural sector should be able to improve its water use efficiency by at least 10% through the modernisation of irrigation systems (repairing leaks, drop-irrigation etc.). Within the Tourism sector, on the other hand, the adaptive capacity is lower. However, some of the stakeholders noted that the technology of washing machines, air-conditioning systems, and dishwashers will improve. According to this, a low increase of water stress would have no serious impacts. The Forestry sector has almost no adaptive capacity by technological measures or management improvement to enhance the water availability, since it is only driven by rainfall. However, more drought tolerant trees could be planted. Additionally, fragmentation could be decreased to increase forest areas. This could have stabilising effects on the water cycle. Another important issue is the increased fire risk in a drier and hotter climate. Several management strategies could be applied to reduce this risk, e.g. enhanced awareness or fire-breaks.

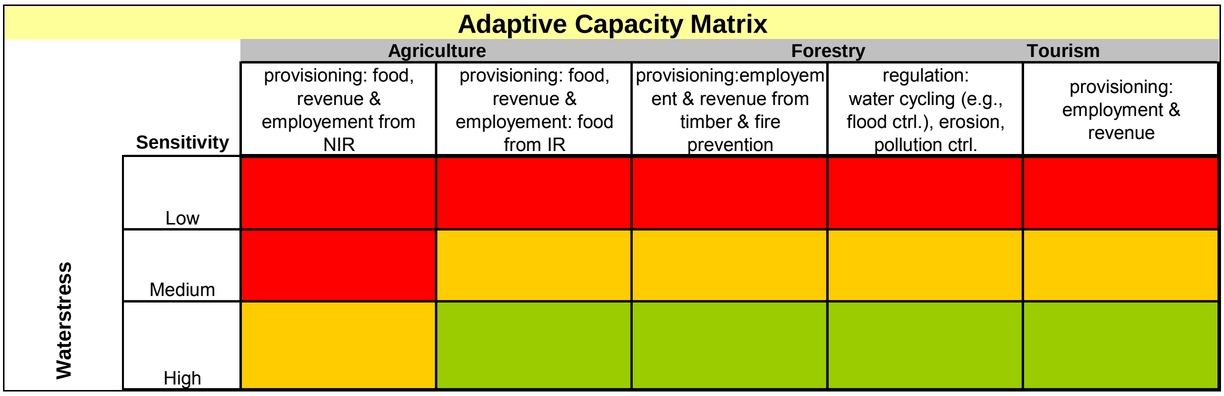

Figure 11: Adaptive capacity matrix. NIR describes non-irrigated agriculture, whereas IR describes irrigated agriculture. The levels of adaptive capacity are indicated by the colours: green = low, orange = slight, red = high.

Finally, the assessment of vulnerability has been done by comparing the maps of future water stress and the 'Vulnerability' matrix (Figure 12) which is simply our interpretation of how the matrices 'Potential Impact' and the 'Adaptive Capacity' may interact. For instance, in the case of non-irrigated agriculture a medium water stress level results in a low potential impact (green) and corresponds with a high adaptive capacity (red) which results in low vulnerability for that sector and its related services. In the case of tourism, however, a medium water stress may result in high potential impact and if the adaptive capacity is medium, the resulting vulnerability is medium as well. By knowing the water stress and the level of vulnerability, the stakeholder and policy makers can discuss ways and means to overcome arising conflicts between the agriculture and tourism sectors.

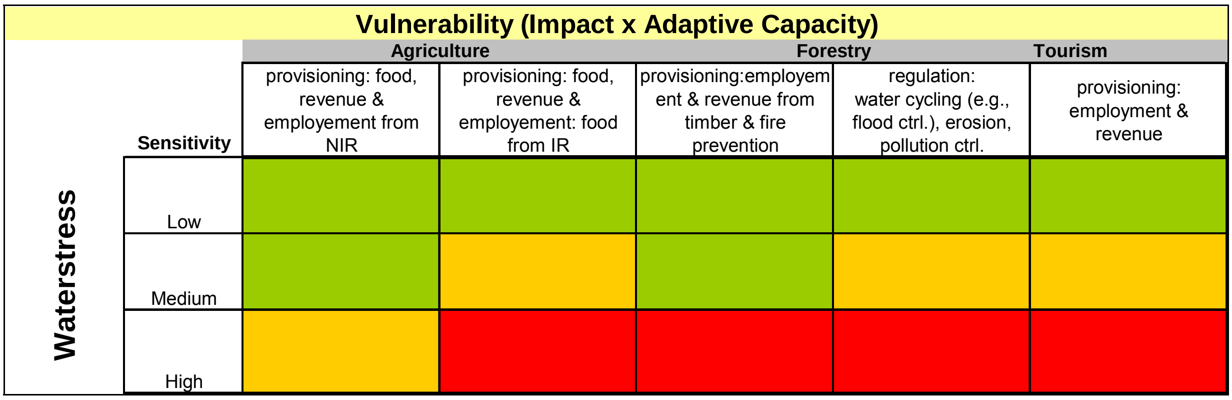

Figure 12: Vulnerability matrix. The levels of vulnerability are indicated by the colours: green = low, orange = slight, red = high.

4. Conclusions

Despite the simplicity of WUNDERBAR, the model is able to capture present day patterns of water availability. It is therefore a valuable tool to explore the distribution of available water amongst sectors under assumed exposures and can indicate the potential vulnerability in the landscape. A much more complex model is needed if the purpose would be to be truly realistic. However, this is beyond the scope of this analysis, while the main purpose of the model is to raise awareness among stakeholders.

It has been shown that high water stress leads to high vulnerability within each sector. Furthermore, the area of high water stress is likely to increase significantly in the near future. Decreasing water availability propagates through the coupled human-environment system in a non-linear fashion since demand for water increases automatically when the already scarce supply further decreases. Technological improvements such as enhancing water use efficiency seem insufficient to cope with the water problem as fundamental socio-economic structural changes are necessary to compensate the rising supply-demand conflict. CAP reform is also needed to prevent the damaging subsidies that often ‘force’ farmers to grow ‘water-hungry’ crops.

Studying the effect of such structural changes will have to consider explicit trade-offs between ecosystem services. Integrated assessment models, forced by different socio-economic scenarios, may provide pathways of sustainable land use, together with continued profitable developments for the future.

5. Discussion

The overall conclusion of the study is that all sectors are potentially very vulnerable to the present and predicted trend of declining water availability. Tourism, forestry and agriculture rely strongly on water availability and are therefore considered to be vulnerable.

The water problems in Spain relate to two major issues - its unsustainable use and scarcity. All sectors are already facing problems given that unsustainable water use is taking place and water shortage occurs in some seasons of some years. A major issue is the conflicting temporal pattern of water supply during winter, and increased water demand during the dry period in summer in conjunction with high inter-annual climate variability. In addition, the climate driven spatial pattern of water availability shows a strong water stress gradient from the wetter northwest to the drier southeast. Buffering the temporal and spatial patterns of water supply and demand is already challenging and requires a sensible integrated water resource management system. Hence, the sensitivity of the water sector is considered to be very high. The high sensitivity, in conjunction with the current drying trend, that is predicted to continue under climate change conditions, make the water sector potentially very vulnerable in the future. Adaptation strategies seem to be limited at the moment, but may include improved water resource management, increasing anthropogenic water use efficiency and decreasing water demand by e.g. decreasing irrigated cropping which involves restructuring within agricultural sector and has implications under CAP.

Facing increasing water demand in conjunction with decreasing water availability under current and predicted climate change makes the agricultural sector very vulnerable. Keeping high yields at competitive prices would cause a severe loss of ecosystem services. Short term adaptation strategies may involve extensive landscape transformation in some cases and hence result in additional losses of cultural services. Medium to long term adaptation strategies may require restructuring the agricultural sector from intensive cash cropping involving irrigation to a ‘cultural hobby’ with sustainable, ‘organic’, agro-forestry and pastoral management systems involving ecotourism. This process would yield three major benefits: (1) decreasing water demand (2) strengthened regulatory ecosystem services that support sensible water management and help to buffer the high imposed climate variability and consequences, (3) enhanced cultural services associated with an aesthetic and functioning landscape that should have a positive effect on people’s wellbeing and the tourism sector.

The vulnerability of the tourist sector depends very much on the cultural services provided by the landscape including weather and water, and to what extent the sector recognises tourist’s tastes and provides appropriate infrastructures. The tourist sector may be able to adapt to dryer and warmer conditions by developing new alternative tourist attractions that take advantage of a warmer north, but this will require both creativity and capital to develop new infrastructures. Southern coastal resorts, however, are the most sensitive to water scarcity. Once the water runs out, and tourists start to experience empty swimming pools, restrictions on water use or the drying up of reservoirs and lakes the tourist sector in these coastal areas could be in severe crisis with reductions in tourist numbers.

Finally, this study is based on a very limited amount of time, resources, facilities, knowledge and experience. Therefore, it is highly subjective. However, it may serve a “thinking tool” to elaborate and explore several hypotheses concerning water issues or constitute the starting point for a more sophisticated vulnerability analysis. Ideally, a more comprehensive version of the tool will provide a means to facilitate dialogue and build consensus among the different sectors.

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