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Climate change, vulnerability and adaptation in North Africa with focus on Morocco

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ABSTRACT

Our study links environmental impacts of climate change to major socio-economic and agricultural developments in North Africa. We jointly investigate climate projections, vulnerability, impacts, and options for adaptation. Precipitation in North Africa is likely to decrease between 10 and 20%, while temperatures are likely to rise between 2 and 3 °C by 2050. This trend is most pronounced in the north-western parts of northern Africa as our own model results suggest. The combination of decreasing supply and strong population growth aggravates the stressed water situation in the region. We further compare the vulnerabilities, adaptive capacities and conflict implications of climate change in Algeria, Egypt, Libya, Morocco, and Tunisia. Climate change will likely have the strongest effect on Morocco where the agricultural sector is of high importance for the country's economy and particularly for poor people. Our analysis of climate impacts and adaptation options in Morocco suggests that the agricultural incentives used in the past are inadequate to buffer drought effects. To increase resilience against climate change, agricultural policies should shift from maximizing agricultural output to stabilizing it. Our bio-economic model results further suggest a considerable potential of replacing firewood by electric energy to sustain pastoral productivity.

1. Introduction

Climate change poses a significant challenge for North Africa, affecting and interacting with both environmental and anthropogenic systems in the region. Among the variables of interest are environmental degradation, agricultural productivity, food security, population growth and economic and societal (in-)stability. So far, the majority of research articles have focused on climate change and its interrelation with one or two of the aforementioned variables (e.g. Bekkoussa et al., 2008; Thomas, 2008; Lhomme et al., 2009; Sowers et al., 2011).

The present article aims to draw a wider, although not exhaustive, picture of climatic and social changes in North Africa by integrating perspectives from climate science, social geography, conflict research, and environmental sciences. We jointly investigate some major interrelations between climate projections, vulnerability, impacts, policy responses and options for adaptation.

The starting point of our investigation is a description of the physical climate variability and climate change as presently observed and its projections for the 21st century. We address the uncertainties of projections and their consequences for extreme events using our own model runs as well as data from the literature (Section 2).

Against this background, we give an overview of the vulnerability to climatic changes of the five North African states Algeria, Egypt, Libya, Morocco and Tunisia (see Fig. 1). The overview servers two purposes: first, it allows us to discuss security concerns of climate change which have been raised even prior to the riots in Tunisia,

Abbreviations: CIA, Central Intelligence Agency; CORDEX, Coordinated Regional Climate Downscaling Experiment; ECHAM, European Centre Hamburg Model; FAO, Food and Agriculture Organization of the United Nations; GCM, general circulation model; GDP, Gross Domestic Product; HDI, Human Development Index; HWSI, Hydrological Water Stress Index; IPCC, Intergovernmental Panel on Climate Change; mts, metric tons; PMV, Plan Maroc Vert (Green Morocco Plan); PPP, Purchasing Power Parity; PRB, Population Reference Bureau; PRIO, Peace Research Institute Oslo; REMO, REgional MOdel; RWPI, Reversed Water Poverty Index; SRES, Special Report on Emissions Scenarios; SWSI, Social Water Scarcity Index; UCDP, Uppsala Conflict Database Program; UNDP, United Nations Development Program; WBGU, German Advisory Council on Global Change; WHO, World Health Organization; WPI, Water Poverty Index.

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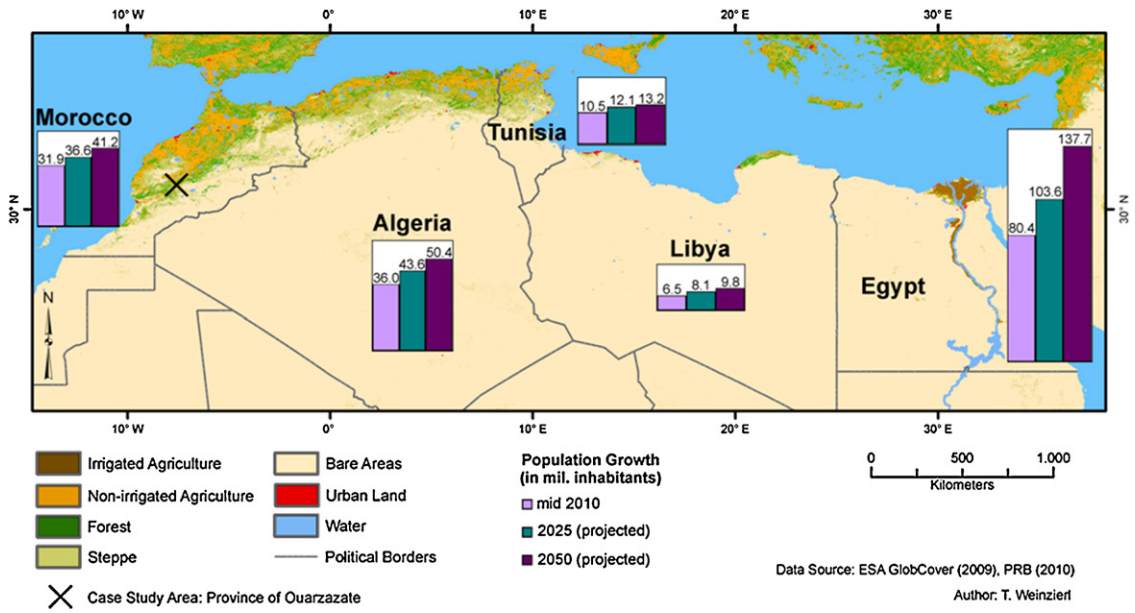

Fig. 1. Land use and population growth in North Africa (own representation based on European Space Agency, 2010; PRB, 2010).

Egypt and Libya in 2011 (WBGU, 2008; Smith and Vivekananda, 2009; Iglesias et al., 2010). Second, the overview enables us to identify countries which are most vulnerable to climate change, in particular Morocco, predominantly because of its high sensitivity to climatic changes and its limited adaptive capacities (Section 3).

Focusing on Morocco, we assess the impacts of climate change on agriculture and society which can be aggravated by unsustainable policy responses and agricultural practices. Based on this finding, we investigate a set of adaptation options using data from local research projects. In addition, a bio-economic model is used to explore the possibility of increasing resilience of pastoral livestock husbandry in semi-arid rangelands. One option is to replace firewood by other energy sources such as solar power (Section 4). The insights from Morocco reveal linkages between climate change, agricultural practices and socio-economic developments which are also relevant for adaptation in other North African countries.

2. Climate change in North Africa

2.1. Recent climate characteristics

Precipitation of North Africa is characterized by a wet season in winter and dry conditions in summer. The rainy season, which starts in October and lasts until April, has its maximum in the months from December to February (Endlicher, 2000; Lionello et al., 2006). Additionally the whole region is characterized by high inter-annual precipitation variability. Thus, long-term mean precipitation, especially in the southern region of North Africa, reflects averages over many dry years and some relatively humid years.

A generalized overview of historical trends in the recent past and likely future trends under enhanced greenhouse warming conditions for temperature and precipitation in the North African countries is given in Table 1. For north-eastern Morocco and north-western Algeria, several studies point to below average annual rainfall rates which have prevailed since about the mid-1970s (Hertig, 2004; Fink et al., 2010; Meddi et al., 2010). Also for the southern parts of the Moroccan Atlantic coast as well as for the Atlas Mountains several periods of below average precipitation occurred in the second half of the 20th century in the winter season, for example in the period 1971 to 1975 and in the period 1979 to 1983, but also some positive anomalies can be found around the late 1980s and 1990s (Hertig, 2004). Due to the observed changes, a general tendency toward warmer and drier conditions can be found in the last decades for the above mentioned regions (Gerstengarbe and Werner, 2007; Born et al., 2008). In contrast to the predominantly negative precipitation evolution in the western parts of Northern Africa, no pronounced precipitation trends have been observed for the eastern regions such as north-eastern Algeria (Meddi and Talia, 2008), Mediterranean Tunisia (Hertig, 2004), central Tunisia (with some decadal variability, Kingumbi et al., 2005), and the Mediterranean parts of Libya and Egypt (Hertig, 2004) during the last decades of the 20th century.

Born et al. (2010) find that the skill of simple statistical seasonal rainfall predictions is limited. Using multivariate statistical analyses, Hertig and Jacobeit (2010a,b) show that precipitation in February in the Atlas Mountains of Morocco, regional temperatures in Algeria and Tunisia in the month of May, and December temperatures in the western parts of Northern Africa can be predicted by taking preceding sea surface temperature anomalies as predictors. Thus, it becomes evident that there is some skill regarding seasonal predictions of temperature and precipitation (see Slimani et al., 2007 for Tunisia). In the scope of possible future enhancements of such predictions, they could become more important, especially in the context of the additional challenges due to climate change.

2.2. Future climate change

For Northern Africa climate change studies indicate that annual precipitation is likely to decrease during the course of the 21st

Table 1
Generalized overview of recent and likely future trends of temperature and precipitation in North Africa (sources see text).

State	Recent trends		Future trends	
	Temperature	Precipitation	Temperature	Precipitation
Algeria	+	–	+	–
Egypt	+	o	+	–
Libya	+	o	+	–
Morocco	+	–	+	–
Tunisia	+	o	+	–

+: increase; –: decrease; o: no change.