Basin: *La Tordera*

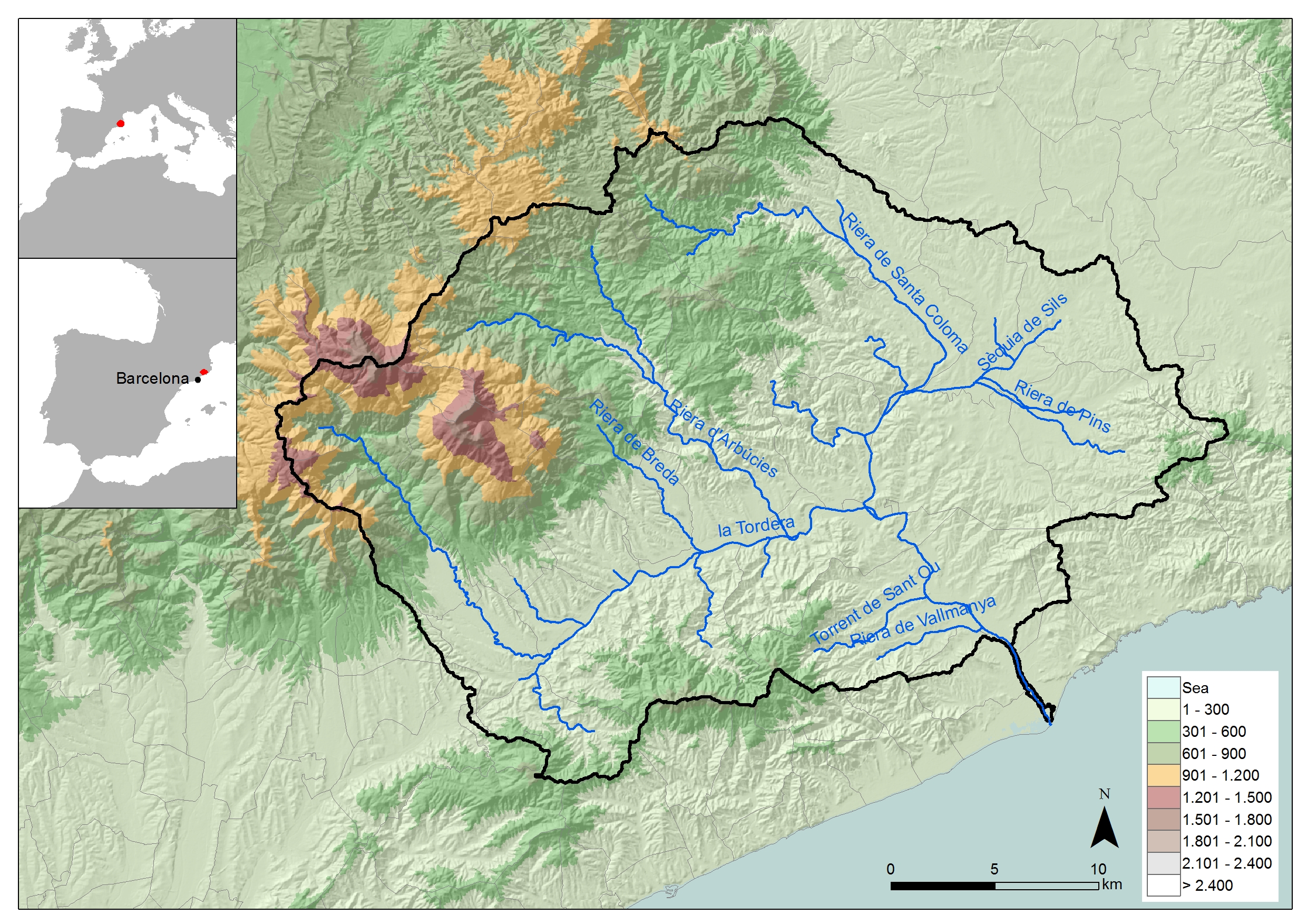
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**1.    Narrative**

**1.1            Description of the basin**

Tordera River Basin is located in the northern part of Catalonia (NE Spain) and presents overall Mediterranean climate conditions but with a high climatic diversity, ranging from the temperate areas at the headwaters mountaintop to the typical Mediterranean conditions in its delta area.



*Figure 1: Geo-localization of the River Tordera Basin. Source: Diana Pascual, 2015*

The Tordera River flows for 55 km along the Catalan Pre-Coastal Range through 3 counties; Vallès Oriental, Selva and Maresme, and covers an area of 894 km2 between the provinces of Barcelona and Girona, 81% of which is covered by forests. Different forms of environmental protection safeguard its richness in biodiversity: some areas are included in the Catalonian network of Natural Protection Sites, a number of them have been declared Habitats of Communitarian Interest and there are two natural parks: Montnegre Corredor and Montseny, the latter designated in 1978 by UNESCO as a biosphere reserve.

This natural landscape, as well as the basin’s proximity to Barcelona and the Mediterranean Sea makes Tordera Basin a very intensive touristic area. The Basin has approximately 111 800 inhabitants[[1]](#footnote-1), being concentrated mainly in the plains of the central section and the delta area (15 000 inh/km2), while in the upper areas of the basin density drops[[2]](#footnote-2) to around 100 inh/km2. This unbalanced distribution is accentuated even more by the major fluctuations in the touristic season, when population of most coastal towns doubles or triples.

The Tordera River is part of the Catalan Internal River Basin District[[3]](#footnote-3), it has an average flow of 5 m3/s with a torrential regime. The River is characterized by intense flooding episodes called *Torderades*, and river dynamics design a bending trace, generating fertile riparian areas often used for agriculture and short rotation timber production. In different places defence structures have been raised to protect activities installed in the riverbed such as gardening centres or industrial areas, as well as inter-regional transport infrastructure (highways, railways, gas, oil and water pipelines).

A highly permeable geological mosaic characterizes the hydrogeology of the basin where surface and groundwater are very much interconnected. Tordera River water use is overriding availability; therefore management has been mostly supply oriented: a desalting plant and connection to inter-basin water transfer systems integrate local resources (ATLL). Indeed, in this unregulated basin, groundwater flows are by far more important than surface water for supplying all users.

Urban supply is the most relevant water demand in the basin (30,9 Hm3/year)[[4]](#footnote-4). Moreover, bottling industry exploits high quality groundwater reserves in the upper part of the basin (2,15 hm3 in 2007) and in different locations along the river thermal water baths represent relevant demands too[[5]](#footnote-5). In addition, demand for irrigation water (13,6 Hm3/year) is crucial in the central (direct river catchment) and lower part of the river (groundwater). In these areas agriculture demand is a direct competitor with urban demand, especially in the summer. Tordera aquifers also provide water to intensive horticulture in areas outside the Tordera basin boundaries in the coastal area of Maresme County. Therefore, this area is included in the analysis, although formally not considered as the Tordera river basin district.

For the last 40 years chemical industry was highly relevant in the basin, but current trends are oriented towards logistic and technology sector development. This transformation has reduced pressure of the industry sector on water resources (7,6 Hm3/year) and increased chemical quality of the river flows.

**1.2           Global change**

Climate change impacts in the Tordera Basin were assessed during the ACCUA Project, and related studies[[6]](#footnote-6) [[7]](#footnote-7). These studies applied future projections covering the 2001–2100 period extracted from a dynamical downscaling procedure that used the atmosphere–ocean coupled model ECHAM5/MPI-OM[[8]](#footnote-8) [[9]](#footnote-9), performed by the Meteorological Service of Catalonia[[10]](#footnote-10) [[11]](#footnote-11). The A2 scenario defined by the IPCC[[12]](#footnote-12) considered, revealed temperature may rise by 0.5 oC between 2000-2025, reaching 1.4oC by 2050.

These same projections indicate that precipitation may decrease by 8.9% in 2025 compared to the reference period 1984 – 2008. Most significant are the projected changes in the rainfall patterns through the year, which show more frequent occurrences of extreme precipitation events in the future. On the one hand this may intensify summer droughts and, on the other hand, although floods frequency may decrease, due to urban expansion in the river space the risk of flood damage may increase.

The impacts of these changes in climate in the basin could be very relevant: both surface and groundwater availability for uses would be affected by the projected reduction of natural flows. The 152.6 hm3/year flow River Tordera carries today may decrease almost 30% by 2025 compared to the reference period 1984 – 2008 and by the same period, groundwater recharge would decrease by almost 10%.

Moreover, population in Tordera basin has shown a noteworthy increase in the last decades[[13]](#footnote-13) and this trend could be plausibly maintained in the coming decades.

These impacts on the Basin’s natural hydrologic cycle are foreseen to increase the disconnection between water bodies, strongly affecting both water quality and quantity, especially endangering wetlands and the delta area of the River. The latter will probably face many related consequences: dropping levels of groundwater would intensify seawater intrusion, as well as disruptions of sediment dynamics would worsen the erosion of beaches and dunes. Moreover, fish population and abundance is strongly dependent on the freshwater nutrients provided by the Tordera, therefore impacts of global change considered for continental waters need to be integrated with those referring to marine environments.

Temperature rise and changes in rainfall patterns will increase overall water demand for irrigation and reduce productivity of heat sensible crops. Nevertheless, these climatic conditions may also influence the vegetative cycle of some species, positively changing the agronomic calendar of crop management and balancing the impact in terms of water demand.

Rising temperatures will also affect people living in the basin, with more tropical nights and heat waves acting on personal comfort. More diseases and extreme events will integrate the complex composition of risks people are likely to be exposed to.

In addition to the climatic changes, land use changes may cause important impacts too: agriculture land abandonment entails the expansion of forested areas, increasing overall evapotranspiration of the vegetation in the basin. Moreover, as these forested areas are not properly managed, an excessive underbrush growth and rising temperatures due to climate change will most probably entail higher wildfire risk.

Projected climatic change may induce important variations in forest ecological functions, like the increase of tree mortality and modification of the suitability of species in the area. Projections indicate that by the end of the century forests may change from carbon sinks into carbon sources, remarking the importance of forest management in the basin to face global change.

**1.3           Challenges**

**1.3.1         Water quantity**

The lack of an adequate environmental flow regime has been identified as the most important factor for the bad ecological status of the water bodies in the basin. In the same line, stakeholders considered the human pressure on the basin’s water as the main challenge in the basin[[14]](#footnote-14).

The current number of gauging stations is considered insufficient and insufficient data are available to adequately monitor actual river flows. In many municipalities people still have private wells dating from the 50’s-70’s, and it is considered that many of these are not correctly registered and monitored, obstructing an adequate control of extraction rates[[15]](#footnote-15). Stakeholders considered that the overall functioning of the control and monitoring plan to assure compliance with WFD water quality standards is insufficient all through the basin.

Tordera’s groundwater bodies are officially declared as overexploited[[16]](#footnote-16). Shallow extractions for irrigated horticulture in the coastal area is causing salt intrusion, while bottling industries located in the upper part of the river extract important quantities of high quality water from deep wells. According to Montseny Natural park studies, the groundwater extraction rate in 2002-2003 increased by factor 20 with respect to 30 years ago, and with respect to measurements in 1988-1989, extraction rates tripled during the last 15 years. These alterations of water bodies negatively affect 34% of flora and fauna and 50% of habitats with interest for environmental protection objectives[[17]](#footnote-17). The wetlands located in Sils, for example, are entirely dependent on groundwater levels.

Unconventional water production (e.g. desalting and recycling) is currently one of the main proposals to face lack of water availability for some uses. In accordance to some stakeholders these projects are crucial adaptive water management strategies to overcome trade-offs between bulk water cost, water demand and availability. Indeed, Tordera has a desalting plant operative since 2002, expanded in 2007, as well as different reclaimed water use initiatives. Nonetheless, other stakeholders indicate these solutions also entail important impacts, like increased energy consumption, concentration of pollutants and reduction of river flows[[18]](#footnote-18).

The Tordera River is connected to the inter-basin water transfer system (ATLL), with the aim of achieving higher flexibility of available volumes for supply. The idea is to enhance the opportunities to complement local resources with those flowing in this regional distribution system, especially in times of drought[[19]](#footnote-19). Unfortunately, this strategy is building expectations among the citizens in the basin so that water availability will no longer be a problem. Nevertheless, the ATLL system depends on the flows of other rivers (Rivers Ter and Llobregat) affected by growing demands, lack of implementation of environmental flow regimes and drought, similar to the situation in the Tordera basin. Bulk water cost Municipalities have to pay to access this resource is considerably higher than those of local resources, and their negotiation capacity with the big corporations managing the ATLL system is low. To summarise, the basin’s self sufficiency of water availability is considered an important challenge by stakeholders[[20]](#footnote-20).

**1.3.2** **Water quality**

Drinking water quality is very high on the agenda in the basin, due to a pollution episode by faecal bacteria that caused the intoxication of 650 people in Santa Maria de Palautordera in 2002[[21]](#footnote-21). The service provider reported that pollution was due to uncontrolled urban wastewater discharge by upstream municipalities, causing great mistrust of tap water quality by local population still present today.

Installation of wastewater treatment plants is considered a challenge in the basin. Many small towns and dwellings, especially in the upper part of the river, are not provided with treatment facilities and discharge their wastewater directly into the river. Although specific depuration development plans are in place, both for industrial and urban users, the lack of a solid funding scheme and sound coordination between public administrations are major obstacles for increasing the quality of river waters.

Problems related to water quality also affect management of infrastructure and treatment facilities. This is illustrated by stakeholders reporting the case of drinkwater supply to Tossa de Mar, Lloret de Mar and Blanes, when demand rose due the touristic development in the 50’s and 60’s. Consequently, Tossa de Mar and LLoret de Mar integrated their supply with wells in the Tordera aquifer, but these wells contained high levels of iron and manganese, making it necessary to provide adequate purifying treatment. To face the costs the Costa Brava Consortium (CCB) was formed, which currently provides bulk water to 27 municipalities of the area, under direct assignment of the Catalan Water Agency. Aquifer quality constrains drinkwater quality and quantity, therefore wells positioned close to the coast are obliged to have a lower extraction rate than those more inland in order to avoid increasing salinity rates. Municipalities are therefore discussing how to negotiate bulk water price they buy from CCB and from the desalting plant (managed by ATLL in Blanes), as some need to integrate with the (expensive) desalted water more than others[[22]](#footnote-22).

**1.3.3        Health of forests and ecosystems**

Tordera’s river basin society emphasized the need to integrate forest management practices as a strategic element of water management in the river basin. Unattended forests are currently undergoing excessive biomass growth and tree mortality, making them more vulnerable to wildfires and affecting the quality of the forest ecosystems. As most forests are private, public policies for adaptation need to be orientated to stimulate good practices by landowners rather than to intervene directly. Therefore the challenge of environmental protection, although being a public administration’s responsibility, is strongly linked to forest exploitation and agriculture sectors[[23]](#footnote-23).

Disappearance of traditional animal husbandry has an important impact on forest structure, resulting in fewer open spaces and meadows, as well as on more understory vegetation, which affects wildfire risk. Stakeholders from the agriculture sector say there is no chance of recovering extensive livestock farming without proper funding programs, as current activities cannot reach economic profitability. In their opinion, cattle management practiced in function of forest management is laborious and lowers the already fragile economic viability. Therefore, when this activity is promoted as a measure for forest management it would be entirely dependent on subsidies, giving birth to the expression *“civil servant sheep”*. Moreover, current subsidies to the agriculture and livestock sectors are said leading to undesired effects[[24]](#footnote-24).

Stakeholders envision the overall challenge for the basin is to overcome the currently unbalanced land use mosaic, combining arable land, forests, areas of natural interest and urban areas, such that it enhances the capacity of the territory develop and maintain itself[[25]](#footnote-25).

Forest management is fundamental also to avoid biodiversity being negatively affected by forest exploitation. Montseny Natural Park authorities indicate profitability of forest exploitation interventions led to the use of non-native or unsuitable (in terms of climate, pests and ecological functions) species (e.g. black poplar). Such species, introduced by humans or developed colonising degraded habitats, constitute a problem for the biodiversity of the park[[26]](#footnote-26).

Moreover, incorrect river flow regime, pressure and impacts on riparian vegetation and infrastructures impeding connectivity between habitats, some invasive species (mostly fish and riparian vegetation) are getting a prominent role in local ecosystems.

Hydro-morphology of the river is significantly modified by infrastructure crossing the region: in the riverbed we find gas and oil pipelines, high speed train track, highways, high tension electricity lines and water pipelines.  Moreover, historical gravel extraction from the riverbed has caused it to deepen significantly, affecting flooding dynamics and connection with groundwater tables. Indeed, sediment mobilization - highly depending on river flow regimes and river morphology - is disrupted, causing increased erosion of the coastline too. Therefore recovering the river space functionality is a crucial challenge in the basin[[27]](#footnote-27).

**1.3.4 Integrated Water Management**

Stakeholders indicated they do not have sufficient access to relevant information on the basin’s water management. For example, information on the exact amount of water extracted by bottling industries is not available, neither for citizens, nor for the Water Agency, as this is regulated under mining legislation and protected by industrial secret. Citizens expressed their basin is providing 27% of total amount of mineral water consumed in Spain and that “*more water flows on the highway than in the river”[[28]](#footnote-28).* Therefore, access and transparency to relevant information is a major challenge for sound adaptive water management and citizen participation. Tordera society considers democratic quality is insufficient, claiming better governance and specific deliberative spaces allowing facing the basin’s challenges.

Water use entitlements are not properly managed; the quantities assigned are higher than the actual flows in the river, making water scarcity directly the result of management practices[[29]](#footnote-29). Entitlements are legislated by Spanish authorities, therefore Catalan Water Agency has limited negotiation capacity to introduce modifications and voluntary agreements need to be established. Main challenge is that in order to recover water entitlements needed for environmental flow regime implementation the Agency is obliged to compensate the users for lost benefits until the entitlement expiration date, entailing unaffordable and unjustified costs. This is particularly challenging with regards to long term service externalization contracts emitted in favour of water supply and treatment corporations[[30]](#footnote-30).

Water economy is a major issue, as Catalonia is experiencing significant problems to properly fund supply infrastructure building, exploitation and maintenance. These challenges involve issues related to the distribution of competences, inconsistencies regarding bulk water cost, water pricing design and management objectives of the water supply and treatment. Indeed, companies exploiting water production and distribution systems need to prioritize economic management criteria to maintain business, while public administrations need to guarantee the quality of supply to all citizens, good status of water bodies and related ecosystems. Given that direct catchments from water bodies are cheaper than unconventional resources and that cost recovery is proportional to the volumes of water sold, these criteria are in open contradiction with general interest: the protection of water bodies and reduction of consumption levels[[31]](#footnote-31).

Moreover, in the basin’s area there are many tourist facilities, including hotels, scattered houses with swimming pools, camping and harbours, etc., as well as transport infrastructures and supply services. All these infrastructures are designed in accordance to attend demand peaks in the touristic season, but costs of operation and maintenance of these fall on the shoulders of the resident population. This situation is considered unfair and leads to intense debates on water pricing in the basin, especially in the delta area[[32]](#footnote-32).

In order to veil for adaptive management practices, public authorities need to face the major challenge to better coordinate at all levels. Stakeholders expressed that many policy objectives are not met due to contradictory sectoral policies and perverse subsidies[[33]](#footnote-33). For example, the Agriculture department is promoting expansion and consolidation of irrigated agriculture while Water Authorities need to reduce extractions from Tordera aquifers. Similarly, municipalities would welcome more coordination and better dialogue with Water Agency, for example on the development of wastewater treatment plants[[34]](#footnote-34). In order to promote the implementation of important measures, municipalities consider they would need better coordination between themselves on issues related to zonal planning, etc.

**1.4           Current status**

The Tordera FCM was designed to reflect the most relevant dynamics of the basin.

Drivers of the system are climatic variables, like temperature and precipitation, as well as population, environmental legislation and WFD objective compliance.

Water availability for supplying water to municipalities, touristic facilities, industry - including bottling plants - and agriculture, as well as the implications of water consumption in terms of water quality or necessary infrastructure are summarised in the factor ‘water uses’.

Very strong relation links water uses to water quantity in water bodies (factor referring both to surface and ground water). The aim assigning such a strong weight is to reflect also the structural overexploitation in the Tordera basin. On the other hand, when water is available, more uses are enhanced, and later consolidated through the possibility to integrate local resources with external water, transferred from other basins or produced through desalination. This management model induces high cost of bulk water, due to the needed infrastructure and energy consumption it entails.

Water quantity and quality are very strongly linked, as water flows in the river have a very strong diluting effect. Moreover, the natural capacity to neutralise pollutants is linked to the water flow regime, providing the adequate habitats both for in-stream, riparian and wetland ecosystems. For groundwater this relation is expressed by the impact indicator salt intrusion.

The factor health of forests reflects the rich biodiversity in the basin, as well as the importance to maintain its conditions as to avoid wildfires to occur, especially with high temperatures in summer.

The factor health of water ecosystems intends to resume the environmental status of water related environments, including wetlands, riparian and in-stream ecosystems.

Agricultural land use is expressed separately for extensive and intensive farm exploitation models, due to their different impact on the environment and different water consumption patterns.

Hydro- geo-morphological related factors are summarized in one factor. On the one hand, it considers flood damage, indicating that when river space is occupied by dwellings or infrastructure, the impact of floods is higher, and on the other hand, it relates to health of forests and ecosystems, indicating the significant importance of this feature for proper river functionality. This factor includes considerations about sediment flows and all characteristics of connectivity: a) linear –migration of species along the stream – b) lateral –riparian habitats – and c) vertical – interrelation between in-stream wetlands and groundwater bodies.

Dwellings and industries located in sensible areas, like the river space, coastal or environmental protected zones are included in the factor urban expansion. This factor also refers to the growing pressure of tourism and population on the territory, referring both to the impacts on hydro-geo-morphology and water availability.

**Table I.1: documentation of the factors in the cognitive maps**

|  |  |  |
| --- | --- | --- |
| Number | Factors | Definition |
| F1 | Wildfire | Forest fire |
| F2 | Health of forests | Composition of species, forest structure and functionality. |
| F3 | Extensive/ traditional agriculture land use | Refers to enterprises with a low input exploitation model. Factor refers to land use, water use these activities enhance is considered part of the F6 |
| F4 | Biodiversity | Indicates level of biodiversity in all ecosystems |
| F5 | Water quality | Refers to chemical and biological quality of rivers; chemical quality of aquifers. |
| F6 | Water uses | Urban, Tourism, Industry, Agriculture, Bottling are main uses considered. |
| F7 | Intensive agriculture land use | Refers to enterprises with a high input exploitation model. Factor refers to land use, water use these activities enhance is considered part of the F6 |
| F8 | Temperature | Temperature of the air |
| F9 | Health of water ecosystems | Quality of wetlands, riparian, in-stream ecosystems |
| F10 | Salt intrusion | Lowering level of freshwater in aquifers entails intrusion of seawater. |
| F11 | Water quantity | Refers to the volumes of water flowing in rivers, the level of aquifers and feed in ratio of all related water bodies. |
| F12 | Hydro - geo- morphological quality | Broad concept, Includes: river space, all forms of connectivity and delta/coastline morphology. This factor includes Sediment flows (mobilization of sand, gravel and all solid components) |
| F13 | Urban expansion | Scattered houses, Camping, Industrial zones and dwelling growth |
| F14 | External water | Refers to all input from no natural sources of the basin: Transferred from other basins or produced through desalinization or reclaiming plants. |
| F15 | Bulk water cost | Refers to the real costs to obtain bulk water |
| F16 | Water treatment | The presence of wastewater treatment facilities, as well as purification plants. |
| F17 | Flood damage | Refers to the impact on people and infrastructure of floods. |
| F18 | Precipitation | Precipitation regime |
| F19 | Population | Refers to both resident and tourist population |
| F20 | WFD | Refers to those management and policy measures implemented to meet WFD objectives |
| F21 | ENVIRONMENTAL PROTECTION | Refers to all legislation aiming at environmental protection: N2K, PEIN, Parks, etc… |

**Table 1.2 documentation of the relationships in the cognitive maps**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **F1** | **F2** | **F3** | **F4** | **F5** | **F6** | **F7** | **F8** | **F9** | **F10** | **F11** | **F12** | **F13** | **F14** | **F15** | **F16** | **F17** | **F18** | **F19** | **F20** | **F21** |
| **F1** | 0 | -0,9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F2** | -0,6 | 0 | 0 | 0,6 | 0 | 0 | 0 | 0 | 0 | 0 | -0,3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F3** | -0,3 | 0,6 | 0 | 0,3 | -0,3 | 0,3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F4** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,6 | 0 | 0 | 0 | 0 | 0 | 0 | -0,3 | 0 | 0 | 0 | 0 | 0 |
| **F6** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0,9 | 0 | 0 | 0,3 | 0 | 0,6 | 0 | 0 | 0 | 0 | 0 |
| **F7** | -0,3 | 0 | 0 | -0,3 | -0,6 | 0,6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F8** | 0,6 | -0,3 | 0 | 0 | 0 | 0,3 | 0 | 0 | -0,3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F9** | 0 | 0 | 0 | 0,9 | 0,3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F10** | 0 | 0 | 0 | 0 | -0,3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F11** | 0 | 0 | 0 | 0 | 0,9 | 0,3 | 0 | 0 | 0,6 | -0,6 | 0 | 0,9 | 0,3 | -0,6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F12** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0,3 | 0 | 0 | 0 | 0 |
| **F13** | 0,3 | 0 | 0 | 0 | -0,3 | 0,6 | 0 | 0 | 0 | 0 | 0 | -0,6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F14** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,3 | 0 | 0,9 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F15** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -0,6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F16** | 0 | 0 | 0 | 0 | 0,9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0,6 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F17** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F18** | 0 | 0,3 | 0,3 | 0 | 0 | 0 | 0,3 | 0 | 0,6 | 0 | 0,9 | 0 | 0 | 0 | 0 | 0 | 0,6 | 0 | 0 | 0 | 0 |
| **F19** | 0 | 0 | 0,6 | 0 | 0 | 0,6 | 0,6 | 0 | 0 | 0 | 0 | 0 | 0,6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F20** | 0 | 0 | 0 | 0 | 0,6 | 0 | 0 | 0 | 0,6 | 0 | 0,6 | 0,6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **F21** | 0 | 0,9 | 0 | 0 | 0 | 0 | 0 | 0 | 0,9 | 0 | 0 | 0 | -0,9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table I.3: documentation of the reasoning behind the relationships in the cognitive maps**

|  |  |
| --- | --- |
| FACTORS RELATED | REASONING |
| F1 Wildfire/ F2 Health of Forests | Strong negative relation because where forest fires occur, it destroys the whole ecosystem. |
| F2 Health of Forests/ F1 Wildfire | Medium negative relation because the structure of forests determinate the conditions for wildfires to occur. |
| F2 Health of Forests/ F4 Biodiversity | Medium positive relation because forest ecological quality and functionality are crucial for biodiversity to develop. |
| F2 Health of Forests/ F11 Water Quantity | Light negative relation because the level of water consumption of the forest evapotranspiration is influenced by its structure and composition. |
| F3 Ext. Agric./F1 Wildfire | Light negative relation because extensive agriculture increases quality of land use mosaic and reduces fuel load in forests through livestock grazing. |
| F3 Ext. Agric./ F2 Health of Forests | Medium positive relation because extensive agriculture helps reducing understory vegetation through livestock grazing. |
| F3 Ext. Agric./F4 Biodiversity | Light positive relation because traditional agricultural practices generate specific ecosystems and may function as ecological niche and corridor. |
| F3 Ext. Agric./ F5 Water Quality | Light negative relation because extensive agriculture uses little pesticides and fertilizers (niche products), uses more adapted crops, has better soil quality and may allow riparian/wetlands to co-exist in plots (bio-depuration). |
|  |  |
| F2 Health of Ecosystems/F1 Wildfire | Medium negative relation because healthy ecosystems the probability of wildfires occurrence, although this is not the only factor involved in prevention conditions. |
| F2 Health Of Ecosystems/F4 Biodiversity | Strong positive relation, as this factor is the main condition for biodiversity to develop. |
| F2 Health Of Ecosystems/ F5 Water Quality | Medium positive relation because healthy ecosystems related to water bodies have a strong depurative function until a certain degree of pollution. |
| F3 Ext. Agric./ F6 Water Uses | Light negative relation because extensive agriculture land use is rainfed or supplied by gravity irrigation. The latter consumes much water, but also has very big return rates. In Tordera hydrogeology return rates go directly back to water bodies. |
| F5 Water Quality/ F9 Health of Water Ecosystems | Light positive relation because clean water enhances ecosystem health, while pollution may be only partially absorbed by ecosystems. |
| F5 Water Quality/F16 Water Treatment | Light negative relation because purification treatment is less intensive when water quality is higher, but still needed in most cases. |
| F6 Water Uses/ F11 Water Quantity | Strong negative relation because Tordera basin suffers strong overexploitation. |
| F6 Water Uses/ F14 External Water | Light positive relation because demand is the main impulse for unconventional water production. |
| F6 Water Uses/ F16 Water Treatment | Medium positive relation because all uses affect water quality and most wastewater should be treated. |
| F7 Intensive Agr./ F1 Wildfire | Light negative relation because intensive agriculture farming clears the land and contributes to land use mosaic, reducing wildfire fuel. |
| F7 Intensive Agr./ F4 Biodiversity | Light negative relation because intensive agriculture farm practices strongly degrade biodiversity |
| F7 Intensive Agr./ F5 Water Quality | Medium negative relation because intensive farming practices are highly polluting and occupy riparian areas (no buffer strips) increasing direct runoff into rivers |
| F7 Intensive Agr./ F6 Water Uses | Medium positive relation because intensive agriculture has a strong and consolidated demand, in the lower part of the river. |
|  |  |
| F5 Water Quality/ F6 Water Uses | Light positive relation because water quality is a limiting factor to water uses, due to high treatment costs. Especially relevant aspect in Tordera. |
| F5 Water Quality/ F 15 Bulk Water Cost | Light negative relation (actually could be stronger) because salt intrusion and nitrate pollution in groundwater are very costly processes to be developed for drinkwater production. |
| F8 Temperature/ F1 Wildfire | Medium positive relation because especially in summer, high temperatures generate the conditions for wildfires to occur. |
| F8 Temperature/ F2 Health of Forests | Light negative relation because forest ecosystems suffer from high temperature, even though some species are adapted. |
| F8 Temperature/F6 Water Uses | Light positive relation because agriculture and urban (tourism) water demands increase with high temperature, but this is not valid for bottling plants and industry. |
| F8 Temperature/ F9 health of water Ecosystems | Light negative relation because temperature increases evaporation and temperature of the water, but the effect on water ecosystems depends on many factors. |
| F9 Health of Water Ecosystems/ F4 Biodiversity | Strong positive relation because water ecosystems highly contribute to quality of biodiversity. |
| F9 Health of Water Ecosystems/ F5 Water Quality | Llight positive relation because the capacity of water depuration by water ecosystems is constraint to many environmental conditions. |
| F10 Salt intrusion/F5 Water Quality | Light negative relation because the phenomenon is limited to the lower part of the basin. In those areas this is a crucial factor and relationship is strong. |
| F11 Water Quantity/ F5 Water Quality | Strong positive relation because quantity determinates water quality at all levels. |
| F11 Water Quantity/ F6 Water Uses | Light positive relation because water quantity is a limiting factor to all uses, but the availability of external water may reduce this weight. |
| F11 Water Quantity/ F9 Health of Water Ecosystems | Medium positive relation because adequate flow regime is a precondition to ecosystems to exist. |
| F11 Water Quantity/ F10 Salt intrusion | Medium negative relation because the phenomenon is limited to the lower part of the basin. In those areas this is a crucial factor and relationship is strong. |
| F11 Water Quantity/ F14 External Water | Medium negative relation because Tordera is an overexploitated Basin and external water is partially compensating the lack available flows for some uses. |
| F12 Hydro-Geo-m./ F9 Health of Water Ecosystems | Strong positive relation because river morphology is crucial to enhance habitats for the ecosystem to develop |
| F12 Hydro-Geo-m./ F17 Flood Damage | Light negative relation as flood damage to dwellings and people is directly proportional to the quality of river morphology. |
| F13 Urban Expansion/ F1 Wildfire | Light positive relation because the more people living in scattered houses or touristic dwellings, the more the risk of wildfire increases |
| F13 Urban Expansion/ F5 Water Quality | Light negative relation because the expansion of dwellings also implies more wastewater pollution and most small settlements do not have any treatment facilities. |
| F13 Urban Expansion/ F6 Water Uses | Medium positive relation because increased settlements entail increased urban water use. |
| F13 Urban Expansion/ F12 Hydro-Geo-m. | Medium negative relation because much urban expansion - especially industrial areas in the middle part of the basin - are positioned in the river space. |
| F14 External Water/ F13 Urban expansion | Light positive relation because when there is no water availability for new demands, unconventional water resources are produced. |
| F14 External Water/ F 15 Bulk Water Cost | Strong positive relation, as water desalting and reclaiming plants are costly investments and entail energy consumption. |
| F 15 Bulk Water Cost/ F11 Water Quantity | Strong negative relation, as direct catchments from water bodies are cheaper than external water, when bulk water price is high, water service entities will increase direct catchments, reducing the water quantity in water bodies. |
| F16 Water Treatment/ F5 Water Quality | Strong positive relation as the presence of water treatment facilities are the main precondition for enhancing water quality. |
| F16 Water Treatment/ F 15 Bulk Water Cost | Medium positive relation because water treatment facilities are costly investments and entail energy consumption. |
| F 18 Precipitation/F2 Heath of Forests | Light positive relation because mediterranean forests ecosystems are sensible to variations in precitpitation |
| F 18 Precipitation/ F3 Ext. Agric. | Light positive relation because extensive agriculture depends a lot on precipitation but also has more resilience due to the use of native species. |
| F 18 Precipitation/ F7 Intensive Agr. | Light positive relation because intensive agricultural practices are depenend on precipitation, but integrate natural resources with irrigation from regulated water bodies. |
| F 18 Precipitation/ F9 Health of Water Ecosystems | Medium positive relation because water related ecosystems are highly dependent on precipitation, especially those in wetlands and smaller streams. |
| F 18 Precipitation/ F11 Water Quantity | Strong positive relation because water flows in all water bodies are depened on preciptation. |
| F 18 Precipitation/ F17 Flood Damage | Medium positive relation because flood intensity is highly related to the intensity of precipitation, allthough the damage largely depends on the presence of infrastructure and people in the flooding zone. |
| F19 Population/ F3 Ext. Agric. | Medium positive relation because extensive agriculture engages a high number of people and food produced is mostly consumed locally. |
| F19 Population/ F6 Water Uses | Medium positive relation because this is the direct pressure on urban demand, the most relevant demand in the Basin. |
| F19 Population/ F7 Intensive Agr. | Medium positive relation because in the lower part of the basin intensive horticulture is the main agriculture activity and engages many people. |
| F19 Population/ F13 Urban Expansion | Medium positive relation because touristic facilities are growing in the basin and so do interregional transport facilities. |
| F20 WFD/ F5 Water Quality | Medium positive relation because this legal framework has many actions orientated to directly increase water quality, but it is only partially implemented. |
| F20 WFD/ F9 Health of Water Ecosystems | Medium positive relation because this legal framework has many actions orientated to directly increase water related ecosystems, but it is only partially implemented. |
| F20 WFD/ F11 Water Quantity | Medium positive relation because this legal framework has many actions orientated to directly increase water flows in rivers and aquifers, but it is only partially implemented. |
| F20 WFD/ F12 Hydro-Geo-m. | Medium positive relation because this legal framework has many actions orientated to directly increase Hydro-geo-morphological quality, but it is only partially implemented. |
| F21 Environmental protection/ F2 Heath of Forests | Strong positive weight because in Tordera most healthy forests are those with more protection strategies. |
| F21 Environmental protection/ F9 Health of Water Ecosystems | Strong positive weight because environmental protection strategies are crucial to avoid complete destruction of Tordera water bodies. |
| F21 Environmental protection/ F13 Urban Expansion | Strong negative weight because constructions are prohibited or limited in environmentally protected areas. |

1. Source: ACCUA 2011, own figures based on data from ACA and IDESCAT [↑](#footnote-ref-1)
2. Source: “Els Sistemes socioecològics de la conca de la Tordera” edited by Martí Boada, Sílvia Mayo and Roser Maneja; Different Autors, Published by Institut d'Estudis Catalans, 2008 [↑](#footnote-ref-2)
3. http://aca-web.gencat.cat/aca/appmanager/aca/aca;jsessionid=vFvKJhVMSG6hCQRGp5m08KgpyCnXbpVCYWJkgyyFBLvH1y57m1W7!-283999339!1745676463?\_nfpb=true&\_pageLabel=P46600176421381934582085 [↑](#footnote-ref-3)
4. Source of all figures on water demand are own figures based on data from ACA and MCSC2005 published in ACCUA 2011 [↑](#footnote-ref-4)
5. Source http://www.selva.cat/agenda21/pla\_comarcal/7\_hidrologiaihidrogeologia.pdf [↑](#footnote-ref-5)
6. Lopez-Bustins J.A., Pascual D., Pla E., Retana J. (2013) Future variability of droughts in three Mediterranean catchments. Natural Hazards. 69: 1405-1421.Doi: 10.1007/s11069-013-0754-3 [↑](#footnote-ref-6)
7. Diana Pascual, Eduard Pla, Joan A. Lopez-Bustins, Javier Retana & Jaume Terradas (2014): Impacts of climate change on water resources in the Mediterranean Basin: a case study in Catalonia, Spain, Hydrological Sciences Journal, DOI: 10.1080/02626667.2014.947290 [↑](#footnote-ref-7)
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9. Roeckner E, Lautenschlager M, Schneider H (2006b) IPCC-AR4 MPI-ECHAM5 T63L31 MPI-OM GR1.5L40 SRESB1 run no. 1: atmosphere 6 HOUR values MPImet/MaD Germany, World Data Center for Climate, Hamburg, Germany. doi:10.1594/WDCC/EH5-T63L31OM-GR1.5L40B116H [↑](#footnote-ref-9)
10. Barrera-Escoda A, Cunillera J (2010) Study of the precipitation evolution in Catalonia using a mesoscale model (1971–2000). Adv Geosci 26:1–6 [↑](#footnote-ref-10)
11. Barrera-Escoda A, Cunillera J (2011) Climate change projections for Catalonia (NE Iberian Peninsula). Part I: regional climate modeling. Tethys 8:75–87 [↑](#footnote-ref-11)
12. IPCC (2007) Climate change 2007: synthesis report. Contribution of working groups I, II and III to the fourth assessment report of the intergovernmental panel on climate change, IPCC Secretariat, Geneva [↑](#footnote-ref-12)
13. Idescat, Institut Estadístic de Catalunya, 2012 [online]. Available from: http://www.idescat.cat/en/ [Accessed March 2013]. [↑](#footnote-ref-13)
14. Source: stakeholder workshop Tordera River Basin, 28.05.2014, session on “desired state” BeWater Tordera Workshop Report chapter 6, section 6.4 [↑](#footnote-ref-14)
15. Source: stakeholder workshop Tordera River Basin, 28.05.2014, session on “challenges and issues” BeWater Tordera Workshop Report chapter 5 [↑](#footnote-ref-15)
16. Overexploitation edict: DOGC N0. 3819 - 11.02.2003 [↑](#footnote-ref-16)
17. Carmona and Puigsaver, 2009 (internal report) cited in “Pla de Conservació del Park Natural del Montseny” pag. 96; available at http://parcs.diba.cat/web/montseny/pladeconservacio [↑](#footnote-ref-17)
18. Information obtained from direct interviews [↑](#footnote-ref-18)
19. Source: stakeholder workshop Tordera River Basin, 28.05.2014, session on “options” BeWater Tordera Workshop Report chapter 7, section 7.2 [↑](#footnote-ref-19)
20. Source: stakeholder workshop Tordera River Basin, 28.05.2014, session on “challenges and issues” BeWater Tordera Workshop Report chapter 5 [↑](#footnote-ref-20)
21. Source direct interviews. Episode analyzed in the study “ social complexity of the Tordera Basin “ available at: http://www.baixmontseny.net/pdf/Complejidad%20social%20en%20la%20cuenca%20del%20rio%20Tordera.pdf [↑](#footnote-ref-21)
22. Source direct interviews. Problem described in press article: http://www.lavanguardia.com/local/girona/20140501/54406500489/maresme-blanes-rebelion-precio-agua-aca.html [↑](#footnote-ref-22)
23. Source direct interviews. [↑](#footnote-ref-23)
24. Source direct interviews. [↑](#footnote-ref-24)
25. Source: stakeholder workshop Tordera River Basin, 28.05.2014, session on “desired state” BeWater Tordera Workshop Report chapter 6, section 6.4 [↑](#footnote-ref-25)
26. Source direct interviews. Problem described in “Pla de Conservació del Park Natural del Montseny”p 332; available at http://parcs.diba.cat/web/montseny/pladeconservacio [↑](#footnote-ref-26)
27. Source: stakeholder workshop Tordera River Basin, 28.05.2014, session on “challenges and issues” BeWater Tordera Workshop Report chapter 5 [↑](#footnote-ref-27)
28. Source direct interview [↑](#footnote-ref-28)
29. Source: stakeholder workshop Tordera River Basin, 28.05.2014, session on “options” BeWater Tordera Workshop Report chapter 7, section 7.1 [↑](#footnote-ref-29)
30. Source: stakeholder workshop Tordera River Basin, 28.05.2014, session on “options” BeWater Tordera Workshop Report chapter 5 [↑](#footnote-ref-30)
31. Source: stakeholder workshop Tordera River Basin, 28.05.2014, session on “options” BeWater Tordera Workshop Report chapter 7, section 7.2 [↑](#footnote-ref-31)
32. Source: stakeholder workshop Tordera River Basin, 28.05.2014, session on “desired state” BeWater Tordera Workshop Report chapter 6, sections 6.3 and 6.4 [↑](#footnote-ref-32)
33. Source direct interviews. [↑](#footnote-ref-33)
34. Source: stakeholder workshop Tordera River Basin, 28.05.2014, session on “challenges and issues” BeWater Tordera Workshop Report chapter 5 [↑](#footnote-ref-34)