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Indicators for Water Resource Management

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Abstract: Physical, social and institutional indicators can be relied on to reveal an inter-play of change. However, it is sometimes problematic to link the dynamics of this change with the reality of a situation. The Marina Baixa County located in the Alicante province of Spain, has been the focus of intensive work to determine the indicators of change in the hydrological network, as well as water supply and demand patterns for incorporation into present and future policy. An aggregation of the results from four studies undertaken over a decade is presented here. Indicators that have been developed provide a rich bank of knowledge about the co-dynamics of the physical, institutional and social aspects of this water using community that currently suffers a seasonal water deficit. This paper attempts to provide an explanation of the meaningfulness of these indicators, as well as a review of how they are being used in a context of change.

Key words: Indicators, co-dynamics, physical-biological, socio-institutional.

One of the primary objectives of the Commission on Sustainable Development is to ensure that clean water is available for all, and that human health and state of the environment indicators will help to point the way to the equitable achievement of this goal (Comprehensive assessment of the freshwater resources of the world, 1997). Almost a decade later however, questions still remain about how best to achieve this goal in an era of what is termed Integrated Water Resource Management. Integrated Water Resource Management (IWRM) equates with the concept of sustainable water management. A concept that is still proving to be problematic when it is operationalized (Eisenhuth *et al.*, 2004).

IWRM however, does provide the multi-disciplinary means in which decision-makers can formulate present, as well as future policy instruments that reflect the goals of sustainable water management in a way that transcends the limitations imposed through the use of individual disciplinary approaches. This is because IWRM provides a far more integrated means with which to make assessments of what could, or could not be, the sustainable management of increasingly scarce water resources. By comparing the indicators produced from multi-disciplinary studies, it is possible to make assessments of how they facilitate the realization of the goals of sustainable water management.

Indicators provide researchers and policy analysts with the means to communicate complex ideas about the sum total of scientific knowledge and judgment currently available. They are the tools that are used to observe, describe and evaluate actual states, to predict desired states or, to compare an actual state with a desired state. Indicators are generally simple numbers, descriptive or normative statements which condense the enormous complexity of the world into a manageable amount of meaningful information (Anonymous, 2003). Within the framework of IWRM, indicators can be used to determine how best to assign the different and competing environmental, domestic, agricultural and industrial usages in an effective manner. Indicators can also be used to assess what would be the optimum use of available water resources in a particular community be it at national, regional or local level. Indicators therefore, reflect the various levels of knowledge available about the water supply and demand patterns that occur within a particular water using community.

Consequently, hydrological indicators are determined by, and also determine, many other indicators within the context of a particular water using community. More specifically, clearer understandings of the dynamics and the interplay of all these indicators can be used to identify and characterize the rapid and unforeseen changes that are inherent to the environmental, social and institutional contexts within which water supply and demand patterns develop. The processional logic here infers that clearer understandings of indicator dynamics could offer the key through which to identify what mix of indicators could represent the type of resilience and adaptive capacity that maintains the long-term sustainability of a water using community.

The literature pertaining to the concepts of resilience and adaptive potential recognizes that resilience refers to the potential of a natural or social system to reorganize or restructure (Walker *et al.*, 2002: see also Gunderson and Holling, 2002). Adaptive potential is understood to be the capacity of an ecological system to transform itself and in a social system to promote innovation; such change facilitating a reconfiguration of the system without a significant decline in its crucial functions. The challenge then for those engaged in IWRM is to determine what mix of indicators enhances the resilience and adaptive potential of a water using community.

The study reported here takes as its frame of reference the Marina Baixa catchment area in Spain (Fig. 1). The catchment covers 671 km^2 and is located on the border between a semi-arid rain shadow climate and a dry climate. It comprises a complex and varied topography characterized by dense land occupation where irrigated crops (medlars, citrus and fruits), dry crops (carobs, olives and almonds) predominate together with developed and industrial areas, as well as a well-defined area of Mediterranean woodland. It is one of the nine counties that together constitute the province of Alicante and is located in a region that has undergone great socio-economic changes due to the fact that today it hosts over 60% of the Valencian community's tourist activity. In its turn, the Marina Baixa County comprises 18 municipalities that exhibit a mosaic of different change trends due to their proximity to the coast (tourism) and the availability of irrigation water (intensive irrigation crops) (Bonet *et al.*, 2006, Peña, 2007).

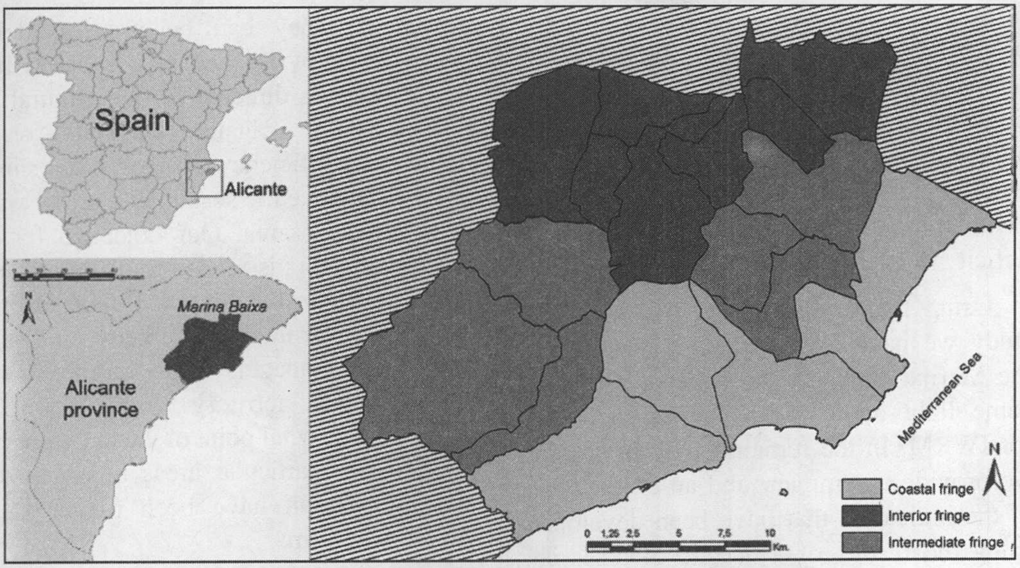

Fig. 1 The location of Marina Baixa County and the three study zones.

Thus far, the Marina Baixa County has been the subject of four studies, each with a different focus, yet all related to the identification of the indicators of the various aspects of water, land-use, institutional and cultural change. The outcomes of these studies: ERMES I and II (1996-1998) (Imeson, 1997), MODULUS (1998-2000), (Imeson *et al.*, 1997; Fillipuci *et al.*, 2000), ARCHAEOMEDES I (1992-1994) and II (1996-1999) (van der Leeuw, 1998) and AQUADAPT (2002-2004) (Jeffrey *et al.*, 2005) provide a rich bank of data and information from which indicators have been developed. These indicators represent the totality of currently available knowledge about the complex processes that have led to changes in the physical, institutional and social contexts of the Marina Baixa catchment.

The ERMES Projects were concerned with the development of multi-scaled models with which to assess the effect of changing land-use patterns on vegetation cover, erosion risks, water run-off and infiltration, changes in ground water and channel flows, and evapotranspiration. Whilst the ARCHAEOMEDES projects investigated how changes to the socio-natural dynamics of Southern Europe could be related to the escalating problems of degradation and desertification in this area. The results of these studies were then integrated into a Decision Support System (DSS) that provides end-users with state-of-the-art knowledge relating to the processes that cause and are caused by land degradation within the framework of the MODULUS Project. The AQUADAPT project was built on the work of the previous projects. It provides data and information that specifically relates to the impact of land-use change on environmental quality, as well as the hydrological system, a hydrological balance for the County, an institutional overview and a profile of water use behavior. Also, within the terms of reference of AQUADAPT, the challenges involved with explaining how these indicators can be used to explain the co-dynamics that occur within a water using community that has a prevailing seasonal deficit were explored.

Using the results of the AQUADAPT study we have extrapolated indicators for the Marina Baixa in the hope of shedding some light about the value of their use for IWRM. In the remainder of this paper, we provide a summary and an explanation of the indicators that have been developed using the results of a decade of research. We then go on to discuss how these indicators can be applied to interpret the change in the physical, land-use and social-institutional aspects of the catchment over a period of 50 years. We also attempt to highlight the challenges associated with selecting the indicators that could represent how the practice of sustainability can occur at a practical level. We conclude by offering a review of how these indicators could facilitate or impede IWRM in a semi-arid region.

Objective and Methodology

Indicators are indispensable tools for policy makers as they can be used:

- to assess environmental problems;
- to identify and prioritize key factors that place pressure on the environment; and,
- to monitor the effects of policy response (EEA, 1999).

However, the use of indicators with which to manage water can be a highly technical procedure. They can be used to define efficiency in water use in a specific field where water is directed for agricultural use (i.e., different irrigation methods) or, to improve the efficiency of urban water supply or try to achieve the sustainable use of water in a particular area. Our objective for the use of indicators is related to water resource management in the Marina Baixa, in order to facilitate the interchange between distinct users and managers of a complex and heterogeneous territory from both the physical and social point of view. Our results refer to two particular areas in which data and information have been obtained and which we term:

- the physical-biological context; and,
- the social and institutional contexts.

In the physical-biological context we group climatic indicators that inform the capacity of a territory to permit the development or not, of different ecosystems as well as to guarantee some maximum levels of biological production in the ecosystems that have been transformed by humans. This capacity is not homogenous throughout the County, which presents a great variety of physical conditions that determine how human activity proceeds in the eighteen municipalities that are integrated to form the county. Whilst in the land-use context we contemplate indicators as the surface dedicated to diverse economic activities and changes over time in terms of dry crops, irrigated crops tourism-residential development and, industry. In the third context, i.e., social and institutional context, we have collected the opinions and perceptions of the different actors involved in the use and management of water. These actors are constituted by

Table 1. Area in km^2, altitude and distance (km) from the sea and population of the municipalities in the three fringes

		Area km^2	Altitude m.a.s.l	Distance in km from the sea	Population by municipality census
Coastal Fringe	L'Alfàs del Pi	19	88	3.5	11.103
	Altea	35	62	0.2	15.910
	Benidorm	39	15	0.2	51.873
	Finestrat	42	238	6.9	2.307
	La Vila Joiosa	59	27	0.2	23.657
	Total	193			
Intermediate Fringe	Callosa d'En Sarrià	34	247	9.2	7.057
	Nucia. la	22	226	9.7	6.587
	Orxeta	24	177	7.6	528
	Polop	22	262	10.4	2.300
	Relleu	78	429	12.7	800
	Sella	39	419	13.3	591
	Total	219			
Interior Fringe	Beniardá	15	464	21.9	245
	Benifato	12	658	22.8	166
	Benimantell	38	547	20.7	402
	Bolulla	13	214	12.3	358
	Castell de Guadalest	16	586	27.6	180
	Confrides	40	785	20.1	309
	Tárbena	31	560	560	715
	Total				166

farmers; water suppliers; citizens; and the institutional stake-holders. These opinions and perceptions were incorporated into a water using profile which was developed from the responses of a survey and interviews conducted in 2004. The results of the survey were obtained through basic frequencies analysis.

Study Zones

We have defined three zones in the Marina Baixa County with contrasting physical, institutional and social dynamics. These are: (i) the Coastal fringe – which includes the municipalities of L'Alfaç, Altea, Benidorm, Finestrat and La Vila, (ii) the Interior fringe which includes the municipalities of Beniardà, Benifato, Benimantell, Bolulla, Confrides, Castell de Guadalest and Tàrbena, and (iii) the Intermediate fringe – which includes the municipalities of Callosa d'En Sarrià, La Nucia, Orxeta, Polop, Relleu and Sella. Table 1 provides the area, altitude and the distance to the sea of the municipalities belonging to these three fringes.

Physical Indicators

Climatic indicators

Actual evapotranspiration: The actual evapotranspiration for different land uses is a relevant output that needs to be quantified. With this aim we studied different land-uses in the County and calculated hydrological balances for different usages to evaluate their contribution to global balance. Due to the importance of actual evapotranspiration we proceeded to apply the VENTÓS hydro-ecophysiological model to the Marina Baixa. This model was developed at the Ventós experimental station located in the province of Alicante (Bellot *et al.*, 1999, 2001; Chirino, 2003) we assume that each pixel of the maps occupied by specific land usage or cover behaves as an experimental plot, with a corresponding balance.

Average annual precipitation: The total amount of rain can be approximated to the capacity of a territory to sustain natural ecosystems and crops. Nevertheless, in the Mediterranean climate, there is a great inter-annual variability of rainfall and dry and wet years above or below these values frequently occur, This alternation of wet and dry years has led water users in the Marina Baixa to exploit groundwater for crops and domestic use. In this case, average yearly precipitation can be used as an input value to the aquifer, as well as an estimate of the theoretical maximum of pumping in order to maintain equilibrium. However, this is not the case in the coastal aquifers in the Alicante province. Aquifers need to be used as reserve for the dry years and so that recharge can take place in the wet years. Spatial heterogeneity is another characteristic of rainfall. Also, due to the change in slope because of mountains that extend to the coast, it is possible to locate a clear gradient between the drier coast (less than 400 annual mm precipitation), the mountainous interior (annual precipitation above 700 mm) and between the intermediate fringe in (annual precipitation approximately 500 mm) (Table 2).

Table 2. Annual inputs by rainfall in the three areas

	Extension km^2	Rainfall input mm	Rainfall input m^3 ha^{-1}	Total rainfall input Hm^3
Coastal Fringe	193.3	379	3790	73.42
Intermediate Fringe	219.0	438	4380	96.03
Interior Fringe	166.1	696	6960	115.61

Effectiveness of rainfall usage: Not all of the rainfall is taken up by the natural vegetation or the crops owing to its torrential characteristics. Generally speaking, an appreciable part of rain falls in a few hours of the year, promoting flash floods and soil losses in unprotected areas. This is despite the fact that main and smaller rivers have been modified with dams (Amadorio, Guadalest); at least 14 Hm^3 (1 Hm^3 = 1 million m^3) of rainfall is lost to the Mediterranean as runoff. Another problem with rainfall is its seasonality. In the Marina Baixa as in other Mediterranean areas, there is a long dry period that comprises summer and some part of spring and autumn. The use of water from many reservoirs of different capacities ranging from *balsas* – small dams - to large dams is how water users cope with summer droughts. Water is pumped from aquifers, and care has to be taken that they are not overexploited because of the overall scarcity of water resources (Murillo and Castaño, 2003).

Total amount of rainfall by hectare: This value is in millimetres, but perhaps it is more easily compared with crop requirements which are usually expressed in m^3 ha^{-1}. There is a total of 400 mm in the coastal fringe which amounts to the same as 4000 m^3 ha^{-1} which is sufficient water for traditional dry crops such as olive and almond trees. Irrigated crops however, require more water (7500 m^3 ha^{-1}).

Hydrological indicators

Urban water demand: Usually, per capita water consumption for domestic use is a good indicator of whether or not users have adapted to the limitations imposed by a semi-arid climate. In most Spanish cities the average per capita daily usage is about 150 L day. However, with increase urbanization, i.e., smaller houses and gardens, it can rise to 300 or 400 L day^{-1}.

From the bibliography and the information contributed by Aquagest (Commercial Water Supplier) we are able to define a module for human consumption in the Marina Baixa. On the other hand, consumption inside and outside the house must be studied separately because of the influence of each on global balance is different, because it contributes in a distinct way to actual evapotranspiration (Eta). The water requirements inside the house can be considered very similar across all of the populations. To estimate this we have based our calculations on a minimum consumption for hygiene and nourishment per inhabitant.

Water use indoors and outdoors: To estimate the consumption both indoors and outdoors we must take into account the garden and swimming pools surfaces for water loss that increase the average use of water by person. We have applied the values developed by Domene and Saurí (2003) in the metropolitan region of Barcelona. These authors estimate the weekly average water consumption for a garden at 10 L m^{-2} (i.e., 5,200 m^3 ha^{-1} $year^{-1}$). This quantity should be added to the precipitation received (we apply 522 mm as an annual average in this balance) (5,220 m^3 ha^{-1} $year^{-1}$) giving input totals of 10,422 m^3 ha^{-1} $year^{-1}$ for the garden, with an average transpiration (Kc) efficiency of 0.9. The swimming pool consumption is also considered to be substantial, because each year evaporation is equivalent to the referenced Eto for the zone (11,605 m^3 ha^{-1} $year^{-1}$) that should be recovered in the larger urban supply (6,383 $m^3 ha^{-1} year^{-1}$) because the recharge for precipitation is only 5,220 m^3 ha^{-1} $year^{-1}$ (45%).

Global consumption for urban use: The consumption required below these parameters is estimated at 28.66 Hm^3 $year^{-1}$, for both indoor and outdoor consumption, for the three types of urban usage. If we consider that the efficiency level estimated by Aquaguest is 80% in Benidorm (although inferior in other municipalities), the supply requirements are elevated to 34.34 Hm^3 $year^{-1}$.

Water demand by crop type: Irrigation is the main consumer of water from the dams and the aquifers. Reducing crop area is effective way to save water in semi-arid areas such as the Marina Baixa. Reductions from 8000 m^3 ha^{-1} to less than 5000 m^3 ha^{-1} can be achieved through the use of drip irrigation

We have investigated the monthly and annual consumption of water for each crop in different zones. Crop water modules indicated water consumption from agricultural sector in the Marina Baixa County tobe 33.81 Hm^3 $year^{-1}$. However, this value should be reduced when it is considered that 40% of the area is under drip irrigation which reduces the water module consumption by 34% (Pruitt *et al.*, 1984). Precipitation inputs are very high (48.44 Hm^3 $year^{-1}$) and these need to be taken into account in order to calculate the total inputs per hectare as well as for the entire county.

The demands for agricultural use are met by treated water from the recycling plants located at Altea, Benidorm and Vilajoiosa. Also, the municipalities of the interior irrigate from streams and small local dams, but without a determined irrigation network. When demands exceeds than what is available from the treatment plants, supply is restored from Guadalest and Amadorio dams. During the hydrological year 1997/98 the quantity of water supplied from Guadalest was 5.42 Hm^3 and 1.75 Hm^3 from Amadorio, which was in addition to the treated water.

Actual crop evapotranspiration global consumption: We have calculated by the water consumed for each crop (dryland or irrigation), using the Kc indicators from FAO (Allen *et al.*, 1998) and for local agricultural organizations, and the atmospheric demands or the referenced evapotranspiration (Eto). Using this total theoretical consumption (CT = Eto*Kc), we can make a contrast with water availability (AD = irrigation + rain), and calculate real consumption or actual Evapotranspiration (Eta).

By analyzing the Eta results of crops we have estimated average transpiration in respect to available water, which could be utilized as a reference to estimate the Eta for cultivated land and to extrapolate data for the region. When we combine the water transpired or consumed for each hectare of cultivated land in each municipality we can calculate annual water turn over. If we compare this with water availability it permits us to obtain average values for transpiration with respect to water availability for each crop and municipality. The results indicate that the evapotranspiration for crops in the county is 38.37 Hm^3 $year^{-1}$, of which 34% corresponds to dryland crops, with an average Eta of 2,183.72 m^3 ha^{-1}. The irrigated crops account for Eta (69%), because the average transpiration for each plot is 5,441.11 m^3 ha^{-1} (Table 3).

To assess impact of technological innovations on hydrological balances, we have decided to follow the advice of Villabos and Fereres (1990). These authors indicate that for drip irrigation the water retention is comparable with that of flood irrigation, if frequency is adequate. As a consequence, the introduction of drip irrigation reduces water consumption up to 34% without affecting the crop efficiency or the productivity.

Land use context: The Marina Baixa has experienced enormous changes in land

Table 3. Annual water flows in crops: input rainfall and output evapotranspiration

	Rainfall input by ha m^3 ha	Extension		Rainfall input agriculture (Hm^3)	Total Eta irrigated (Hm^3)	Total Eta dryland (Hm^3)
		Dryland ha	Irrigated ha			
Coastal Fringe	3797.2	167	1922	8.13	11.57	0.37
Intermediate Fringe	4384.2	4315	2317	27.11	11.75	8.52
Interior Fringe	6958.7	1476	426	13.20	2.05	4.12

use (Peña *et al.*, 2007). The land in the County is mainly used for: (i) traditional agriculture, (ii) intensive agriculture, (iii) forest, and (iv) urban.

Figure 2 reveals a decrease in the irrigated crop area in the coastal region and the increase in the urbanized area owing to the development of the tourism industry which has resulted in an increase of low residence density. Whilst in the intermediate fringe increases in irrigation are due to the economic relevance of some crops such as medlar, and in the interior fringe there has been a decrease in population and no change in the type of crops that are cultivated.

Socio-institutional area

Population density: This provides a primary index of the grade of human pressure on local resources. There has been a decrease in population in the interior fringe due to agricultural changes owing to the abandonment of unirrigated crops. While there has been an increase in area under irrigated crops, in the intermediate fringe this can be related to a decrease in population in this zone. It is easier to detect changes in the coastal fringe due to the exponential tourism related development (Fig. 3).

Water using profile: Part of the work undertaken within the AQUADAPT project was the development of a water using profile. The results of structured interviews were integrated with the following demographic information.

Gender: In the Comunidad Valencia, on the whole there is the persistence of a patriarchal society (Garcia, 2004). This fact could explain the lack of knowledge of the female respondents to questions about water suppliers, sources of water, etc. This fact is also consistent when it is considered that women are more concerned with saving water on the domestic front.

Income: The level of income in the Marina Baixa does not represent a distinguishing variable. Only in some of the questions posed for this demographic indicator, the higher and lower income groups favored economic development proposals.

Age: 76.2% of the respondents who were less than 34-year-old believed that the role of water is to support natural life. 63.5% of those respondents aged between 35 and 50 years believe that the role of water is to support natural life. Respondents aged between 51 and 64 years believe that the role of water is to satisfy human needs. Whilst 57.8% of the respondents aged 65 years or older fall in to line with those aged between 51 and 64.

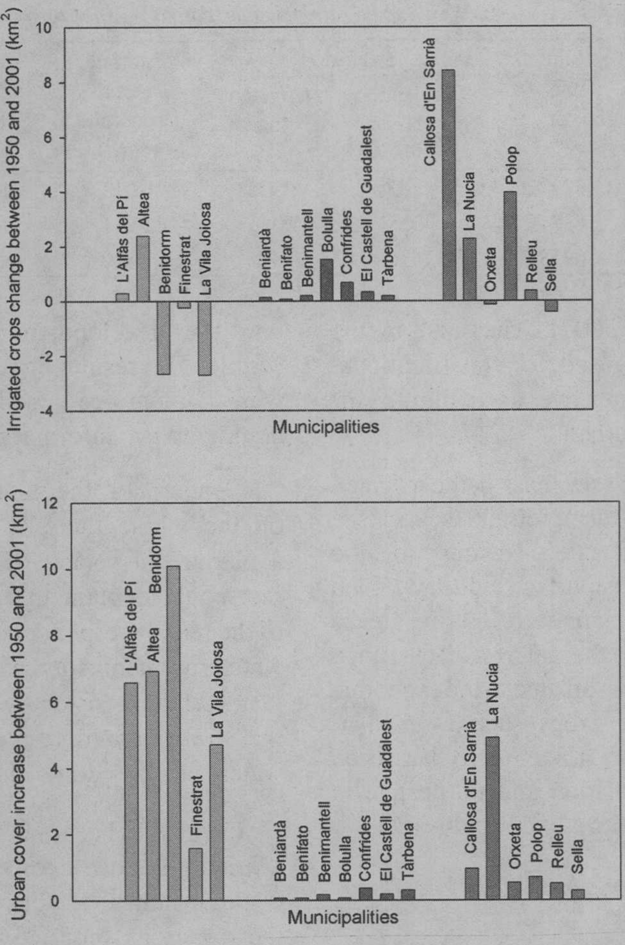

Fig. 2. Changes in land use (irrigated crops and urbanized areas) of the municipalities in the three study zones in km^2.

Educational level: When questioned about the role of water 47.2% of those with no studies and 40.4% of those who undertook primary studies believed that the role of water is to satisfy human needs. As education level increased, 28.7% of those with secondary studies and 29% with university studies agree with the first two groups interviewed.

The following indicators were extrapolated from the profile:

Environmental concerns: 62% of water users surveyed believe that the function of water is to support natural life. 16% of water users surveyed believe that environmental problems are generated by the rate of urban development in the County. 13% displayed concern about the lack of freshwater resources in the County. 66% believe that water resource management is something that should be addressed as a matter of urgency.

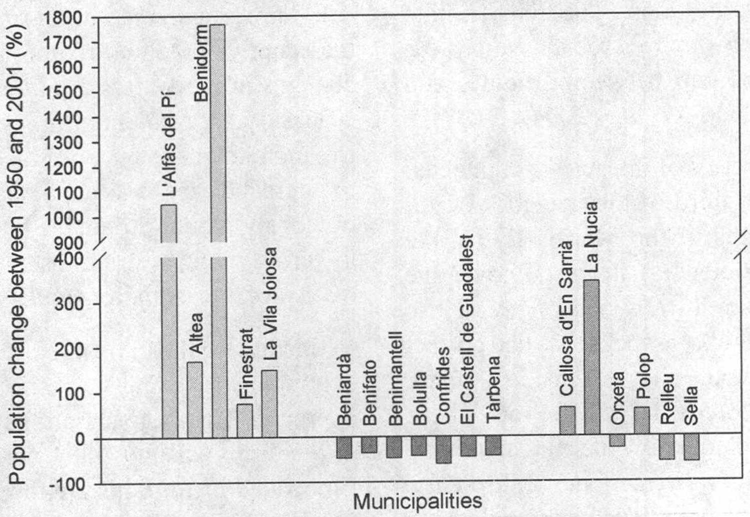

Fig. 3. Population change (%) by census in the municipalities of the three study zones.

Individual perception and knowledge of water resource management: 54% of those surveyed were not willing to be involved in discussions regarding water resource management because of the 'politics of water' in the Marina Baixa.

Individual knowledge of the drinking water cycle: Because water distribution is undertaken by a commercial entity in most of the municipalities, the answers to the questions posed in this section are quite close to the 'reality' of the situation.

Water users and water quantity: 64% of those surveyed believe that tourism was the greatest consumer of water, followed by household consumption – 31% and 17% believed that agriculture has the highest water demand.

Water prices and related behaviors: Only 10% of the respondents claimed to know how much water their household consumes each day. 56% reported it to be less that 200 L and 90% admitted that they had no idea how much water was consumed in their household on a daily basis. Other statistics generated outside of this study revealed that within the Comunidad de Valencia average household consumption ranges between 460-560 L day^{-1}. 51% of respondents believe that their water is 'cheap' or 'neither cheap nor expensive'.

Water saving behaviors: 57% of the respondents agreed that the best way to save water is to use it in off-peak hours. Only 50% agreed that they would take measures to reduce consumption if the cost of water is increased by a quarter, whilst 43% refused to take any action. However, 61% of those surveyed agreed to pay an additional charge to protect the 'water' environment.

21% of the population has swimming pools. When this response is analyzed it strengthens the contradiction that exists between environmental and non-environmental attitudes. The tension that exists between these social values is reflected in the gap between attitudes and behaviors (Aledo *et al.,* 2004).

Also, in a series of interviews conducted in 2004 with a third of the irrigation water user associations of the Marina Baixa, the following defficiencies in user knowledge were encountered. Only 37% of those irrigation water user associations had correct knowledge about the extensions under irrigation. Moreover, 78% of those interviewed did not know the annual volume of water used for irrigation, while at the same time only 79% had adequate knowledge of the amount of water used to irrigate their crops. Finally, 59% of those irrigation water users associations interviewed did not mention the relationship between rainfall and irrigation (for example, they did not see the need to cease irrigating when there was sufficient rainfall).

Institutions

To locate indicators that are meaningful, as well as to represent the significance of the role of an institution is a challenging task. Mostly because such decisions are somewhat arbitrary given the qualitative context in which the indicators must be selected. For example, some scientists and social scientists consider that to apply indicators, such as 'institutional path dependency' is akin to 'nailing jelly to the wall' (Dues, 2005). Nevertheless, institutional path dependency can be applied to indicate that particular institution within a particular institutional setting could be locked into a particular management style, which could be difficult to alter in the short-term. Moreover, this path dependency could prevent an institution from displaying the adaptive potential required to cope with changes in the water resource management scenario i.e., a potential move from supply to augmentation to one that is oriented to demand management. This situation obviously would produce a knock-on effect in terms of how water users perceive the reality of the situation with water supply.

Institutional indicators can also be extrapolated using another qualitative approach. That is, to undertake the assigning of the terms 'disembedded' or 'embedded'. Embedded institutions are those institutions that are, local cultural, cognitive, structural and political institutions, which allocate environmental resources (Zukin and DiMaggia, 1990). Therefore, 'disembedded' institutions will be those institutions that are not directly engaged in management at the coal face. Thus, in order to elicit indicators for those institutions engaged in water resource management in the case study area, we have applied both of the foregoing qualitative approaches.

Property rights also determine how water resources are governed. In this case study they provide useful indicators of the co-dynamics between the three fringes. In the Marina Baixa there are two groups of property rights for those who extract either surface or groundwater resources. Concessions for water use can be administrative or shared, as is the case with the Irrigation Associations or can be private concessions that were granted prior to the 1985 Ley de Aguas. These concessions are of two types: water is linked to the land that it intends to irrigate, or, water and land rights can be separated. These types of concessions or property rights determine whether or not water from the Interior and Intermediate fringes can be sold and then transferred to Coastal fringe via the Consorcio de Aguas de la Marina Baixa.

Institutions dedicated to the governance of water resources: Using this qualitative approach, the first task that needs to be undertaken is to identify useful indicators that signify the role of each institution engaged in water management. The second task is to determine those institutions that can be said to be locked into a type of path dependency that erodes or prevents adaptive potential. Currently, in the Marina Baixa, the institutions engaged in water resource are:

- The European Union in the form of the Water Framework Directive (2000/60) which provides guidelines for how Member States should carry out the process of IWRM at a local level.

- Ministerio de Medio Ambiente. Central Government, Spain, in the form of financial investments for infrastructure such as desalinization plants, securing increases to inter-basin transfers or to local water supply, as well as monitoring increases of the impact to the marine environment.

- Confederación Hidrográfica del Júcar which is the institution responsible for the management of the water resources of the river basin and sub-river basins that do not flow directly into nearby rivers, as well as systems of interchange of water resources (i.e. inter-changes of potable water and recycled water to deal with seasonal deficits).

Organizations dedicated to the exploitation of water resources:

- Consorcio de Aguas de la Marina Baixa the principal function of this institution is to ensure the optimal use of water, among agricultural and urban usage.

- Ayuntamientos (Town Halls) of which there are a total of 18 in the County. Some of these Ayuntamientos exploit and distribute resources, and some delegate distribution and infrastructure maintenance to commercial water companies.

- Sindicato Central de Regantes which is a relatively new entity (2006) that unites all who farmers irrigate a substantial zone of the County. This institution is made up of Irrigator associations that total 69 in number (with very few irrigators in each association).

Figure 4 provides details regarding the institutional context that currently exists in the Marina Baixa.

Discussion

Three environmental units of the Marina Baixa as these relate to conflicts over scarce water resources

The values calculated for the physical, social and institutional indicators can be applied to distinguish the differences between the three zones in the Marina Baixa. By comparing indicators between these zones planning indicators are obtained, how the population in each zone has modified the rate of territory transformation, as well as how to control water consumption per capita; or by surface unit, that when put together will provide the most sustainable use of water resources.

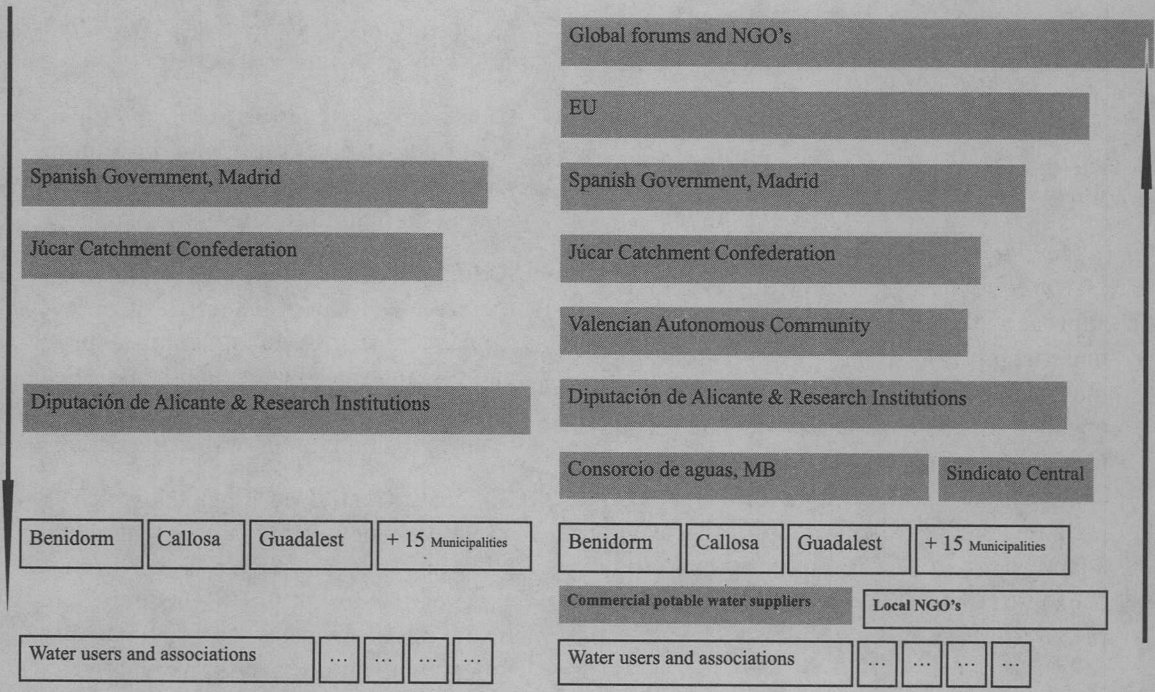

Fig. 4. Embedded and disembedded institutions in the Marina Baixa. Disembedded institutions are highlighted in grey.

The climate that dominates in each of the zones differs between the 3 environmental units within the study area as it relates to precipitation function and temperature. These have been delineated within the three zones to demonstrate dynamic differences in land use. In the coastal fringe, the fundamental economic activity is tourism; in the interior fringe, the principal activity is agriculture and in the intermediate zone, agriculture dominates in one part and tourism dominates the other. Within each of these three fringes the environmental changes that have taken place are distinct. They can therefore be treated as distinct zones in this analysis.

Coastal fringe: In this zone tourism has had the most effect in environmental terms, which has produced major changes in land use and a huge demand for new construction. The demand for water has also increased because of very large population increases in particular periods of the year, mostly in summer.

Nearly all of the municipalities in this fringe possess characteristics that automatically incorporate them into the nominated coastal environment unit. The exception of which is Finestrat, a small part of which dominates the coast, while the rest of this area can be considered to be within the intermediate fringe. It is an interesting municipality that possesses characteristics of two distinct areas.

Interior fringe: In this zone agriculture is the most important activity of development and changes the average conditions. Also there has been a change in exploitation conditions, as it was fundamentally dryland (almond, olive and citrus). However, during the past 15 years agricultural crop production under plastic (winter crops) such as medlar has emerged. Large extensions of abandoned traditional cultivations have been converted. On the other hand, it is the zone where there are forests of a particular type that generate masses of typical Mediterranean forestlands that frequently suffer the impact of large forest fires. Therefore, in the interior zone the major problems are the abandonment of traditional crops, the proliferation of masses of controlled monoculture, and an overexploitation of aquifers to supply the water demand for these crops.

Intermediate fringe: This fringe of territory, which for years was mainly under traditional crops and small farming villages, has undergone the most perceptible change. Ten years ago, the interior gained a high acceptance by the tourists that came to Spain, who not only demanded the model of sun and beach that makes the coast famous, but also they sort out these peaceful villages with less tourism development. It is therefore a zone that has undergone changes similar to the first two zones, with part dedicated to agriculture, which is changing to winter cultivation and the tourist zone as a source of income. This zone continues to display changes as it adapts to tourist demands.

There are problems with the loss of agricultural soil, land abandonment and changes in the use of agricultural soil through changes to winter cultivations. There is a greater demand for water with which to irrigate these crops, and the demands associated with tourism and villages where population increases fluctuate on a seasonal basis. The result being that there is a higher demand for water in these tourist seasons and changes in the traditional customs of this zone. Therefore, the necessities of a zone are of various types and sustainable in the conditions of each of these zones. The coastal fringe requires a contribution of sufficient quality water for human consumption to maintain its source of income, and land use planning, so that the tourism model can be maintained over time.

In the interior fringe the agricultural requirements of new crops need to be supported. However it is important that the aquifers are not further overexploited, nor proliferated, so that cultivation is sustainable and of quality. There is a need to maintain traditional agriculture and the development of mediating subsidies or aid to sustain these fields in a state of activity so that they will not be abandoned. Also, there is the need to control the forest masses to avoid the possibility of forest fires.

The intermediate fringe is where there needs to be more control on all resources. It is a small fringe of territory where the demands are the same as in the other two zones, such as the requirement for potable water for and water for the crops that are generated. Also there needs to be a more sustainable use of soil in order to maintain the equilibrium between the cultivated zones and the zones dedicated to tourism.

Water users' profile

The thing to note with these indicators is that some sectors of the surveyed population link the scarcity of water with an increase in demand. Also, the 'environment' is perceived in 'urban' terms. This can explain the ignorance of respondents to questions relating to the water cycle. There has been a change in perception of the 'cultural' value of water over the fifty-year study period. The high percentage of individual user misinformation about the source of fresh water is reasonably high. This situation can be related to the 'misinformation' about flows and ecological regional cycles, as well as about the formation of natural resources.

Relatively high percentages (64%) of water users believe that tourism sector has the greatest demand for water. Here, it is interesting to note that the results of another study undertaken as part of the AQUADAPT project agrees with the results obtained in this survey viz., that there is equal demand between urban development and agriculture – 49% in each sector. Although there are data to suggest that agriculture has the highest demand for water, the social perception is slanted towards tourism as having the highest water demand. This is not an isolated case. In other surveys conducted in Spain and the Comunidad de Valencia, respondents consider that agriculture is a positive activity, even though there are other industry sectors that contribute far more to the Gross Domestic Product.

Institutional indicators

The usefulness or not of the institutional indicators we have selected viz. property rights, path dependency and the 'embeddedness' or not of an institution, can be tested by evaluating exactly how these entities influence the different users or groups of users that have a legitimate claim to specific types of uses. The 1985 Water Law decreed that water is part of the public domin i.e., water is a public good. However, in the Marina Baixa there continue to exist 'private historical' concessions that at the time of writing have still not been placed on the Register of Water Concessions. The resulting effect is that in an area of water scarcity, where conflict for access to new supplies prevails, the 'selling and transferring' of some of these 'private historical' concessions continue outside of the regulation of the Confederación Hidrográfica del Júcar. This situation has obvious implications for the successful co-ordinated land-use planning of the County. It also places pressure on some of those Ayuntamientos and water user associations located in the interior and intermediate fringe, where water and land rights are separate, to continue to sell and transfer water to the Consorcio de la Marina Baixa, which represents the interests of those municipalities where the greatest urban development has taken place.

Institutions that we consider to be embedded function on at least three different levels; at community, municipal and local NGOs level. However, the irrigator water user associations that extract and allocate water predominantly for irrigation and the Ayuntamientos that source and allocate potable water appear to be the significant local actors in the allocation process. Despite the apparent hierarchy of embedded and disembedded institutions, both institutional context and water resource legislation is such that these embedded institutions operate with a fair degree of autonomy that would seem to imply that it is at this level that the capacity to adapt to changes in water supply and demand pattern changes could be detected. These institutions maintain constant and direct interaction with the resource. Therefore, it can be assumed that if there is evidence of resilience and adaptive capacity at an institutional level, it is most likely to be in these embedded institutions.

This situation, despite the scepticism of some institutional theorists about the probability of institutional path dependency, means that in the Marina Baixa it is not all that difficult to isolate which 'disembedded' institutions, that because of their indirect role in the exploitation of resources, can be said to have 'locked the County in' to a certain type of water using behavior. This water using behavior limits the capacity of both these institutions and the user groups that they serve to extend their learning or to assimilate new knowledge that could increase institutional adaptive capacity.

It is now generally accepted that the capacity of an environmental resource allocation institution to adapt to changing water supply and demand patterns needs to be determined over long periods of time. This is because institutions evolve in ways that may not be predictable. Nevertheless, they do follow a particular logic that makes sense only within a discrete institutional context in which the next steps are constantly being renegotiated under the notion of "bounded change" (Weir, 1992). In the Marina Baixa, this notion of bounded change has been and is currently determined by the institutional context that has emerged to sustain the development patterns in each of the fringes discussed above.

In terms of the effect of disembedded institutions it is difficult to neglect the emergence of the Consorcio in 1977, a municipal consortium whose sole task is to seek and administer water supply for the coastal municipalities where tourism development has been concentrated or the formation of the Sindicato Central that is to administer the proposed Júcar-Vinalopó water transfer, of which the Marina Baixa is to receive 11.5 Hm^3 water. The emergence of these two institutions – whose sole task is to source and administer water supply – has established path dependence for the governance context of the Marina Baixa. That is, the current water governance context is one that is difficult to change because of the existence of these two institutions and their respective charters. This is primarily because these institutions only exist to promote water transfers (Eisenhuth, 2005).

Conclusions

The increase in water use over time is due to increases in urban and irrigated area, which has been mitigated in part by the implementation of new technologies such as drip irrigation and the re-use of water for irrigation with recycled water from sewage treatment plants. Despite this current situation, if the increase in water consumption continues at the current rate, it could be difficult to keep on introducing new technologies to maintain the sustainability of the resource. The water use indicators we have developed can be used to increase existing knowledge about the water cycle in the county and the real availability of water. They could also be used to assist to resolve conflicts between zones with an increased demand and zones with a decrease in population and crop abandonment where the availability of the resource is higher.

However, water users confess to have a general lack of knowledge regarding water demand on a household basis. The Marina Baixa respondents have a perception that the amount of water consumed in the household is far lower than real consumption. There is also a remarkable lack of knowledge about the functioning of the domestic water cycle, individual consumption and electrical appliance usage. This could account for the general lack of interest in water saving behavior and the partial interest in saving water if the cost of the resource was to increase. Paradoxically, a high percentage of those surveyed agreed to pay an additional charge to protect the 'water' environment. The overall perception of water is questionable: water users believe that is both an environmental as well as an economic good. This confusion is clearly visible when the gap between attitudes and behaviors of users is analyzed in detail.

Also, in many of the irrigator water user associations there is a general lack of knowledge regarding the area of extensions of land under irrigation, the annual volumes of water used to irrigate or the sources of water. These variations come about as the result of either cyclical water scarcity or new clearances of land. In the Marina Baixa some of the embedded institutions do not know the exact amount of water that is used on an annual basis and even fewer know exactly how much water is extracted and/or transferred from different water sources. This situation would seem to suggest that there is a distinct lack of the type of social adaptive capacity that leads to innovation in water supply and demand patterns. Despite the introduction of drip irrigation, the general lack of knowledge in the embedded institutions regarding areas of land under irrigation, the volumes of water applied to irrigation and water sources indicates that the water using culture of the Marina Baixa, particularly in terms of irrigation, is one that promotes the philosophy of supply augmentation. It also legitimizes the role of those disembedded institutions engaged in the exploitation and transfer of water from both within and from outside of the catchment.

When these physical and socio-institutional indicators are viewed in a context of water scarcity it becomes obvious that the tension that exists is largely a result of increased demands and a lack of knowledge about the 'reality' of the availability of the resource. The embedded institutions that have emerged since the mid 1970s to counter the hydrological imbalance have ultimately determined a water-using path for the Marina Baixa that will be problematic to solve unless water users are willing to access new knowledge about the imbalance that exists between supply and demand in the catchment. This situation suggests that while indicators can be useful in terms of policy formulation, they need to be viewed as tools that cannot necessarily be applied in isolation as discrete units of knowledge with which to achieve IWRM. Moreover, the co-dynamics of these indicators should not be overlooked by the decision-makers who seek to determine what or what could not be the sustainable use of water in a semi-arid region.

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