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Assessing the Regional Impacts of Climate Change on Economic Sectors in the Low-lying Coastal Zone of Mediterranean East Morocco

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ABSTRACT

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The Mediterranean region has been found to be specifically vulnerable to climatic variability and change. Projections based on observations since the beginning of the 20th century point to a further increase of water deficiency due to climatic and human pressures in the area. The Mediterranean part of Morocco's coastline is most vulnerable due to its low-lying deltaic plain of the Moulouya River, the main water provider in the region, and due to its increasing economic relevance for the country. Accelerated sea-level-rise is projected to aggravate coastal erosion, risk of flooding and groundwater salinization. At the same time sediment shortage as a result of river damming affects natural delta and beach nourishment. It has been shown that the complex interactions of human encroachment, climatic variability and sea-level-rise will lead to a further degradation of the coastal environment and will hinder economic development, which in particular focuses on the tourism sector. To support this argument a regional assessment is undertaken. CRU long time data series for seasonal precipitation and temperature (1901-2005) were used to evaluate trends in regional climatic variability; regional vulnerability regarding water availability, and the main water consuming economic activities were assessed. The analysis shows that there is no alternative for the development and implementation of comprehensive climate change policies and appropriate adaptation strategies. Otherwise sustainable long-term development seems impossible, in particular with regard to water availability and coastal tourism.

ADITIONAL INDEX WORDS: *Water budget, coastal vulnerability, coastal tourism.*

INTRODUCTION

As global warming is accelerating the Mediterranean region has been identified as one of the global hotspots of climate change, particularly due to the regional increase of mean temperatures and lower levels of precipitation over the last decades, and as well due to inter-annual seasonal variability and changes in precipitation distribution that have been observed. (DIFFENBAUGH ET AL., 2007; GIORGI, 2006; GAO ET AL., 2006; IPCC, 2007). Mediterranean ecosystems and population will be pressured significantly by climatic impacts on water resources and their availability. The development of adequate adaptation strategies on national or smaller administrative levels requires the analysis of scale-adequate – regional or local – characteristics, as the Mediterranean topographic, geographic and socio-economic structures are quite heterogeneous.

However, the broad definition of "Mediterranean", including parts of Europe, North Africa and Asia, makes it clear that a small-scale analysis of climate change impacts and sea-level rise should be undertaken in a deductive and individually specified manner to consider national or sub-national characteristics.

If the underlying purpose of an impact and vulnerability analysis is to develop adequate reaction towards the impacts of climate change and sea-level rise and further the deduction of potential regional adaptation strategies in a region, complex interactions of the natural and human sphere should gradually be assessed.

Complexity and uncertainties concerning climatic but as well societal development makes future-oriented decision making difficult. Impact assessment on a small-scale can be helpful to reduce the overall complexity of an issue and to allow the derivation of adequate responses that could support the stabilization of a region and its economic development. We consider the Moulouya River Basin (Figure 1) and its coastal plain as a natural and economic entity with characteristics that differ from those of greater Morocco. Therefore we geographically look at the low-lying coastal zone of North-East Morocco, between Beni Anzar and Saidia city, which is topographically characterized by Morocco's largest Lagoon of Nador (Sebkha Bou Areg), and by the delta and the estuary of the Moulouya River, the region's single natural water source and supplier with a river basin extent of approx. 54,000 km^2. The Moulouya river source is located in the High Atlas Mountains and the river itself runs approx. 600 kilometers before ending in a Mediterranean estuary near Saidia city. Long stretches of sandy beaches make the shoreline vulnerable to increasing sea levels even at a centimeter scale (SNOUSSI ET AL., 2008).

The Moulouya River represents a life line in Eastern and North-Eastern Morocco. Along its long course agriculture is the main economic activity; at its coastal estuary the population density is high and economic growth is expected to increase due to the rapid extension of the tourist sector in the near future. Both economic sectors are profoundly water consuming. Water therefore is the

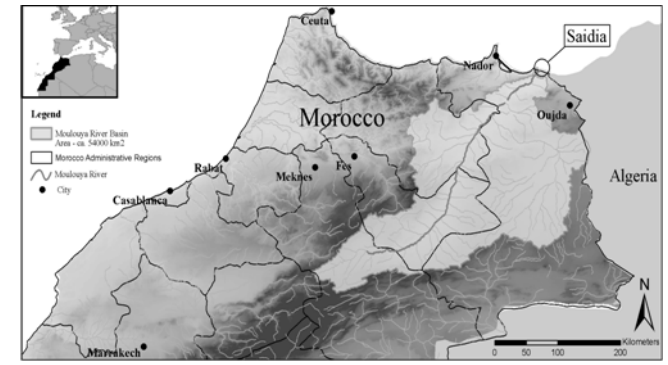

Figure 1: Moulouya River Basin, Morocco

most critical resource in this marginal and semi-arid region and its availability a decisive criterion for regional development in both terms, economically and ecologically. An increasing variability in water availability could exceed the regions adaptive capacity.

Consequently, we evaluate climatic developments along the course of the Moulouya River and assume as other authors (DOUKKALI, 2005) that water availability and demand is already balanced. Damming along the river might still provide water for agriculture at its current stake; the coastal plain though suffers from sediment shortage and lacking accretion. Individual wells are already salinized indicating an overexploitation of water resources by agricultural activities. It can be expected that an increasing sea level will worsen this situation due to an increased hydraulic pressure on groundwater aquifers. On the other hand it is a political will to extend touristic facilities near Saidia causing additional demand for water, which has to be provided by the Moulouya River as well. Further, the plans for the touristic development will not only increase the demand by the sector itself. Similar holds for agriculture and other industries which have to support the tourism sector.

Thus, changes in seasonal precipitation might harm agricultural routines and increase the regional water gap in the case study area.

However, with the region-specific analysis of climatic developments of the past century and the generation of estimates for the future we want to contribute to adaptation-oriented climate research. Without knowledge of the regional impacts and potential future implications of increasing water deficiency decision making might be erratic and inadequate. Nonetheless knowledge provision is not sufficient when parallel risk perception is little (cf. Eisenack et al. 2007).

FRAMING PARAMETERS OF REGIONAL VULNERABILITY

Regional assessments in most cases focus on geographically or socio-economically coherent areas (YARNAL, 1998). The Moulouya River Basin represents both and we want to point out that climatic developments – and therewith local water availability in the upper stream of the river – are essential for water availability in its coastal estuary where water demand is constantly growing. The River Basin though is a coupled dynamic human-environment system which is subject to mutual interplay. We follow an interdisciplinary regional approach that identifies main endogenous and exogenous parameters of vulnerability in the region to systematically focus on the main management requirements in the water sector under accelerated climate change.

To derive assumptions as regards the evolution of the regional water demand-supply-gap specifically in the costal area of the Moulouya Basin we evaluate regional climatic variability: historic climatic endogenous parameters of temperature and precipitation from 1901-2005, differentiated by annual seasons. Secondly we select exogenous (anthropogenic) parameters assumed to aggravate the current situation of deficiency. Case study area-relevant precipitation and temperature data evaluation was undertaken to provide a regional climate change profile for the past decade. Referring to this, consistent precipitation and temperature data on longer and comprehensive timescales and as well on a regional grid-scale are not available for Morocco. Therefore CRU (Climate Research Unit of East Anglia University, Norwich, UK) long time data series for seasonal precipitation and temperature data on a monthly basis were acquired and evaluated for gridded data points (data resolution 0.5 degrees) in the Moulouya River Basin (NEW ET AL., 2002).

From the CRU values, shifts in seasonal temperature (Figure 2)

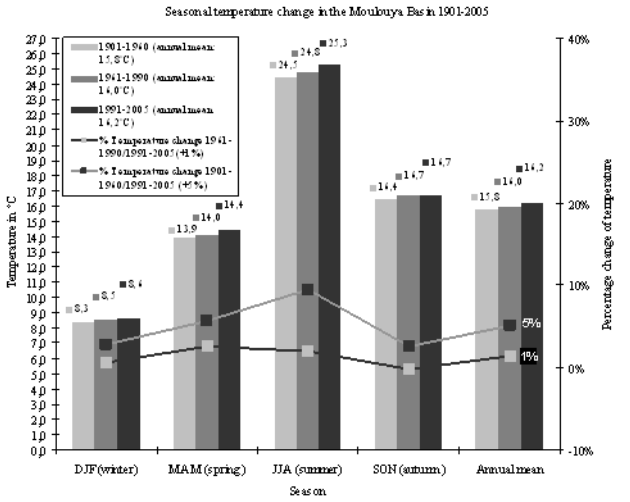

Figure 2: Seasonal temperature change in the Moulouya Basin 1901-2005.

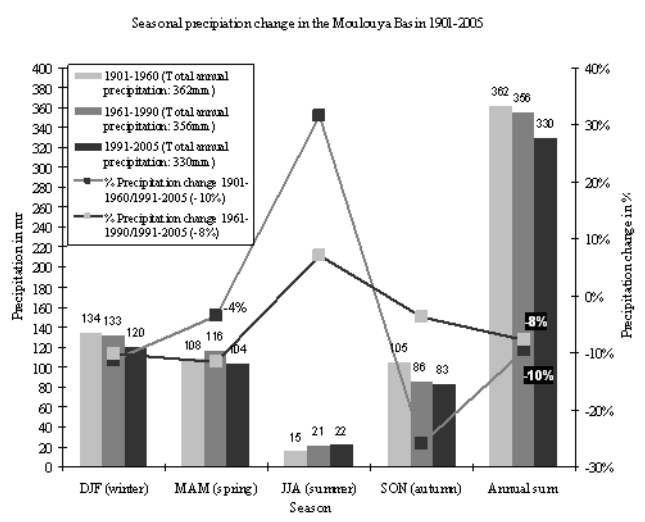

Figure 3: Seasonal precipitation change in the Moulouya Basin 1901-2005.

and precipitation (Figure 3) are depicted for spring (MAM), summer (JJA), autumn (SON) and winter (DJF) for the time periods 1901-1960, 1961-1990 (reference period) and 1991-2005.

The respective decadal and annual mean/sum of temperature and precipitation and as well temperature/precipitation change of the three analyzed time periods on a century-scale was generated (temperature/precipitation change for the periods 1961-1990/1991-2005 and 1901-1960/1991-2005).

Box 1: **Endogenous and exogenous parameters of regional vulnerability**

***Endogenous parameters*:**
System inherent, i.e. no direct influence possible. Examples used in this analysis: temperature and precipitation and their seasonal shift

Exogenous parameters:
Not originally inherent in a system, interaction possible. Examples referred to in this analysis: anthropogenic activities, e.g. inadequate water management

***Vulnerability resulting from endogenous parameters*:**
Limited water availability, seasonal shift of precipitation distribution, increasing evapotranspiration, water deficiency for natural and human environments, sea level rise

***Vulnerability resulting from exogenous parameters*:**
Damming leading to decline of sediment accumulation in the coastal plain Moulouya, increasing stress on groundwater resources due to economic activities and overexploitation, sea water intrusion into coastal aquifers

Further we identify the main contributors of coastal modification and water stress in the region. Parameters creating or influencing regional vulnerability from climate change and sea-level rise are presented. We localize specific regional characteristics and primary economic activities that can/will be negatively influenced by accelerated climate change and sea level rise. We identify decisive (natural) endogenous parameters of vulnerability in the case study area: changing temperature and precipitation along the course of the Moulouya River, and sea-level rise in the Mediterranean coastal zone and river's estuary. Selected exogenous parameters contributing to the aggravation of the current situation are damming, intensive withdrawal of water and sea water intrusion in coastal aquifers (see Box 1). In order to make clear the need for political action we undertook a water-demand-and-supply-analysis based on assumptions regarding a realistic growth scenario for the coastal area around the Moulouya mouth (Table 1).

RESULTS

Regional climatic variability

For the Moulouya River Basin we found relevant modifications for both parameters temperature and precipitation, and as well for seasonal shifts: specifically for interannual precipitation distribution. Precipitation: over the course of the 20th century annual sum of precipitation has been decreasing from annual 362mm in 1901/1960 to 330mm in 1991/2005. Between 1961/1990 (reference period) and 1991/2005 annual precipitation dropped by 8% (-26mm) from 356mm to 330mm, respectively. Over longer time scales (1901/1960 to 1991/2005) average annual precipitation dropped about 10%.

Further, seasonal precipitation distribution is of great importance for regional production cycles in agriculture and farming. Since 1961/1990 until 1991/2005 modifications in seasonal averages and dispersion have been noticed. A slight increase of precipitation in the hot summer months (+7%) has been observed, with a minor increase of variability (positive trend in standard deviation). Nevertheless, this increase in summer precipitation reveals to be too marginal to contribute substantially to the regional water balance and surpluses are negatively adjusted by high summer evapotranspiration.

Relevant decreases of precipitation can be found in winter (-10%) and spring (-12%), and a small decrease is noted in autumn (-4%). For winter and autumn a clear narrowing trend of precipitation variability can be observed (standard deviation for winter 1961/1990-1991/1990: -35% and for autumn: -34% for the same reference period).

Small, but relevant changes in regional seasonal temperatures between the reference period 1961/1990 and 1991/2005 can be observed for spring (+0,4°C) and summer (+0,5°C). Respectively, a slight increase for winter (+0,1°C) is noted, with no observable trends in the standard deviation of the values. The annual mean temperature increased by +0,2°C.

Sectoral climate sensitivity for agricultural production in Morocco is high; climatic conditions are the main parameter for the growing and yield period (BRUSCHEK AND WECHSUNG, unpubl.). Relevant shifts for temperature and precipitation can be

Table 1: Estimates for development of regional water supply and demand for the 2005 and 2015

	2005	**2005** (10^6 m^3/yr)	**2015**	**2015** (10^6 m^3/yr)	**Growth**
Drinking water for population (water needs: ~38m^3/p/c/y)	2.4 Mio	91.2	2.5 Mio	95	+4%
Golf courses (water needs: ~9000 m^3/ha/yr)	210 ha	1.9	400 ha	3.6	+88%
Irrigated land (water needs*: ~6500 m^3/ha/yr)	150 10^3 ha	975	180 10^3 ha	1170	+20%
Tourists** (water needs: ~0,6 m^3/day)	~100.000	0.6	~500.000	3	+400%
Other industries	--	80	--	117	+46%
Sum of water demand		1149		1388	+20%
Regional water supply		1330		1130	-15%
Regional water deficit		**+181**		**-258**	

* for agriculture it was assumed a considerable lower need of water for irrigation due to savings and increase in efficiency; the current value averages up to 13.000m^3/ha/yr

** estimated length of average stay: 10 days

observed for the winter and spring season; the concurrence of higher temperature and lower precipitation is highest for spring +0,4°C/-12%). As a preliminary result we expect this trend to add substantially to the already existing regional water deficiency and to amplify the regional water supply-demand-gap, specifically when regarding the growing irrigation needs in the whole River Basin.

Considering these factors we tried to estimate growth scenarios for the different sectors in the case study area. As climate change scenario we assume the A2 scenario (IPCC SRES: NAKICENOVIC & SWART, 2000), since recent literature indicates that anthropogenic climate change is accelerating and due to the fact the humankinds emission profile currently lies above the A1FI forcing (A1 storyline: fossil intensive, see above) (RAUPACH ET AL. 2007). On this basis estimates on potential regional water availability were calculated for 2005 and 2015, respectively. For the socio-demographic and economic development we refer to census data of Morocco and regional development plans (for results see Table 1).

DISCUSSION

The most important economic sector in the larger areas of Nador city and Saidia, but as well along the upstream course of the Moulouya River, is agriculture and livestock breeding. Agriculture currently employs approx. 30% of working population (ROYAUME DU MAROC, 2005) and contributes substantially to smallholder subsistence agriculture (MORTON, 2007). Irrigated agriculture though is the primary water consumer in the region. The water demand per hectare varies between 6,000 and 13,000 m^3/yr/ha and, due to the ascending demand and high levels of exploitation, pressures on groundwater resources are fundamental (FETOUANI ET AL., 2008). In the coastal provinces of the case study region 77% of agricultural areas are irrigated. In the Moulouya Basin irrigation ensures the production of cereals, legumes and fruits, and with an uprising trend livestock and dairy farming (ROYAUME DU MAROC, 2005). Regarding the results in Table 1 agriculture as the largest consumer needs to modify its current water management into a sustainable modus. The tourism sector is as well highly water consuming, specifically in arid and semi-arid regions. Given the economic development plans of the Moroccan government, the regional agricultural sector will provide for the supply of the Saidia tourist resort. This shows the narrow interplay of both sectors and makes clear that for both sectors a combined and well-defined adaptation and growth strategy is demanded.

This holds in particular when considering the ambitious economic plan to develop further the national tourism sector ("Vision 2010") by the establishment of nationwide six new resorts. One resort will be located at the Mediterranean coastline of Morocco, close to Saidia with an extent of 713 hectares and a capacity of approx. 30,000 beds (ROYAUME DU MAROC, 2001; SNOUSSI et al., 2008). The resort shall contribute substantially to the regional and national added value, particularly by the increase of regional employment of approx. 48,000 employees (ROYAUME DU MAROC, 2008). However, hydrologic imbalance is specific for the semi-arid parts of the Mediterranean and limits the expansion of groundwater based activities (ANDREO and DURÁN, 2008). Our analyses show that even in an unchanged climate these development aims would exceed the regions (natural) limits. Once again this makes clear that appropriate climate change adaptation strategies are mandatory for the region. If not initiated very soon, this can lead to economic losses, i.e. in terms of disinvestments, but also lead to severe environmental degradation. At the end this can cause a situation where the life support function of the Moulouya is completely disrupted.

CONCLUSION

The analysis depicted that socio-economic development plans for North-Eastern Morocco are limited by clear environmental constraints, in particular with regard to water resources and water availability. Due to accelerating climate change it is very likely that the situation will be worsening. The situation is threatening, specifically as current adaptation strategies are not aligned to mitigate the regional water demand-supply-gap. However, the regional water budget will determine the success or failure of regional economic development. The degree of vulnerability can only be influenced by the establishment of region-adequate adaptation strategies, acknowledging respective endogenous and exogenous parameters. Therefore, it is mandatory for regional and national decision makers to start with this process very soon, e.g. via an integrated trans-sectoral analysis. Although the results of this work are preliminary they already make clear the urgent need for action. Nevertheless, advanced analysis is needed in particular, with regard to the internal and trans-sectoral effects of the different sectors under given growth and climate change scenarios.

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