Socio-economic vulnerability to climate change: a regional assessment in the context of water stress and tourism development in north-eastern Morocco

I n a u g u r a l d i s s e r t a t i o n

zur

Erlangung des akademischen Grades eines

Doktors der Naturwissenschaften (Dr. rer. nat.)

der

Mathematisch-Naturwissenschaftlichen Fakultät

der

Ernst-Moritz-Arndt-Universität Greifswald

vorgelegt von
Vera Tekken
geboren am 05.01.1971
in Norden

Greifswald, 05.03.2013

Dekan: Prof. Dr. Klaus Fesser

1. Gutachterin: Prof. Dr. Susanne Stoll-Kleemann
2. Gutachter: Prof. Dr. Jürgen Scheffran

Tag der Promotion: 11.09.2013

Gewidmet
meiner Mutter Ilse Theda Tekken († 27 November 1978)
und
meinem Vater Johann Theodor Tekken.

Summary

Water resources in north-eastern Morocco are increasingly under pressure from a growing human demand and a regional drying trend caused by changing climate patterns. Recently, water resources have reached or already fallen below critical limits. The human exploitation of water resources represents the main reason for an alarming decrease of freshwater resources: caused by population growth, high agricultural irrigation water needs, and the recent implementation of a water-intense tourism sector. The lack of appropriate policies to respond to these challenges determines regional vulnerability und puts socio-economic development at risk.

The overarching research objective of this thesis **is the identification of human and climate-induced drivers for increasing water stress in north-eastern Morocco** with a focus on regional tourism development. With particular regard to climate change and to the water-intense regional development plans, it is necessary to analyse how this will influence the near-term water situation and water demand, respectively.

The key economic sectors with the highest share of working population are highly water-dependent, thus sufficient water availability represents the basis for socio-economic development. Climate change in the region can aggravate the scarcity situation: precipitation is now the main hydrological variable, as the quality and quantity of groundwater resources has seriously deteriorated and as water efficiency measures and technologies currently are not appropriate to cover increasing demands.

Further, this thesis aims to support the development process of improved water management strategies for the facilitation of socio-economic development. By the means of an integrative research approach the vulnerability to increasing water scarcity is empirically investigated. The chosen research design is a vulnerability assessment approach. Vulnerability assessments have emerged over the past decade as appropriate frame of analysis to assess the impact and scope of different drivers causing socio-ecological vulnerability in the context of climate change. The underlying hypothesis is that regional climate change aggravates existing water scarcity in north-eastern Morocco, which is currently pressured by an inadequate demand-supply ratio (water deficit situation). From this general aim overarching research questions and issues have emerged and were refined by sub-questions during the process of research.

The causes and the extent of vulnerability and the development and governance context of water scarcity are subject to four articles which support the present thesis. Article I outlines the specific regional problems of the coastal zone of the case study area under climate change and socio-economic development pressure. Article II contrasts the human influence (indicators: population growth, water demand) on decreasing freshwater availability with the potential impacts of a changing regional climate (indicators: precipitation, temperatures, evapotranspiration). Article III analyses the additional water demand in north-eastern Morocco caused by the recent establishment of a large-scale luxury tourism sector in the coastal zone. Article IV discusses the sustainability of regional development plans in the light of severe water problems and outlines concrete adaptation measures for the regional water management.

The results show that water availability already fell below minimum water levels needed to ensure the water regional water supply. The regional water situation is in a status of disequilibrium of water abstraction and water availability. Further population growth and water-intense economic development pathways will increase the risk of recurring water shortfalls. The analysis of long-term climate series reveals a manifest drying trend and shifting climate patterns. The "*absolute water scarcity level*" that is "*beyond the water barrier of manageable capability*" has become a normal situation (based on the Falkenmark Index; Falkenmark 1989; Gleick et al. 2002).

Governmental development plans focus on luxury tourism to diversify the regional economy. Tourism is a promising sector in Morocco, and is needed to diversify the agriculture-dependent economy. However, tourism requires continuous water supply and contributes to the increase of seasonal water demand.

All four articles in this thesis emphasize the urgent need for societal and institutional responses to safeguard water supply in the Moulouya basin. Given the aggravating water situation and the underlying two-fold causes, three main strategies are considered reasonable and achievable:

(1) Increase of regional water efficiency: the modernization of water infrastructures (no-open channel water transport, no gravity irrigation), the inclusion of 'green' water in calculations of water supply, innovative water collection measures, using the opportunities of virtual water trade;

(2) Modernization of the regional water management: monitoring of the water situation and climatic variability, participatory approaches to engage the local population and to create awareness; and the

(3) Implementation of legally-binding regulations for the public administration, supported by national water policies.

Clearly, these measures require substantial investments. However, this thesis emphasizes, that regional natural water resources are finite and already in a state of severe degradation. A better understanding of the respective influence of climate-induced or human-induced pressures provides the basis for the implementation of adequate adaptation strategies. Human-induced impact can be influenced by policies, and with this the degree of socio-economic vulnerability. Water-based economies, which do not explicitly react to aggravating pressures, are at risk of economic failure, as (a) climate change is an irreversible process, and (b) as socio-economic development builds upon water availability.

Zusammenfassung

Weltweit nimmt der Druck auf die natürlichen Wasserressourcen zu. Dies hat unterschiedliche Gründe, ist jedoch zum größten Teil verursacht durch einen stetig ansteigenden Bedarf. Faktoren wie Bevölkerungswachstum, die In- und Extensivierung landwirtschaftlicher Produktion, veränderte Lebensstile mit gleichzeitiger Erhöhung des individuellen Wasserverbrauchs, tragen regional unterschiedlich zu einer Verknappung bei.

Neben dem anthropogenem Einfluss auf Wasserressourcen stellt Klimawandel ein zusätzliches Problem dar. Viele Länder sind sich der begrenzten Verfügbarkeit ihrer Ressourcen zwar bewusst, einfache Lösungen zur nachhaltigen Bewältigung des steigenden Bedarfs existieren jedoch zumeist nicht. Momentan folgen die meisten Länder dem Paradigma des ökonomischen Wachstums, um Ernährungssicherheit, Beschäftigung und sozialen Fortschritt zu gewährleisten. Die exzessive Ausbeutung natürlicher Ressourcen stellt immer noch den Standard dar, um sozio-ökonomische Entwicklung zu ermöglichen. Daher ist bei der Vereinbarung von ökonomischem Wachstum und Umweltnachhaltigkeit nur schwer ein Fortschritt zu erkennen. In diesem Zusammenhang spielt Wasser eine Schlüsselrolle: der Zugang zu und die Nutzung von Wasser war und ist eine wesentliche Voraussetzung für sozio-ökonomische Entwicklung. In den vergangenen Jahrzehnten wurden kritische Wasserlimits trotz wachsenden Bedarfs überschritten. Demnach mangelt es in vielen Ländern an einem angepassten Wassermanagement. Zudem sind Maßnahmen zum Schutz der Wasserressourcen insbesondere im Hinblick auf eine zukünftige Nutzung unzureichend. Nord-Afrika ist eine Region mit schwerwiegenden Problemen bezüglich ausreichender Wasserverfügbarkeit. Die Übernutzung hat bereits zu einem alarmierenden Rückgang vorhandener Frischwasserressourcen geführt. Wasser ist aber gleichermaßen die Schlüsselressource für ökonomisches Wachstum und sozio-ökonomische Entwicklung. Daher ist die Implementierung einer adäquaten Wasserbedarfsteuerung unentbehrlich.

Der thematische Fokus dieser Dissertation liegt auf der Analyse der problematischen Wassersituation im nordöstlichen Marokko.

In der Region sind Wasserressourcen in hohem Maße vulnerabel durch einen stetig steigenden Bedarf. Dieser ist verursacht durch Bevölkerungswachstum, hohen landwirtschaftlichen Bewässerungsbedarf sowie durch die jüngst erfolgte Etablierung eines wasser-intensiven Tourismussektors. Zusätzlich wirkt sich Klimawandel auf die bereits übernutzten Ressourcen aus. Der momentane Mangel an angepassten Strategien als Antwort auf die Herausforderungen eines steigenden Bedarfs verstärkt durch Klimawandel hat negative Auswirkungen auf die regional angestrebte sozio-ökonomische Entwicklung.

Diese Dissertation untersucht die Gründe einer sich verringernden regionalen Wasserverfügbarkeit unter Einbeziehung des menschlichen sowie des klimatischen Einflusses auf das Wasserbudget. Die regionale Ökonomie hängt ab von der ausreichender Wasserverfügbarkeit. Wasserpolitiken sind daher wichtig und sollten die Ursachen der Wasserprobleme realistisch betrachten.

Der räumliche Rahmen vorliegender Analyse ist das Einzugsgebiet des Moulouya-Flusses. Dieses stellt eine hydrologische Einheit dar, und umfasst ca. 54.000 km^2. Der Fluss selbst hat eine Länge von ca. 600 km und mündet in einem Delta mit einzigartigen Feuchtgebieten an der Küste des Mittelmeers. Der Moulouya-Fluss ist der wichtigste Frischwasserversorger der gesamten nordöstlichen Landesregion. Mit einer jährlichen Niederschlagsumme von ca. 330 mm gehört die Region zu den trockensten des Landes.

Ein Ziel der vorliegenden Arbeit ist es, Forschungslücken zu füllen und Information bereitzustellen, die Zusammenhänge der Exponiertheit gegenüber Wasserstress verdeutlichen können. Zudem soll die Etablierung eines verbesserten Wassermanagements als Grundlage sozio-ökonomischer Entwicklung unterstützt werden. In einer interdisziplinären Herangehensweise wird Wasserknappheit in der Region empirisch analysiert. In vier wissenschaftlichen Artikeln werden die Gründe und das Ausmaß von Vulnerabilität sowie der Entwicklungs-Governance-Kontext im Hinblick auf Wasserknappheit untersucht. Artikel I erörtert die spezifischen regionalen Probleme der Küstenzone, die sich unter starkem Entwicklungsdruck befindet und die Auswirkungen des Klimawandels bereits spürt. Artikel II kontrastiert den menschlichen Einfluss auf Frischwasserverfügbarkeit (Indikatoren: Bevölkerungswachstum, Wassernachfrage) mit den möglichen Auswirkungen einer regionalen Klimaveränderung (Indikatoren: Niederschlag, Temperaturen, Evapotranspiration). Artikel III analysiert den zusätzlichen Wasserbedarf in Nord-Ost-Marokko, der durch die Etablierung von Luxustourismusresorts entsteht, die in der Küstenzone errichtet werden. Artikel IV diskutiert die Nachhaltigkeit der regionalen Entwicklungspläne im Lichte des Wasserproblems.

Die Ergebnisse zeigen, dass die Wassernachfrage die Wasserverfügbarkeit bereits überschritten hat. Bevölkerungswachstum und wasserbasierte ökonomische Entwicklung werden diesen Trend verstärken, so dass die Region mit hoher Wahrscheinlichkeit unter problematischen Wassermangel leiden wird. Die Analysen regionaler Klimatrends deuten hin auf eine Verschiebung der Niederschlagsmuster bei gleichzeitigem Rückgang der Niederschlagssummen. In Verbindung mit den aktuellen Nachfrageraten ist die Verfügbarkeitsgrenze bereits überschritten. Regierungspläne, die den Ausbau des Luxustourismus fördern, haben zum Ziel, die regionale Ökonomie zu diversifizieren und die Abhängigkeit vom Agrarsektor zu reduzieren. Luxustourismus ist allerdings auf permanente Wasserversorgung angewiesen und wird dadurch eine zusätzliche Belastung für die regionale Wasserverfügbarkeit darstellen.

Alle vier Artikel betonen die Notwendigkeit für rasche soziale und institutionelle Antworten auf die beschriebenen Herausforderungen, um die Wasserversorgung zu gewährleisten. Daher werden folgende Empfehlungen formuliert:

- Erhöhung der Wassereffizienz (z.B. durch modernisierte Bewässerungstechnologien, “green water management” für regenwasser-gespeiste Bewässerung);
- Etablierung moderner Wassertechnologien zum Wasserschutz, oder unkonventioneller Wasserproduktion);
- Etablierung urbaner und ländlicher Abwassersammlung und –behandlung, sowie Wiederverwertung;
- Einbeziehung von Klimawandel in Berechnungen des zukünftigen Wasserbudgets;
- Aufbau von kleinskaligen Wasseraufbereitungsanlagen für wasserintensive Unternehmen, z.B. Tourismusinfrastrukturen.

Derartige Maßnahmen sind kostenintensiv. Dennoch ist es das Ziel dieser Dissertation zu betonen, dass natürliche Wasservorräte begrenzt und in Nord-Ost-Marokko bereits stark degradiert sind. Ein besseres Verständnis der jeweiligen Einflussfaktoren, anthropogen oder klimatisch verursacht, ist die Basis für die Implementation problem-ausgerichteter Anpassungsstrategien. Anthropogen verursachte Auswirkungen können durch Politiken beeinflusst werden. Wenn wasserbasierte Volkswirtschaften nicht adäquat auf den zunehmenden Druck auf Wasserressourcen reagieren, riskieren sie ökonomisches Scheitern.

List of Articles

This thesis is a cumulative dissertation and consists of the following four double-blind and peer-reviewed articles (full articles can be found in Annex A):

I	Tekken, V., Costa, L. and Kropp, J.P. (2009): Assessing the regional impacts of climate change on economic sectors in the low-lying coastal zone of Mediterranean Morocco. *Journal of Coastal Research SI 56*, 272-276.
II	Tekken, V. and Kropp, J.P. (2012): Climate-driven or human-induced: Indicating severe water scarcity in the Moulouya river basin (Morocco). *WATER* 4(4), 959-982.
III	Tekken, V., Costa, L. and Kropp, J.P. (2013): Increasing pressure, declining water and climate change in north-eastern Morocco. *Journal of Coastal Conservation (online first).*
IV	Tekken, V. and Stoll-Kleemann, S.: Resource pragmatism vs. resource reality: sustainable tourism development in north-eastern Morocco. Submitted manuscript to: *Tourism Management Perspectives*.

Contribution of authors to the research articles:

In all articles the main research design, fieldwork, data collection, literature research, empirical data analysis, and statistical calculations, as well as the lead in the process of writing was performed by myself. Luis Costa from Potsdam-Institute of Climate Impact Research (co-author in paper I and III) supported me regarding the acquisitions of long-term historical climate data series 1901-2005 from CRU TS2.1 (Climate Research Unit, Norwich, UK) and in the mapping of results. Prof. Dr. J. P. Kropp from Potsdam-Institute of Climate Impact Research (PIK) was co-author in article I, II, and III in his position as the head of the German part of the ACCMA project. Prof. Dr. Susanne Stoll-Kleemann co-authored article IV. Her contribution focused on the research design, and on the theoretical basis of sustainability in the context of environmental management.

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List of Acronyms

ACCMA	Adaptation to Climate Change in Morocco
AD	Anno Domini
BC	Before Christ
CCAA	Climate Change Adaptation in Africa
CRU	Climate Research Unit, University of East Anglia, Norwich UK
CRU TS 2.1	Monthly grids of terrestrial surface climate (temperature and precipitation) for 1901-2005 of CRU
CRU/PIK	Aggregated and homogenised monthly precipitation dataset of CRU for 1901-2005
CWB	Climatic Water Balance
DFID	Department for International Development of the United Kingdom
EUCC	Coastal and Marine Union
FAO	Food and Agriculture Organization of the United Nations
HDI	Human Development Index
FI	Falkenmark Index
ICZM	Integrated Coastal Zone Management
IDRC	International Development Research Centre of the Canadian government
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
MAP	Mediterranean Action Plan

MDGs	Millennium Development Goals of the United Nations Development Programme
MENA	Middle East and North Africa
OECD	Organisation for Economic Co-operation and Development
PET	Reference Evapotranspiration
Pot.ET	Potential Evapotranspiration
UN	United Nations
UNEP	United Nations Environmental Programme
WBGU	Wissenschaftlicher Beirat der Bundesregierung zu Umweltfragen

1 General Introduction

1.1 Background

The 4th assessment report of the IPCC reinforces that anthropogenic climate change is a fact (IPCC 2007). The IPCC defines climate change as *"a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity" (IPCC 2007).*

Climate change and its implications for geophysical, biological and socio-economic systems represent one of the most pressing challenges in the 21th century (Newell 2004; Schneider et al. 2007). Many questions arise from the complexity of problems associated with increasing temperatures, changing precipitation patterns, and sea level rise. Key impacts[1] are already observed or being expected for ecosystems and species, food and food production, coastal areas, health, human activities (industry, settlement, societies), and water resources (IPCC 2007).

Despite climate change being a global phenomenon, it affects some regions more than others. Developing countries are found to be highly vulnerable[2], as climate change adds additional pressure to already existing problems such as poverty, unequal access to natural resources, environmental degradation, risks from natural hazards, and decreasing freshwater availability (IPCC 2007b; UNDP 2007; WBGU 2007; Yohe et al. 2007).

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[1] Definition of 'impact' in the context of climate change: "*An impact describes a specific change in a system caused by its exposure to climate change. Impacts may be judged to be harmful or beneficial*." (Schneider et al. 2007).

[2] Definition of 'vulnerability': *"The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity"* (IPCC 2007b).

The underlying root causes, such as human-induced degradation and unsustainable management of resources, are intensified by increasing climate variability. Societies and economies that are highly dependent on natural resources will be affected most (Adger et al. 2003). In particular for developing countries it will become even more difficult to achieve the ecological, economic and social objectives targeted in the *Millennium Development Goals* (see Box 1 for definition of MDGs) (IPCC 2007b; Yohe et al 2007). Therefore, climate change is aggravating man-made threats to ecosystems, in particular if those are already suffering from overexploitation (Chambwera and Stage 2010). In regions that are already experiencing serious economic and social problems, climate change will interfere with development efforts and "*pose an additional burden to societies"* (Olowa et al. 2011). In many developing countries, such as Morocco[3], existing socio-economic vulnerability is a result of both the unsustainable use of resources and development pressures, thus exacerbated but not primarily caused by climate change (Schipper 2007). The reduction of these existing pressures represents a necessary prerequisite for the adaptation to climate change (Schipper 2007).

Box 1: The Millennium Development Goals (MDGs)

As a follow-up of the Millennium Declaration of the General Assembly of the United Nations in the year 2000, all United Nations members and 23 international organizations agreed on the achievement of 8 development goals until 2015 to improve social and economic development in the world's poorest countries. Those goals include:

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development.

[3] Morocco is classified as "*lower middle income country*" with a per capita GNI of $1,006 $ 3,975 in the year 2010, after OECD, see URL: http://www.oecd.org/dac/aidstatistics (last accessed February 2013).

Globally, the hydrological system is significantly affected by climate change and by its feedbacks on temperatures, precipitation and evapo(trans)piration (Bates et al. 2008). Severely increasing water stress is expected for the semi-arid low latitudes, where decreasing water availability and higher frequencies of droughts are already observed (IPCC 2007).

The African continent is most vulnerable to climate change (Schneider et al. 2007). A major risk lies in the reduction of agricultural productivity, particularly subsistence agriculture, and therewith threatens food security (Schneider et al. 2007). Recently, many countries in the Middle East and North Africa are experiencing political unrest. Problems regarding equal and affordable food supply but as well the quality of water resources play a considerable role as cause for conflicts (Lagi et al. 2011). In particular marginal, or the poor, population with limited income alternatives depends on adequate decision making to guarantee at least a minimum "*standard of survival*" (Lagi et al. 2011). A sufficient water supply is thus crucial, but becomes increasingly problematic.

North African countries are among the driest and most water limited regions of the world, with only 1 % of the world's freshwater resources (Hassan et al. 2005; García-Ruiz et al. 2011). The region suffers from a physical water scarcity[4], meaning that water resources are a critically limited resource, driven by population growth, increasing demand and high water exploitation rates, unsustainable water-intense activities and changing climate patterns (Puigdefabregas and Mendizabal 1998; IPCC 2007a; Molden et al. 2007). Climate models project an aggravating situation, with detrimental effects for run-off rates, high potential for a disruption of water supplies, a deteriorating water quality, and problems for the agricultural production (IPCC 2007; Schneider et al. 2007).

In Morocco, located in the most north-western part of North Africa, freshwater resources are under high pressure. Increasing water scarcity endangers economic

[4] Physical water scarcity "*occurs when available water resources are insufficient to meet all demands, including minimum environmental flow requirements*", while economic water scarcity "*occurs when investments needed to keep up with growing water demand are constrained by financial, human, or institutional capacity*" (Molden et al. 2007).

development. The northern parts of the country belong to the Mediterranean basin, a region that is classified as a climate change or desertification "*hot spot*" (Giorgi 2006; Giorgi and Lionello 2008). North-eastern Morocco is an example for the combination of water scarcity, population growth and high development pressure. Traditionally, agriculture is the key economic sector in the region, currently contributing up to 20 % to national GDP[5], with a share of more than 40 % of total employment (and up to 80 % in rural areas) (Imassi 2007). Agriculture, and in particular subsistence production, is mainly rain-fed, thus the regional income depends to a great extent on climate conditions (Khrouz et al. 2000). In the recent past, recurring droughts and severe water deficits have caused high yield losses. Water availability continues to decrease, mainly due to the significant reduction of groundwater recharge rates, the salinization of aquifers, the overexploitation of water resources, and precipitation left as the main hydrological variable (Snoussi 2004; Döll 2009). The region is susceptible for a worsening trend of precipitation and increasing temperatures (Tekken and Kropp 2012). The causes for water stress are complex and very region-specific, and depend on the level of development and adaptation (Schneider et al. 2007). As the population is growing and development strategies are based on water-intense activities (luxury tourism: "Plan Azur"; intensification and extension of agricultural production: "Plan Maroc Vert"), adaptation to water deficiency must be a major component of regional development strategies (Royaume du Maroc 2008, 2008a).

Currently, there is a research gap regarding the small-scale assessment of the impacts of changing regional climate conditions on water availability, the key resource for regional development. Scientific information is needed in order to support the development of adequate adaptation strategies to ensure water security. Regional water management thus faces a major challenge: the development of strategies and policies to ensure a sustainable water management under consideration of climate change, decreasing water availability and increasing demand.

[5] Data for Morocco: The World Bank, see http://www.worldbank.org/en/country/morocco/overview (last accessed 20 February 2013).

1.2 Research purpose and objectives

The main purpose of this thesis is to contribute to and to enhance the current state of region-specific knowledge on causes and drivers of and for water vulnerability in north-eastern Morocco with a focus on the influence of climate change on regional water availability, the impact of population growth on water demand, and the sustainability of targeted development pathways. This information is necessary for the reconsideration and alignment of adequate sectoral policies in order to safeguard future water availability.

The focus is on climate- and human-induced vulnerability to water scarcity in north-eastern Morocco. To be precise, climate change is often considered as main vulnerability-causing parameter in the context of resource degradation or shortage. There is a scientific consensus, that climate change represents an appreciable risk for ecosystem change, its functions and services, and that respective detrimental impacts are reflected in societal vulnerability to different extents (IPCC 2007).

In Morocco, there is a considerable need for research regarding small-scale implications of climate change on water resources taking into account different pressures. Such information is necessary for the development of sectoral management strategies and the delineation of adequate water policies, both crucial aspects for a successful and sustainable regional development.

The overarching research objective of this thesis **is the identification of human and climate-induced driving forces for increasing water stress in north-eastern Morocco** with a focus on regional tourism development. With particular regard to climate change and to the water-intense regional development plans, it is necessary to analyse how this will influence the near-term water situation and regional water demand, respectively.

The specific research objectives of this thesis are:

(1) to assess and indicate changes in regional climate patterns in the hydrological unit of the Moulouya river basin over the recent past using historical meteorological data;

(2) to assess the influence of population growth and water-intensive human activities on regional per capita water availability based on population projections and development pathways;

(3) to estimate increasing seasonal water demand in the particular context of regional luxury tourism development;

(4) to analyse the adequacy of regional development strategies under aggravating water scarcity; and

(5) to derive recommendations for a sustainable regional water management.

1.3 Project affiliation of this thesis

In order to address the abovementioned severe problems and to improve the capacity of African countries or regions to adapt to climate change, Canada's International Development Research Centre (IDRC)[6] (http://www.idrc.ca) and the United Kingdom's Department for International Development (DFID) jointly launched the CCAA program (Climate Change Adaptation in Africa) in the year 2006. Part of the program was the interdisciplinary research project ACCMA (ADAPTATION AUX CHANGEMENTS CLIMATIQUES AU MAROC, runtime 2007-2011)[7]. Firstly, on the one hand, the project's purpose was to identify regional vulnerabilities caused by changing climate conditions, pressures from increasing concentration of human population, loss of land and valuable resources by environmental degradation and coastal exposure to increasing sea levels in Morocco's Mediterranean provinces Nador and Berkane (region l'Oriental). Secondly, it aimed to raise the awareness of regional and national decision-makers concerning additional pressures resulting from climate change in the region. Results from ACCMA were supposed to contribute to the

[6] See URL: http://www.idrc.ca (last accessed February 2013).

[7] See URL: http://www.idrc.ca/EN/Regions/Middle_East_and_North_Africa/Pages/ResultDetails.Aspx ?ResultID=39 (last accessed February 2013).

formulation of strategic coastal planning policies (inter alia to inform the Nador ICZM[8] Action plan, developed by the EUCC-led project CAP Nador)[9] and to support the assessment and implementation of adaptation measures in a regional context. The particular concern of ACCMA was to deliver small-scale vulnerability assessments to provide stakeholders and decision-makers with adequate knowledge regarding necessary action to be taken in the light of regional climate change. As a result of stakeholder meetings, focus group discussions with regional decision-makers and famers, and discussions regarding the role of climate change for socio-economic development, the research questions for this thesis were adapted accordingly. It became apparent, that the key regional constraint for developmental progress lies within the problematic water situation. However, small-scale assessments for the region did not exist but were urgently needed to give recommendation to the regional water management authorities.

The participatory and transdisciplinary approach to outline the research hypothesis aimed to enhance the scientific understanding of the respective influence of human and climate-induced pressures in order to derive adaptation strategies to support a sustainable regional development. The analytical approach used in this thesis ties up with the project's overall objectives. It is small-scaled in nature in order to secure a close relationship between the research and its outcomes' target audience.

1.4 Thesis structure

This cumulative dissertation contains four peer-reviewed academic research articles that address the vulnerability of water resources in north-eastern Morocco within the context of climate change and socio-economic development. All articles contain a relevant literature review, a description of selected and applied methodologies for data analysis and results, and a discussion and conclusion section. The thesis combines approaches from human and physical geography under disciplinary consideration of hydrological, socio-economic, and

[8] ICZM: Integrated Coastal Zone Management.

[9] See homepage of EUCC (Coastal & Marine Union) for further information about the CAP Nador project under URL: http://www.eucc.nl/en/capnador/ (last accessed February 2013).

demographic perspectives. The thesis is divided into 6 chapters. After this introduction and presentation of research purpose and objectives, Chapter 2 provides comprehensive information on the case study area of this research, north-eastern Mediterranean Morocco. Chapter 3 introduces the underlying concepts. In Chapter 4 the research design and analysis process are described under inclusion of the research sub-questions and methods applied in the four articles. Chapter 5 summarizes the key findings of the articles with regard to the overall research purpose and the research objectives. Conclusions are drawn in Chapter 6.

2 Study area

2.1 Regional context – climate change, water stress and population growth in Mediterranean North Africa

In North Africa, climate change adds to an already precarious situation: increasing environmental degradation causes biophysical and social vulnerability, while the adaptive capacity[10] is low (Sowers et al. 2011). Current institutions are unable to handle the complexity of impacts, as the context of damages has changed and traditional practices will not be sufficient to cope with future climate change (Boko et al. 2007; IPCC 2007b).

Further, agriculture is of substantial relevance for most North African countries, in particular due to its role for subsistence farming and food security. Problems such as the increasing frequency of water shortfalls, drought, floods and soil erosion do not only have the potential to lead to economic failure, and increasing poverty rates. These problems inherit large potential for humanitarian catastrophes (IPCC 2007a). For example, the estimated number of people at risk of increased climate-induced water scarcity[11] in North Africa is projected to rise to 90 up to 140 million in 2055 under the likely assumption of further increasing global temperatures (Boko et al. 2007; IPCC 2007a; Sabater and Barceló 2010).

Currently, water-related problems in North Africa are primarily driven by increasing demand due to population growth, urbanization, agricultural intensification, insufficient water infrastructures, and the establishment or further extension of water intense economic sectors (Ben Kabbour et al. 2005; Cudennec et al. 2007). In general, depending on

[10] Definition of 'adaptive capacity': *"The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences"* (IPCC 2007b).

[11] Definition of 'water scarcity': "*Water scarcity is a structural persistent drought affecting resources and aquatic ecosystems, with implications in water quality and societal needs. Scarcity results in repeated drought episodes. While drought is a temporary (and often normally associated to climatic patterns) decrease in water resources, water scarcity occurs when water demand exceeds exploitable water*" (Sabater and Barceló 2010).

their specific vulnerability countries or regions will have to adapt[12] to the impacts of climate change in order to avoid or lessen irreversible damages, and to avoid the exceedance of physical limits (Gueye and Bzioul 2005; Boko et al. 2007; IPCC 2007a).

2.1.1 The coastal areas

In the year 2000, 143 million inhabited the Mediterranean coastline, or, in other numbers, 33% of the Mediterranean population lived in 13 % of the area (European Environment Agency 2006; UNEP/MAP 2009). A spread of human activities leading to urbanization and growing population density in coastal areas can be observed in all Mediterranean countries, with above-average increases in North African and MENA countries[13] (UNEP/MAP/PAP 2001; UNEP/MAP 2009) (Table 1).

Table 1: Population dynamics observed in Mediterranean coastal regions 1970-2000 (Source: UNEP/MAP/PAP 2001).

Country/Region	Population in coastal areas (in 1000)		Average annual growth rate (%)	Urban Population in coastal areas (in 1000)		Average annual growth rate (%)
	1970	2000	1970-2000	1970	2000	1970-2000
MENA	29 172	59 858	2,4	15 641	30 032	3,6
North Africa	23 973	50 374	2,5	12 332	31 828	3,2
Morocco	1 678	3233	2,2	450	1 582	4,3
Mediterranean	95 021	143 335	1,4	59 805	100 869	1,8

Many pressures are associated with the coastal urbanization trend. The spread of urban areas leads to an increase of built infrastructures, or pressures on the hydrological system due to local over-abstraction of groundwater. To ensure water supply river dams are constructed for water storage, causing the reduction of sediment supply in the coastal zones (UNEP/MAP/PAP 2001).

[12] Definition of adaptation: "The adjustment in natural or human systems in response to actual or expected climatic stimuli or their effect, which moderates harm or exploits beneficial opportunities" (IPCC 2007b).

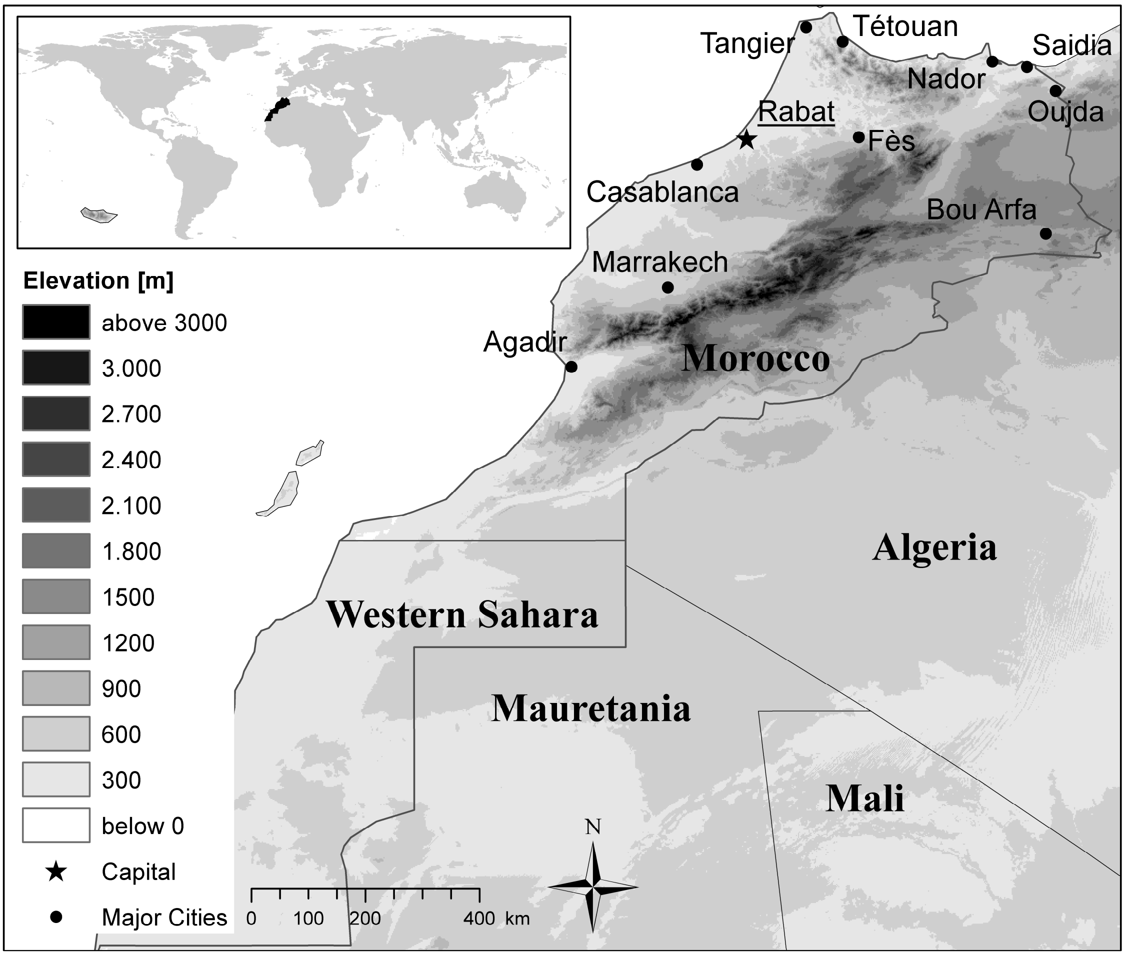
[13] MENA: World Bank definition for a larger region than the ones we analyse in this chapter, MENA countries referred to in this chapter are from west to east Morocco, Algeria, Tunisia, Libya, Egypt, Israel, Lebanon, and Syria.

Further, different scenarios agree on the high vulnerability of the Mediterranean region towards global warming and with this increasing sea levels (Smit and Pilifosova 2001; Hinkel and Klein 2007; Nicholls et al. 2007). Coastal erosion caused by rising sea levels can harm ecological functionality, impair and reduce beaches and built infrastructures (Snoussi et al. 2008). The exposure depends on parameters such as the particular coastal geography and geomorphology but as well on human encroachment. In particular, African countries are projected to struggle with huge expenditures necessary to avoid or to compensate for damages (Dasgupta et al. 2007). Not all areas or countries in North Africa will be exposed equally; but those with economically important low-lying areas will be affected by sea-level rise (Dasgupta et al. 2007). However, the combination of sea-level rise and human-caused environmental degradation is a highly challenging policy issue. Strategies to deal with potential impacts which could affect coastal sites should be integral part of each country's regional planning. It's important to consider that shoreline and sandy beach erosion and damages to touristic infrastructures caused by sea level rise could lead to financial losses greater than local gains for employment and from tourism revenues in general (UNWTO 2008).

2.2 Morocco

The Kingdom of Morocco is located between the latitudes 27°-36°N and 1°-14°W in the most north-western part of the African continent, with an area of 446.500km^2 (area under exclusion of Western Sahara) and a population of ca. 32,3 million in 2011 (African Development Bank 2012) (Figure 1).

Figure 1: Map of Morocco with country boundaries (own illustration).



A large share of the country is mountainous, with the Rif Mountains in the north-western to the north-eastern Mediterranean region, and the Atlas Mountains spanning from the south-west via the centre to the north-east of the country. The southern part is characterized by the Sahara desert. The climate is mainly arid in the south to semi-arid in the northern parts of the country. Morocco has a coastline of 1.835 km along its western (North Atlantic Ocean) and northern (part of Mediterranean coastline ca. 500 km) margins, where it borders Spain through the Strait of Gibraltar. The eastern part of the country shares a border with Algeria, the southern part includes the Western Sahara, which is occupied by Morocco against recognition of international law. Today, Morocco is administratively subdivided in 16 main regions, its capital is Rabat. The main part of the population concentrates along the urbanized areas at the Atlantic and Mediterranean coastal zones.

The country has an eventful history: first settlements took place ca. in the 2nd millennium BC by the original culture of the Berbers, either as settled farmers or nomads. Since the Arab conquest ca. 800 AD the Islam spread and became the cultural foundation in the region (Sater 2010). During the following centuries different political dynasties presided more or less dependent on the tolerance of Berber leaders. In the 18th century the European interest in the region started to increase and took advantage of a politically unstable situation (Sater 2010). Since 1912 Morocco was under French and Spanish protectorate and gained independence in 1956, except for the two Spanish exclaves Ceuta and Melilla located at the Mediterranean coast. After its independence Morocco became a parliamentarian constitutional monarchy in 1977. Since the enthronement of the Moroccan king Mohammed VI. in 1999, the country is seeking to bring about extensive political, social and economic reforms. The political movements in other MENA countries have also enveloped Morocco; however the political situation is relatively stable. One reason is the rapid policy response towards civil critique by a constitutional referendum in 2011, enacting reforms, including the decentralization of governance and an independent judiciary[14].

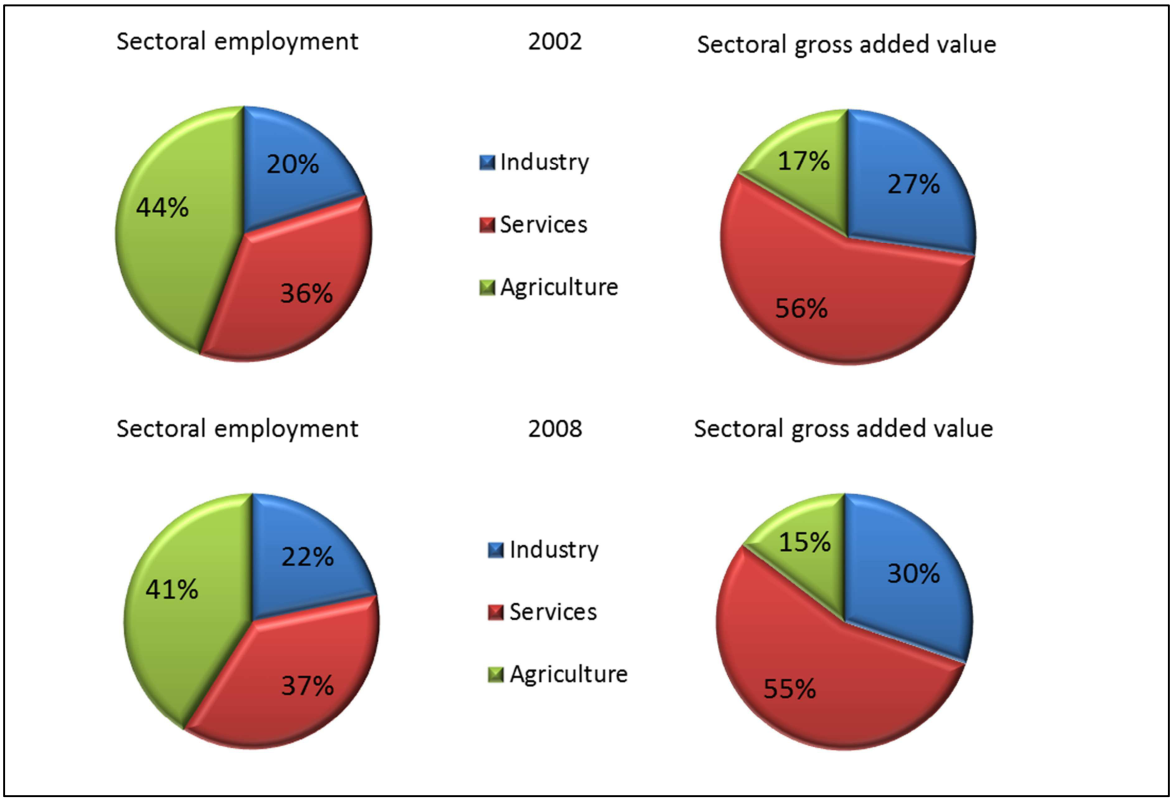
2.2.1 The economic and development context

Economically, the agricultural sector plays a significant role in the Moroccan economy, not in terms of contribution to the national GDP, but as most important sectoral employer

[14] The World Bank, see URL http://www.worldbank.org/en/country/morocco/overview (accessed February 2013).

of working population (Figure 2). As the agricultural sector depends on climate conditions, it is climate sensitive and subject to high year-to-year variations (Figure 3) (African Development Bank 2012). Thus, the GDP is very much affected by the cyclic fluctuations of the agricultural production. Therefore the Moroccan government gives high priority to endeavour a structural transformation towards tertiarization (African Development Bank 2012).

Figure 2: Sectoral share GDP contribution compared to sectoral employment (own illustration on the basis of data from World Bank 2013[15]).

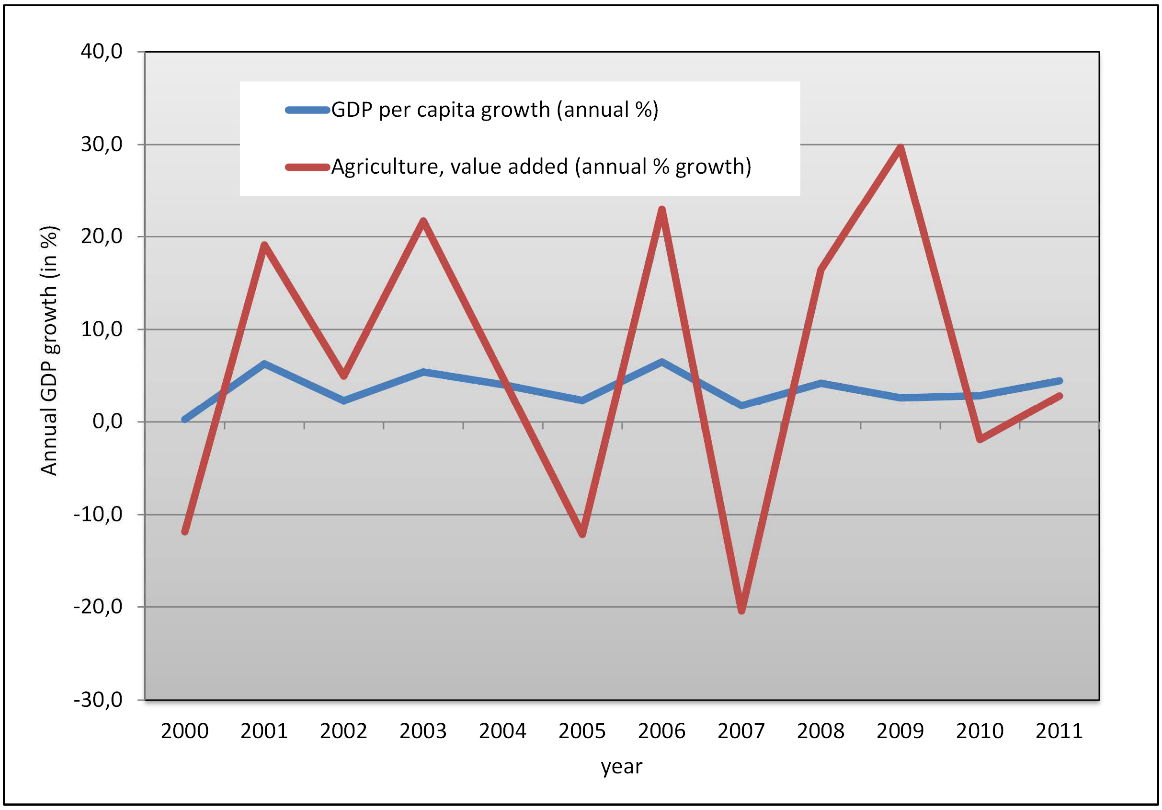


To reduce the structural dependency of the climate sensitive agricultural sector the Moroccan government focuses on the economic diversification by the particular potential-

[15] Data source: World dataBank, World Development Indicators (WDI), see URL http://databank.worldbank.org (last accessed February 2013).

oriented development of regions and the implementation of sectoral strategies, inter alia by attracting private investments (African Development Bank 2012).

Figure 3: Year-to-year variation of agricultural growth compared to the average GDP per capita growth in Morocco (own illustration on the basis of data from World Bank 2013[16]).

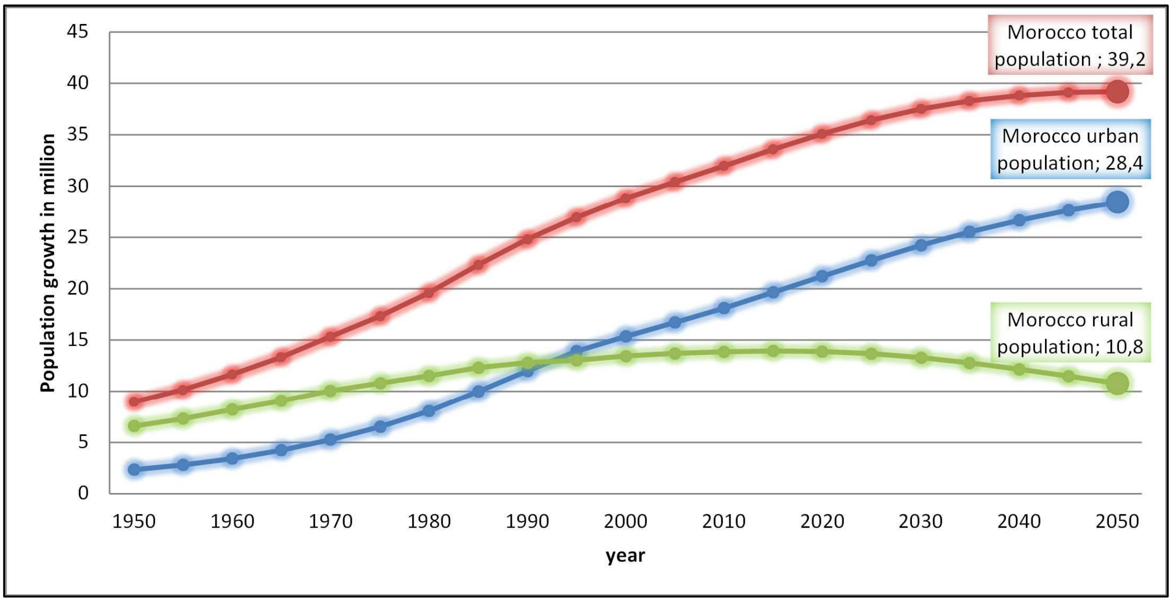


Next to the modernization of key sectors, new regional development processes are induced. Sectoral strategies include agricultural development, a water strategy and a tourism strategy (African Development Bank 2012). The overall aim is to create regional *"development poles*" and to create conditions for a "*balanced development*" (African Development Bank 2012) in particular under consideration of population growth

[16] Data source: World dataBank, World Development Indicators (WDI), see URL http://databank.worldbank.org (last accessed February 2013).

projections (Figure 4). Morocco's population is growing. Internal migration processes enhance urbanization processes, particularly in the coastal areas of the country, leading to the growth, extension and enlargement of cities, which creates major challenges to water management systems in the areas concerned.

Figure 4: Population projections for Morocco: total, urban and rural population development 1950-2050 (own illustration based on the data base of UN Population Division 2011).

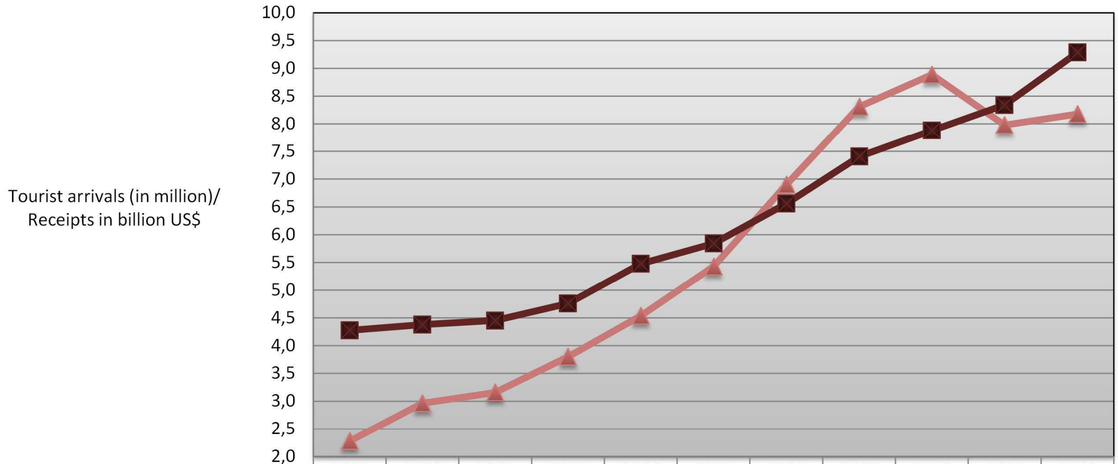


2.2.2 Tourism as economic diversification strategy

However, the economic opportunities of the tourism sector provided the impetus for the Moroccan government to induce an economic diversification strategy to reduce the structural dependency on the agricultural sector and with this to lessen the socio-economic vulnerability to climate change.

The tourism sector is continuously growing (Figure 5). In particular in rural areas, the development of the tourism sector is regarded as a strategy to tackle the still very severe poverty situation (Royaume du Maroc 2008a).

Figure 5: Tourism arrivals and tourism receipts in Morocco 2000-2010 (own illustration on the basis of data from World Bank 2013[17]).



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Tourism receipts (in billion US$)	2,3	3,0	3,2	3,8	4,5	5,4	6,9	8,3	8,9	8,0	8,2
Tourist arrivals (in millions)	4,3	4,4	4,5	4,8	5,5	5,8	6,6	7,4	7,9	8,3	9,3

The development programme, the “Plan Azur/Vision 2010”, concentrates on the establishment of seven large scale luxury tourist destinations located at the country’s Atlantic and Mediterranean coastal zones (Royaume du Maroc 2008a). The overall aim is to raise Morocco to be in the top 25 holiday destinations worldwide until 2010 (Lalou 2011). Further, the “Plan Azur/Vision 2010” intends to create ca. 48.000 new jobs, and thus strengthen the socio-economic development (Royaume du Maroc 2010). All newly constructed tourist destinations include luxury standard facilities, including 5-star hotels and private villas with amenities such as pools, restaurants, spas, large garden areas, golf courses and partly marinas. Luxury tourism is considered to avoid mass tourism from the outset and to set quality standards (Royaume du Maroc 2008a; Roudies 2010). The ambitious plans are only partly realized to date, however, as 2010 has passed, the “Plan Azur/Horizon 2010” is followed by the revised and complementary development plan “Vision/Horizon 2020” (Roudies 2010; Royaume du Maroc 2010). Here, next to the coastal sites currently being established as major tourist destinations, further parts of the country

[17] Ibid.

are to be included in the tourism expansion strategy to raise new bed capacities up to ca. 200.000 by 2020 (Royaume du Maroc 2010). This renewed objective aims to turn tourism into the second most important economic sector of the country, to create 470.000 direct jobs and one million indirect jobs until 2020, to increase revenues from foreign tourism expenditures, and to shift Morocco among the top twenty global holiday destinations (Royaume du Maroc 2010).

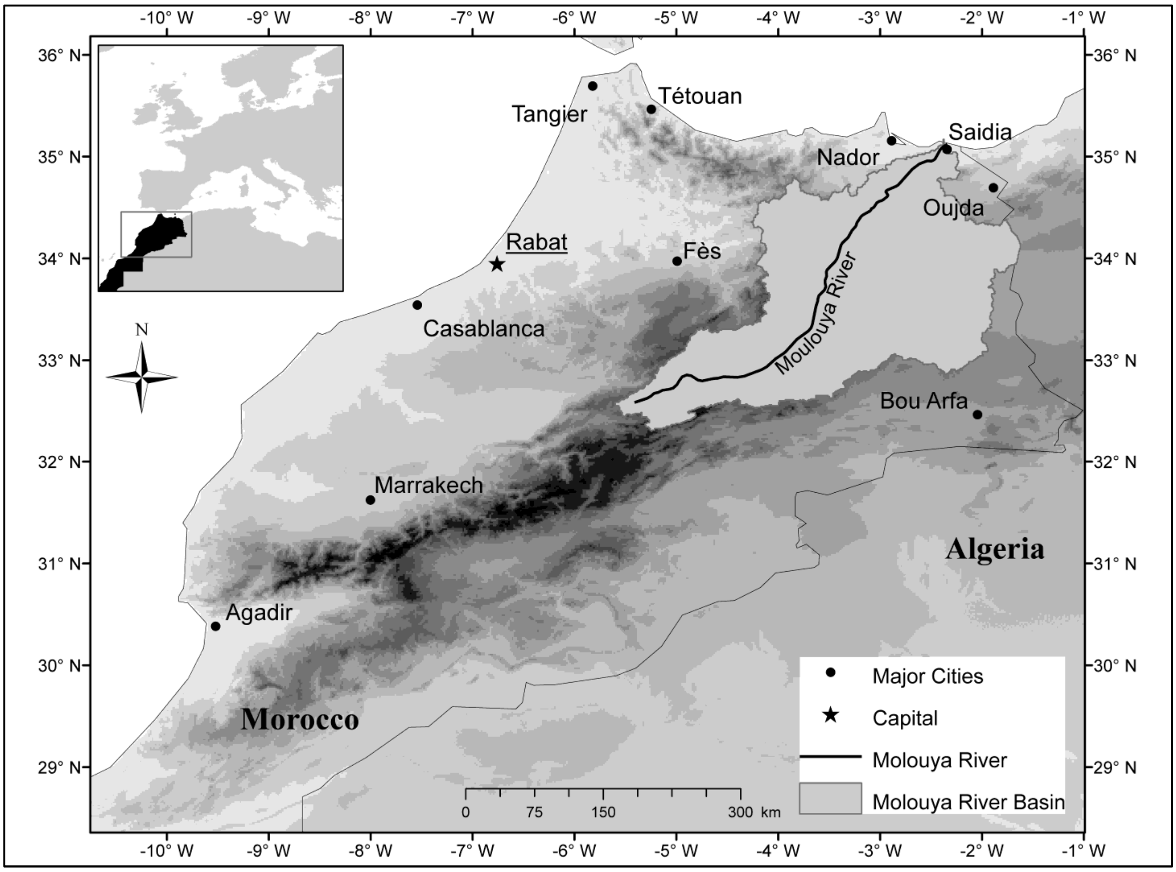
2.3 The Moulouya river basin

The climate analysis and estimates for water availability, demand and supply focus on area of the Moulouya river basin, as it the administrative unit for regional water management (Agence du Bassin Hydraulique de la Moulouya)[18]. Geographically, the Moulouya river basin represents a hydrological unit whose functions determine environmental conditions and human activities from its source in the High Atlas Mountains to its low-lying mouth at the eastern Mediterranean coast of Morocco near the city of Saidia (Figure 6). Located between 35°N|2°W and 32°N|6°W the basin surface area covers ca. 54,000 km^2 and is the largest river basin in North Africa (Snoussi et al. 2002; Snoussi 2004; Melhaoui 2010). The Moulouya river has a length of ca. 600 km and is the second longest African river after the Nile (IUCN 2010). On its way from the spring to the mouth the river overcomes a steep gradient of a height difference of more than 1775 meters (Imassi 2007). Along the rivers' course and its branches, ca. 50 dams have been built since the 1950s to ensure regional all-year water supply for agricultural production (Snoussi et al. 2002; Snoussi 2004; IUCN 2010). Water storage is mainly secured by five major dams with large reservoirs and storage volumes of more than 22 million cubic meters (IUCN 2010). The intention was to support regional development by securing the water supply for agricultural and industrial activities (IUCN 2010). But increasing sediment accumulation and the subsequent loss of storage capacity represents a severe problem for the future functionality of the Moulouya dams (Snoussi et al. 2002; Snoussi 2004). This is one reason for a

[18] See URL: http://www.abhm.ma (last accessed February 2013).

dramatically deteriorating water situation. Further, groundwater resources have already reached capacity limits due to intensive withdrawal and decreasing groundwater recharge rates (Snoussi 2004; Carneiro et al. 2010). In the coastal zones, groundwater degradation caused by saltwater intrusion poses a serious problem for water quality and is a further limitation of freshwater resources (Snoussi 2004; Carneiro et al. 2010).

Figure 6: The Moulouya river basin in north-eastern Morocco (own illustration).



Traditionally, the region’s income derives primarily from agricultural activities. The area of land, which can be used for agriculture amounts to 1.484 km^2, mainly located along the fertile river plains and in the northern part of the basin (Imassi 2007; IUCN 2010). Intensively farmed areas can be found in the northern and low-lying part of the basin, with irrigation schemes of 654 km^2 supplied by river freshwater (gravity and sprinkler irrigation)

(Snoussi et al. 2002; Snoussi 2004). In the southern and rural parts pastoralism is the dominating agricultural activity (IUCN 2010).

2.3.1 Biodiversity hot spot: The RAMSAR site Moulouya river estuary

Since 2005 the River Basin's deltaic plain is a designated RAMSAR site (RAMSAR Convention on Wetlands), emphasizing the ecological importance, its sensitivity to disturbances and its worth to be protected[19]. The area includes 3.000 ha in the estuary and floodplains of the Moulouya river and is of high aesthetic and ecological value[20] (Figure 7). These coastal ecosystems of the Moulouya river mouth are of particular significance for endemic species and their habitats, particularly waterfowl, many of them endangered (IUCN 2010). The area is severely threatened by the loss of biodiversity due to the extension of agricultural activities, disturbances of the hydrological balance and deterioration of the water quality, and further due to ill-planned urbanization and tourism development[21]. The RAMSAR designation is not a legal protection category, the implementation of conservation is on a voluntary basis and reliant on the commitment of signatory countries.

Figure 7: RAMSAR site Moulouya wetland: branch of the river estuary with the Rif Mountains in the background (taken 2009).

[19] See URL: http://www.ramsar.org (last accessed February 2013).

[20] Ibid.

[21] Ibid.

2.3.2 Demographic development

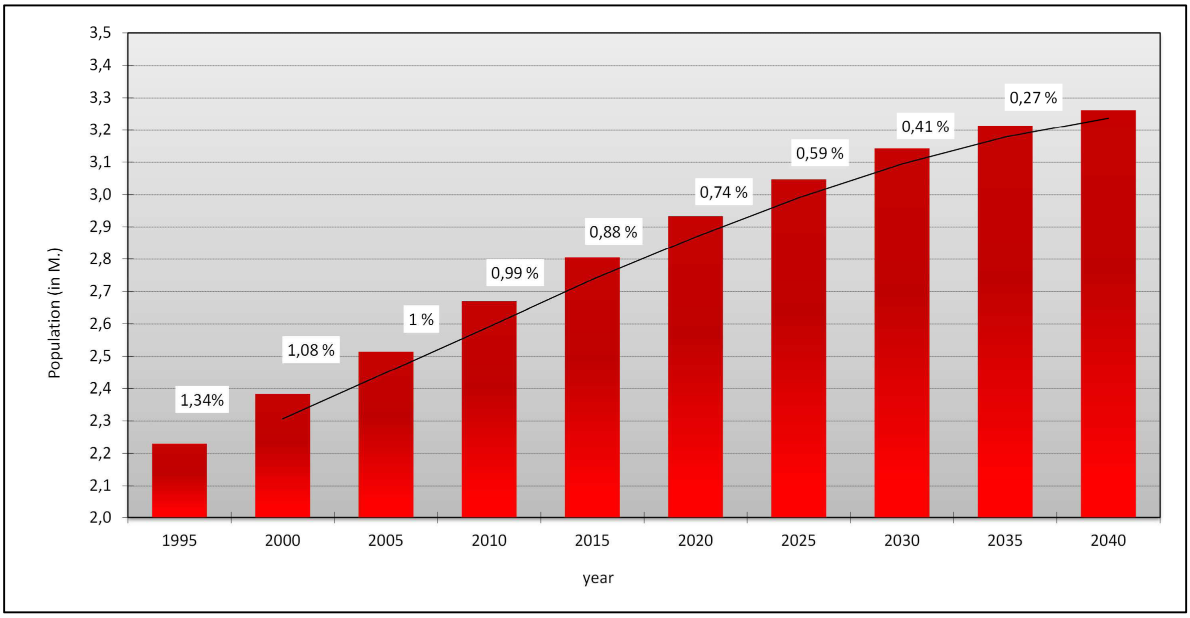
Population growth represents a main driver for water stress, if not accompanied by measures for capacity increase (Sullivan et al. 2002). In the Moulouya river basin, the population is growing, despite an expected slight slowdown of the growth dynamic (Figure 8). Decentralization policies since the 1970ies have contributed to internal migration processes with direction to the growth poles of rural provinces instead of migrating to the big cities, mainly smaller or medium-sized towns (de Haas 2005). In north-eastern Morocco, in particular the urban areas in the province of Nador are experiencing a remarkable population increase (Table 2).

Table 2: Urbanisation trend in the province Nador, north-eastern Morocco 1994/2004 (Royaume du Maroc 2005).

Province of Nador	Total population (2004)	Population change (1994/2004)
Urban population	369 102	+ 49,8%
Rural population	359 532	- 17,9%

A further population increase is expected due to hinterland migration towards the urbanizing coastal areas due to employment opportunities in the growing tourism sector. Even under a deceleration of population growth, the region will have to supply a considerable amount of additional water consumers in particular in urban areas, which are mainly located in the near coastal areas. With this, the geographical relocation of water demand has implications for the water supply and requires the adaptation of water infrastructures. Population growth and increasing land use add pressure on existing water resources, which show already strong degradation symptoms, mainly caused by unorganized dwelling, and lavish irrigation (Snoussi et al. 2008).

Figure 8: Population projections for the Moulouya river basin 1995–2040. Values in bars refer to the potential population in the respective 5-year segments based on the UN population growth rate for Morocco (own calculations and illustration based on data of UN Population Division 2011).



2.3.3 Economic context and tourism development

Since recently, the Moroccan government strives to achieve short-term economic growth and long-term economic development in peripheral areas of the country (Royaume du Maroc 2010; Spilanis et al. 2012). This catch-up process of development of structurally weak regions aims to strengthen the economic performance, to alleviate rural poverty, but as well to contribute to sectoral diversification of the national economy. The focus in north-eastern Morocco has been on agricultural production, however. Development opportunities in this sector are very limited due to unfavourable climate conditions.

Tourism is considered to be a promising sector to facilitate regional development, mainly due to the expected beneficial effects on direct and indirect income (Spilanis et al. 2011). Tourism has enhanced economic growth, regional development, and led to an increase and the diversification of regional employment in many other Mediterranean countries (Klein et al. 2004; Katircioglu 2009; Belloumi 2010).

One out of the seven coastal tourist destinations, “*Saïdia Mediterránea*”[22], listed in the “Plan Azur/Vision 2010” is located in the most north-eastern Mediterranean part of Morocco, in the low-lying coastal zone between the deltaic plain of the Moulouya river and the city of Saidia, at the border of Algeria. The coastal zone has suitable beaches and a unique natural environment. Located in short distance tourist facilities covering an area of 713 ha have been constructed close to the beach area (stretches over 14 km), including 5-star hotels, golf courses, pool areas, private villas, a marina and beach promenades. The concept aims to achieve a capacity of 27.000 hotel beds and private accommodation for national and international clientele (Royaume du Maroc 2008a, 2010; Roudies 2010) (Figure 9).

Figure 9: Construction site *Saïdia Mediterránea* in the coastal zone near the Moulouya RAMSAR wetlands close to the city of Saidia (pictures taken in 2008).

2.3.4 *The regional water situation*

Groundwater resources in the Moulouya basin have already reached physical capacity limits due to intensive withdrawal and decreasing groundwater recharge rates (Snoussi 2004; Carneiro et al. 2010). Additionally, in the coastal zones, groundwater salinization due

[22] See URL: http://www.marocainsdumonde.gov.ma/media/27444/les_plans%20strategiques.pdf (last accessed February 2013).

to sea water intrusion poses a serious problem for water quality (Snoussi 2004; Carneiro et al. 2010). The per capita water availability falls below the benchmark of 500 m^3 per capita/year, an indicator for absolute water scarcity and a severe constraint to human life and health, as set out in the Falkenmark Water Stress Index (Falkenmark 1989). The hydrological balance in the region is already critical due to the strong increase of water demand caused by regional population growth and the extension of water intensive human activities (Andreo and Duran 2008; Fetouani et al. 2008; Snoussi et al. 2008).

Impacts resulting from an increasing water scarcity are predominantly felt in highly populated areas. Those are located along the fertile river plains, in the coastal hinterland areas and in the coastal zones. Two-third of the population in the River Basin lives in the area between Nador and Oujda, close to the Mediterranean See (IUCN 2010).

A major problem the region has to cope with is the aggravating water scarcity situation (Tekken and Kropp 2012). The regional water balance is increasingly under pressure not only by decreasing precipitation amounts and a high interannnual precipitation variability, but as well due to the significant reduction of groundwater recharge rates (Moustadraf et al. 2008; Döll 2009). If this observed trend continues, reduced rainfall will severely aggravate the regional freshwater deficit (Anfuso and Nachite 2011). Still, water withdrawals are the major source of freshwater in Morocco (Benoit and Comeau 2005). But despite steadily increasing demands and alarming signals of overexploitation, water policies, planning and management focus mainly on opportunities to enhance withdrawals (Benoit and Comeau 2005). The amounts of produced water from non-conventional resources or wastewater reuse are still negligible (Benoit and Comeau 2005). Current development trajectories, focusing on coastal tourism development, will lead to population growth and thus further enhance pressures on natural resources, in particular on water. Sufficient water availability is the key requirement for the implementation of regional development plans. Large-scale luxury tourism is water-intense and will contribute to rising regional water demand. Continuous water supply must be guaranteed; water shortfalls will not be tolerated at high-level tourism sites. At the moment, the regional water demand-supply-ratio is balanced, with little scope for an additional water consumer. Thus, at the one hand the tourism sector needs to adapt to a chronic water deficit situation, and on the other hand it contributes to it. However, tourism at the coastline of north-eastern Morocco is a growing sector and has a paramount role for socio-economic development (Anfuso and Nachite 2011). Thus, it is all the more important to develop sustainable management strategies that account for the particular local vulnerability of tourism to climate change and sea level rise (Jones and Phillips 2011).

2.3.5 Regional climate characteristics

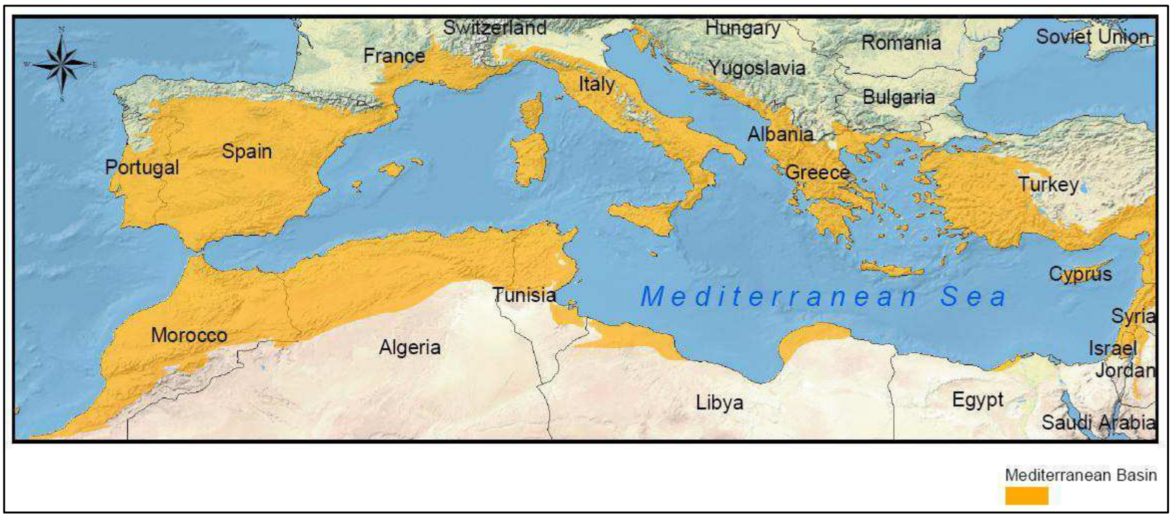
The Moulouya basin belongs to the driest regions in Morocco with an irregular average annual rainfall, and different climates along its course, varying from a very arid, or montane climate towards a Mediterranean climate in the north (IUCN 2010). The climate regime can be classified semi-arid and Csa[23] after Köppen: warm temperate climate with winter precipitation and hot and dry summers (Köppen 1936). The low-lying area is characterized by mild, wet winters and dry summers, and subject to high inter-annual precipitation variability (Bolle 2003). In average, the wet season starts in October and ends in March (Xoplaki et al. 2004; Luterbacher et al. 2006). The area is part of the larger Mediterranean basin (Figure 10), a region that identified as one of the global *"hot spots"* of climate change, particularly due the regional increase of mean temperatures and observed lower levels of precipitation over the last decades (Giorgi 2006; Xoplaki et al. 2006). Since the second half of the 20th century precipitation shows a general downwards trend, thus reflected in increasing drought conditions in many areas (Xoplaki et al. 2004). Regional precipitation averages from a set of 21 global models for the A1B[24] scenario used in the IPCC's regional

[23] The climate classification after Köppen (1936) is based on threshold values for temperature and precipitation and annual distribution of precipitation. Köppen classified 5 types of main global climate zones with 13 specified climate types and further climate sub-types. Csa climate stands for "C" (warm temperate climate), "s" means summer dry and "a" stands for hot summers with the warmest month > 22°C. Csa climates receive precipitation mainly during the winter season.

[24] IPCC emission scenarios (SRES – Special Report on Emission scenarios) describe potential development pathways relevant for future climate change under inclusion of human behaviour. Each of four "storylines (A1, A2, B1, B2) contains different assumptions regarding the development of economy, governance and technologies under both a regional or environmental emphasis. Hence the share and potential impact of anthropogenic CO2 emissions can be derived as a baseline for adequate mitigation policies.

climate projections for southern Europe and the Mediterranean Basin (30°N/10°W to 48°N/40°E) show significant modifications: a decrease of mean precipitation up to 20 % is assumed to be *"very likely"* (IPCC 2007a) based on the SRES A1B emissions scenario 2080-2099 with the reference period 1980-1999 for North Africa (Christensen et al. 2007). Climate change is likely to produce more frequent and longer droughts in the Mediterranean region (Lloret et. al 2000). Consistent across these multi-model projections and classified as *"very likely"* is the increase in length and frequency of dry spells; classified as *"likely"* is the risk of drought due to a *"consistent change in precipitation"* (Christensen et al. 2007).

Figure 10: The Mediterranean Basin in Europe and bordering countries (own illustration).



In the Moulouya river basin trends in climate patterns are observable (Figure 11). Seasonality is an important parameter for regional water availability in semi-arid regions, where winter rainfall is essential for the annual water budget. Seasonal modifications that lead to dryer conditions in the rainfall season thus have severe consequences for the hydrological situation, e.g. decreasing groundwater recharge and freshwater availability. Shifting climate patterns can also be a signal for the increase of extreme conditions, such as a higher frequency of occurrence of hydrological droughts or torrential precipitation and river floods. In the Moulouya basin the overall water demand, in particular in the dry summer months (JJA)[25], has to be supplied from stored and accumulated autumn (SON) and winter (DJF) rainfall stored in dams along the Moulouya River. The agricultural sector depends on rainfall in the crop growing season, it provides the basis for the agricultural cycle, mostly beginning in autumn and ending in spring. A decrease of rainfall thus either leads to yield losses or the increasing demand for irrigation water. Under the current water situation irrigation water does not suffice to meet the additional demand. Further, crop harvesting takes place in spring (MAM), the increase of wet events and at also increasing dryness would be harmful for agriculturally managed areas.

Seasonal precipitation (measured in annual means of the long-term and in separated data periods that span 35 years, respectively) in the Moulouya basin shows long-term decreases in particular in the winter-relevant autumn (SON) and winter season (DJF) (Figure 11). Taken the standard deviation (σ= standard variation, statistical variance) as indicator for climate variability, the respective decreases in both seasons point towards a stabilizing situation, which is a worsening trend regarding the impact on water accumulation. The situation in spring does not show significant modification over the long-term. The summer season is getting wetter, however, the very small amounts of the precipitation sum in summer cannot compensate for the losses in the colder annual period. Further, as temperatures are increasing at the same time, the additional amounts will be lost due to an increasing evapotranspiration[26]. Temperatures in the Moulouya basin have been increasing during the 20th century seasonally mostly pronounced in spring, summer and autumn (Figure 9). The standard deviation remains relatively constant, pointing towards a stabilizing situation. Increasing temperatures can cause the enhancement of evapotranspiration rates. Precipitation is not equal to later water availability from run-off or groundwater. The influence of temperature on evapotranspiration is assumed to be detrimental for the regional climate situation in the overall Moulouya river basin.

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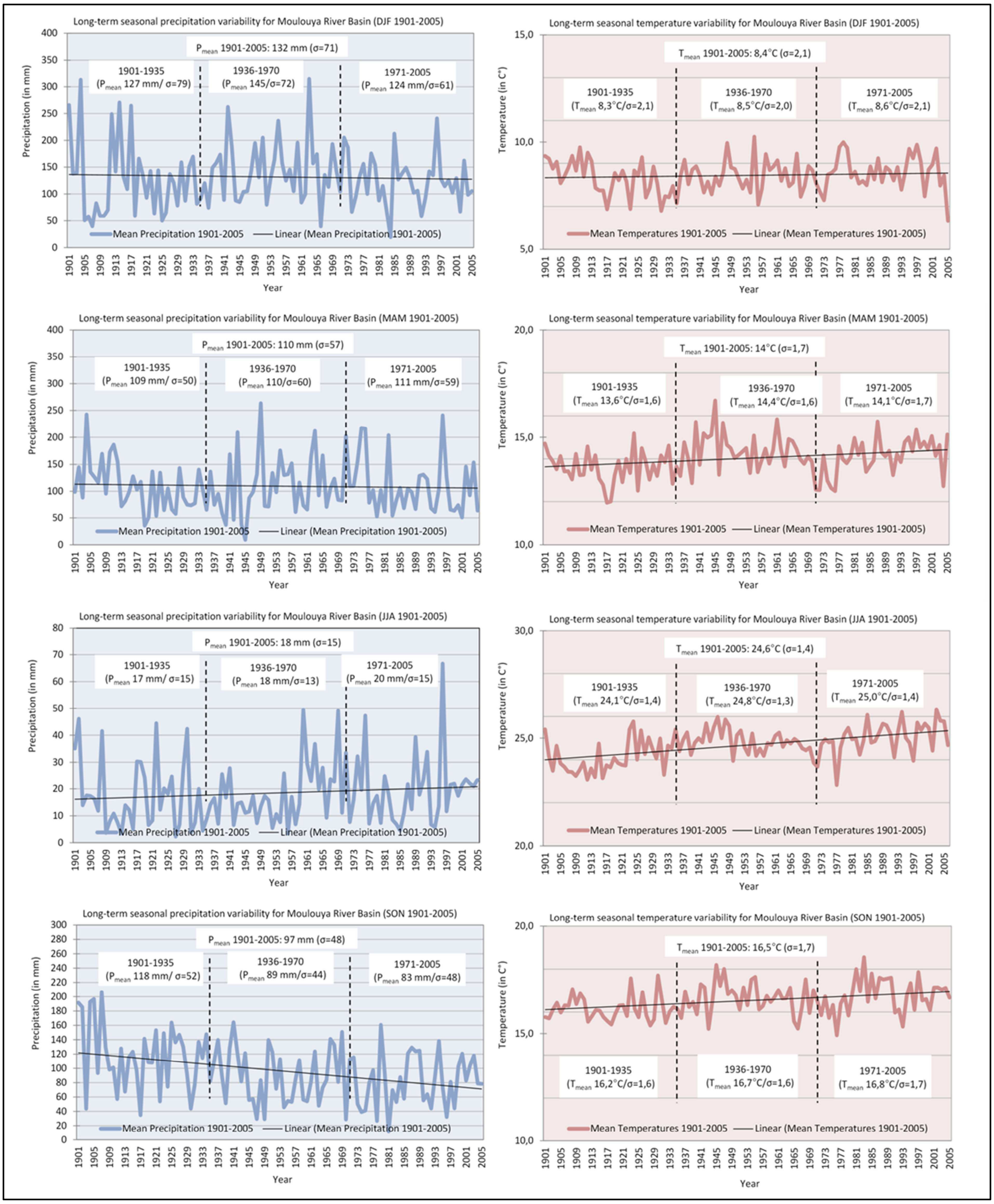
[25] Seasonal acronyms for the respective months of the seasonal analysis of climate variability: DJF (December, January, February - winter), MAM (March, April, May- spring), JJA (June, July, August - summer), SON (September, October, November - autumn).

[26] Definition of evapotranspiration: *"The combined process of water evaporation from the Earth's surface and transpiration from vegetation"* (IPCC 2007).

Figure 11: Long-term climate variability in the Moulouya river basin 1901-2005 and periodical characteristics: annual and seasonal precipitation and temperatures (own illustration based on the long-term climate record from CRU TS.2.1, New et al. 2002; Österle et al. 2003).



On a sub-basin scale, trends for precipitation and temperatures in the Moulouya river basin for 1971-2005 (with reference period 1936-1970) indicate increasing drought situations (Figures 12a and 12b).

For precipitation a comprehensive decrease is observed in the whole basin; but seasonally pronounced in winter (DJF) and autumn (SON) (Figure 12a). In particular the north-eastern part of the basin underwent a strong decline of precipitation, which is critical, as this area represents the most productive and intensively managed agricultural region, where rainfall is already insufficient (Fetouani et al. 2008, Snoussi 2004). A further decrease will enhance agricultural irrigation needs and freshwater demand from stored river waters. Groundwater accumulation in the rivers drainage area might be harmed as well, as in the upper course of the river precipitation decreases are observed as well (DJF and SON). The summer season (JJA) shows precipitation increases (+12 % compared to 1936-1970) in the south-western areas. However, decreases are observed as well in the north-east. Further, summer precipitation is comparatively small in amounts, and cannot substantially contribute to the overall water budget (also caused by evapotranspiration as described above). In spring precipitation sums, except for declines in the north-eastern parts, do not noticeably change (+2 %). In general, precipitation variability decreases basin-wide, but mostly in north-eastern areas, thus signalling a stabilizing aggravating trend towards drought.

Temperature increase is assumed to be a drought-causing parameter, in particular if under simultaneously occurrence with precipitation decrease. Modifications of mean local temperatures and temperature variability show only little variation for winter, summer and autumn on the scale of the entire basin (ca.+ 0,1°C), but large increases in temperature variability (DJF: +15 %; JJA: +44 %; SON: +11 %) (Figure 12b). The spring is getting cooler, in average by ca. -0,3°C. Comparable to the precipitation trends local temperature increases are mainly occurring in the north-eastern part of the basin.

To conclude, recent climate trends in the overall basin point towards an aggravating climate situation, with an enhanced trend towards precipitation reductions and drought. As

Figure 12a: Sub-regional precipitation change and variability for 1971-2005 (ref. period 1936-1970) in Moulouya river basin (own illustration based on the climate record from CRU TS.2.1, New et al. 2002; Österle et al. 2003).

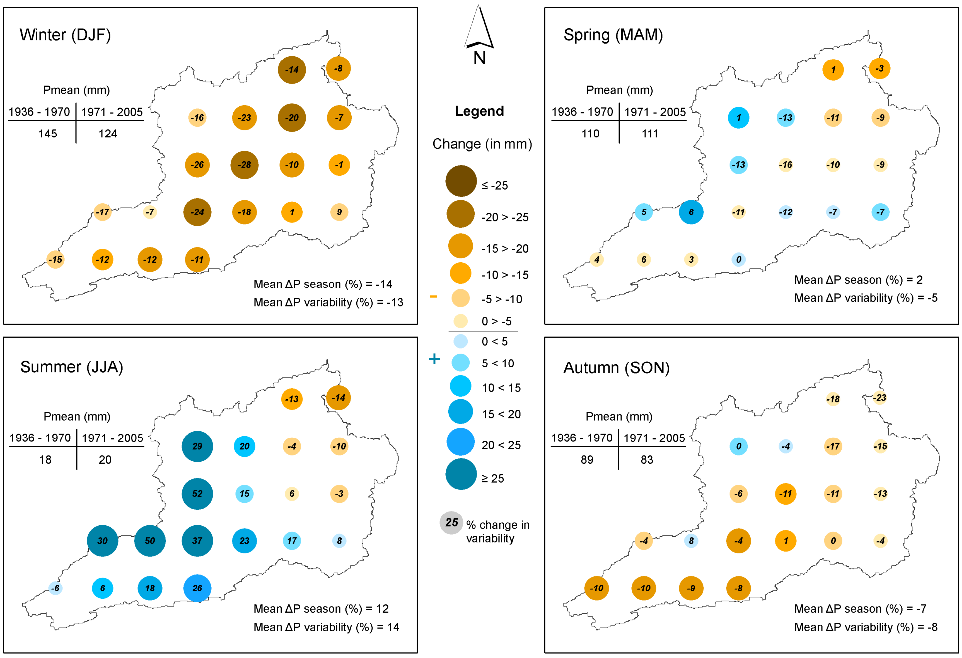
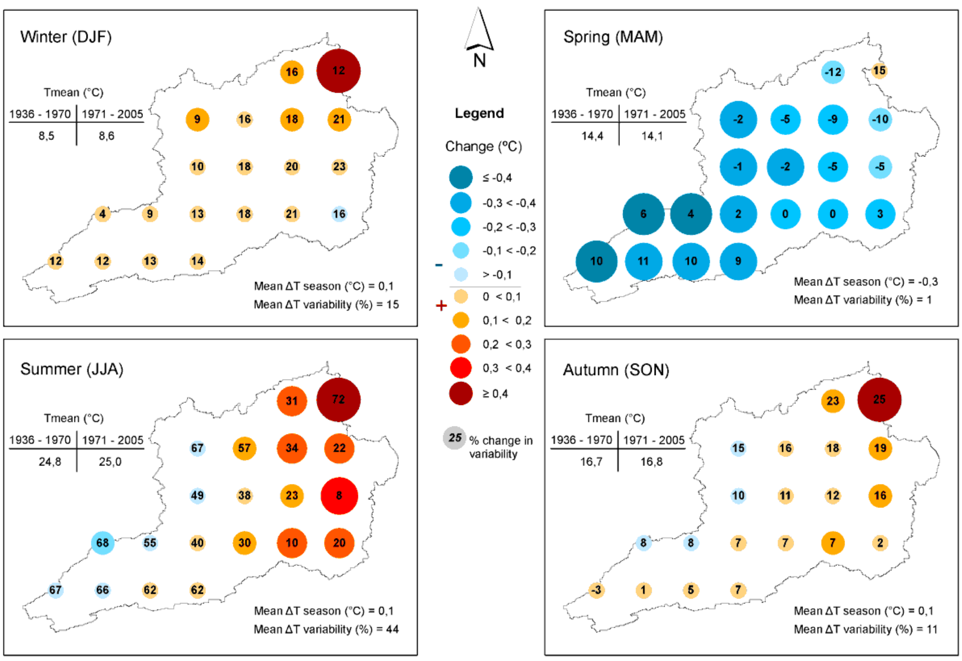


Figure 12b: Sub-regional temperature change and variability for 1971-2005 (ref. period 1936-1970) in Moulouya river basin (own illustration based on the climate record from CRU TS.2.1, New et al. 2002; Österle et al. 2003).



regards changes in mean temperatures, hot-spots of warming (≥ + 0,4°C) are detected mainly in the north-eastern parts of the Basin. Here, where increasing temperatures correlate with decreasing precipitation drought might occur more frequently.

If detected trends reflect the future situation of climate conditions, a permanent water shortage situation will be the result given the very likely increase of regional water demand. The sustained drying represents a severe risk for rain-fed but as well for irrigated agriculture. Hence, the economic dependency on agriculture makes this region very vulnerable to changing climate pattern (Fetouani et al. 2008, Snoussi 2004). The situation is even aggravated by the increasingly inadequate water storage infrastructures, not able to cope with the high sedimentation rates of Moulouya river dams (Snoussi et al. 2002). For example, the biggest surface water reservoir of the Moulouya river, Mohammed V. with an initial storage capacity of 730 million m^3 and operational since 1967, has experienced a loss of storage capacity of ca. 35 % between 1976 and 1991 (Lahlou 1996). The dam is located 70 km from the Mediterranean Sea and supplies drinking water for the coastal cities Nador, Berkane and the tourism zone in Saidia; it delivers water for regional agricultural production, and produces electricity by a hydroelectric plant (IUCN 2010). The water supply in particular in the lower Moulouya region is thus severely at risk due to the further increasing drought situation and dam sedimentation as a result of inter alia increasing aridity and wind erosion (IUCN 2010).

3 Conceptual framework

With a focus on the Moulouya Basin in north-eastern Morocco, one aim of this thesis is to provide information on the causal factors of regional vulnerability to water stress. The concept of vulnerability to climate change underlies the research conducted in this thesis to analyse and describe the regional stresses. Vulnerability-reducing recommendations are formulated taking into account vulnerability-creating human activities in order to support the necessary adaptation in the region.

3.1 Concept, definitions and assessments of vulnerability to climate change

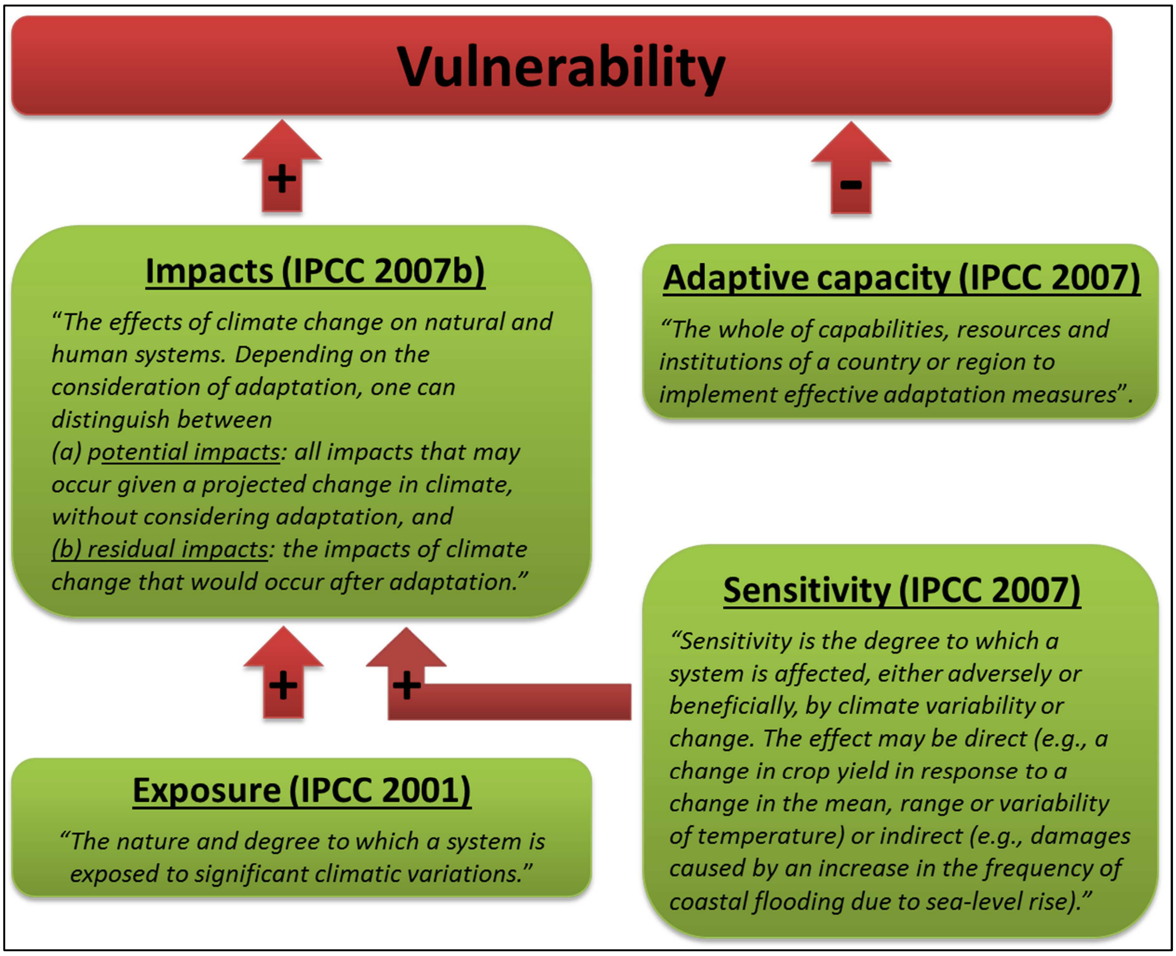
The term ‘vulnerability’ has become a central concept in many climate-related research contexts (Füssel 2007), and refers to *“the degree, to which a system, subsystem, or system component is likely to experience harm due to exposure to a hazard, either a perturbation or stress/stressor”* (Turner et al. 2003).

In the context of climate change adaptation, it is important to understand the underlying causes of vulnerability. Different vulnerability definitions and concepts have been developed (Füssel and Klein 2006). The most prominent concept in the context of global change and climate change research is defined in the IPCC Forth Assessment Report, and describes vulnerability as a ‘function of exposure, sensitivity, and adaptive capacity’ (McCarthy et al. 2001; Brooks 2003; Turner et al. 2003; O’Brien et al 2004; Füssel and Klein 2006; IPCC 2007b; O’Brien et al. 2008) (Figure 13).

Under this conceptualisation, socio-ecological systems are exposed to external changes or stressors; however, the extent of vulnerability of affected people, groups or societies depends on their capacity to react or to adapt to theses stresses.

A multitude of different approaches exist to conceptualize vulnerability, but the diversity of underlying contexts of systems exposed makes it difficult to delineate a generally applicable framework (Füssel and Klein 2006; Füssel 2007).

Figure 13: Components and definitions of the Vulnerability framework (own illustration based on definitions from IPCC 2001, IPCC 2007 and IPCC 2007b).



However, vulnerability assessments are a *"conceptual cluster"* for integrative human-environment research (Füssel 2007). Most vulnerability assessments focus on a context-relevant scale, to being able to deliver tangible information for decision-makers or stakeholders. The motivation to conduct a vulnerability assessment depends on different contexts and interests of stakeholders (Füssel 2006). Füssel (2006) differentiates three major contexts: the (i) "*specification of long-term targets for the mitigation of global change*"; the (ii) *"identification of particularly vulnerable regions and/or groups in society to prioritize resource allocation for research and for adaptation*"; and the (iii) "*recommendation of adaptation measures for specific regions and sectors*".

Vulnerability assessments allow identifying climate-induced regional, local or sectoral risks (Füssel and Klein 2006). The results aim to inform respective policies, and to integrate climate change with other stresses on the environment or human populations. This corresponds to stakeholder demands for science-driven assessments to estimate potential impacts (Füssel and Klein 2006). Policy responses are needed either to mitigate, to lessen greenhouse gas emissions, or/and to adapt to climate change to lessen the adverse impacts *"through a wide range of actions that are targeted at the vulnerable system or population"* (Füssel 2006). Since climate change is one out of multiple drivers for vulnerability, assessments should target an integrated approach and thus differentiate between human- and climate-induced risks (Turner et al. 2003; O'Brien et al. 2009).

Vulnerability assessments also support the identification of potential hot spots, where adaptation might become necessary. Thus, they assessments are supportive tools to evaluate the particular vulnerability of people and places under environmental and social pressures and represent the basis for adaptation (Luers 2005). Further, vulnerability assessments can assist planners to develop anticipating strategies to avoid unmanageable situations (Schellnhuber et al. 2006).

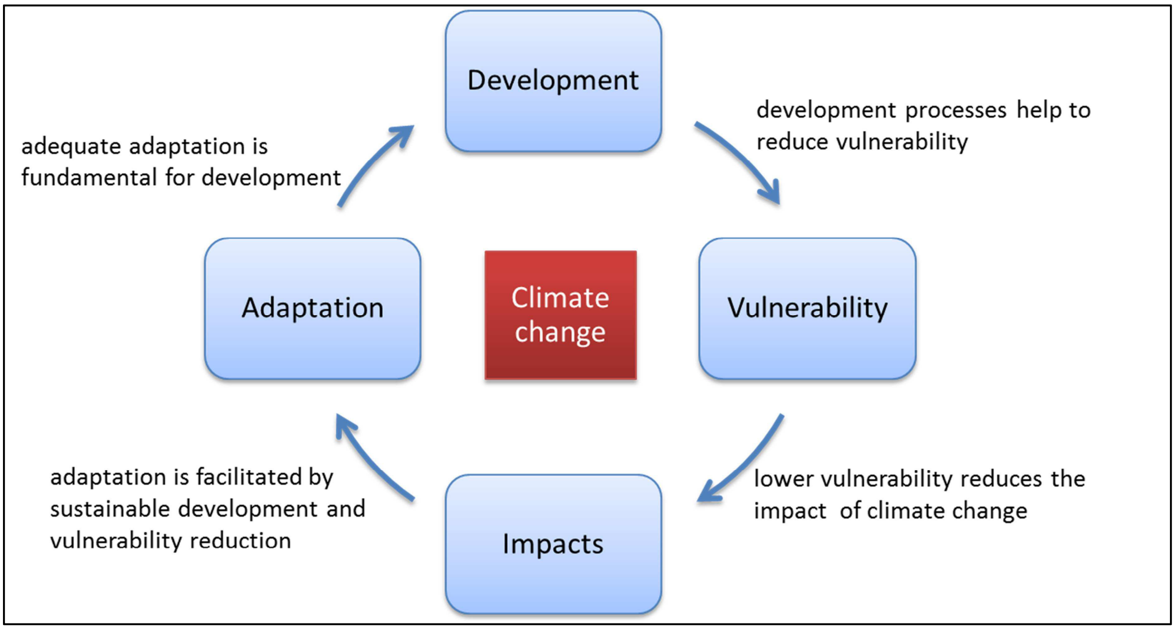
3.2 Socio-economic vulnerability, adaptive capacity and adaptation

In its Second Assessment Report (SAR), published in 1996, the Intergovernmental Panel on Climate Change (IPCC) addressed the challenges of the socio-economic dimension of vulnerability to climate change (IPCC 1996). Here, vulnerability is defined as "*the extent to which climate change may damage or harm a system"*, but vulnerability does not only "*depend [...] on a system's sensitivity, but also on its ability to adapt to new climatic conditions"* (Watson et al. 1996). The former mainstream research perspective of vulnerability that is referring to the inherent systems vulnerability without external stressors is thus extended by the social component (Watson et al. 1996). Füssel and Klein (2006) later defined vulnerability to climate change as "*the degree to which geophysical, biological and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change".*

The vulnerability of a region depends on its level of socio-economic development and its institutional capacities to adapt, and on its sensitivity or exposure to climate change (Watson et al. 1996). Developing countries are likely to be hit hardest by climate change, as their capacities to adapt are lowest (Watson et al. 1996). Adaptive capacity is defined as *"the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences"* (IPCC 2007b) or from an institutional point of view as the *„whole of capabilities, resources and institutions of a country or region to implement effective adaptation measures*" (IPCC 2007). Developing countries have a limited capacity to cope with additional pressures, thus undermining growth opportunities (Dasgupta and Baschieri 2010). In recent years research on adaptation to climate change has gained much importance in the context of designing (sustainable) development pathways in developing countries (Burton et al. 2002). An extensive portfolio of case studies examines associated impacts, risks and vulnerabilities; many emphasize an urgent need regarding sectoral adaptation. Many developing countries already face severe socio-economic problems due to environmental degradation (Sowers et al. 2011; Adger et al. 2003). Knowledge on climate-caused exposures threatening environments and socio-economic systems is constantly growing (Hare et al. 2011), and with it the awareness that climate change must be considered as an important component in the design of environmental management and policies, particularly in countries with high exposure. The importance of adaptation in developing countries has gained considerable attention, as vulnerability to climate change is closely related to poverty, as the *"poor are least able to respond to climatic stimuli"* (Burton 1997). In this context Adger (2000) defines social vulnerability as "*the exposure of groups of people or individuals to stress as a result of the impacts of environmental change including climate change".* Developing countries should focus on current problems and not on the *"distant future"* to agree on their particular vulnerabilities, thus due to uncertainties regarding climate development and further due to the need to tackle the underlying root causes (Burton 1997).

Most vulnerability assessments focus on a context-relevant scale, to being able to deliver tangible information for decision-makers or stakeholders. For successful adaptation to climate change the underlying causes of vulnerability need to be addressed to contribute to development. However, if adaptation exclusively addresses climate change, specific impacts might be reduced but not the vulnerability-causing factors (Schipper 2007). In many developing countries existing social vulnerability is a result of both the unsustainable use of resources and development pressures, thus exacerbated but not primarily caused by climate change (Schipper 2007). The reduction of these existing pressures represents a necessary prerequisite for adaptation to climate change (Schipper 2007). Vulnerability reduction implies to reconsider and to modernize or to adapt resource management to address both, human-caused and climate-caused pressures (Schipper 2007). Adaptation to climate change will be facilitated if vulnerability can be reduced (Figure 14).

Figure 14: Vulnerability reduction framework (own illustration based on Schipper 2007).



Vulnerability determines adaptive capacity; therefore it is essential to view vulnerability as a starting point for analysis (O'Brien et al. 2004). Adaptations are manifestations of adaptive capacity and they represent ways of reducing vulnerability (Smit and Wandel

2006). Adaptation thus refers to the *"adjustment in natural or systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities"* (IPCC 2007). The following types of adaptation can be distinguished:

(i) *"anticipatory or proactive adaptation – takes place before impacts of climate change are observed";*

(ii) *"autonomous or spontaneous adaptation - does not constitute a conscious response to climatic stimuli but is triggered by ecological changes in natural systems and by market or welfare changes inhuman systems;*

(iii) *"planned adaptation - is the result of a deliberate policy decision, based on an awareness that conditions have changed or are about to change and that action is required to return to, maintain, or achieve a desired state*" (IPCC 2007).

3.3 Water scarcity[27]

Globally, population and economic growth lead to increasing water demand (Arnell 2004). Water resources are sensitive to climate variation, as they are involved in all components of the climate system: in the "*atmosphere, hydrosphere, cryosphere, land surface and biosphere"* (Bates et al. 2008). Observed changes in the last decades provide evidence that the future availability of water resources will be strongly impacted with harming consequences for human societies and ecosystems (Bates et al. 2008.)

The consideration and assessment of the human impact on freshwater resources, the non-climatic drivers, is an emerging question (Vörösmarty et al. 2000; Bates et al. 2008). The rapidly accelerating exploitation of natural water resources caused by population growth, the intensification of agricultural production, and changing lifestyles associated with an increase of consumption represent the key reasons to cause severe environmental degradation (García-Ruiz et al. 2011; Sowers et al. 2011; Bogardi et al. 2012). Increasingly,

[27] Text passages of this chapter are partly derived from chapter 2 in: Tekken, V. and Kropp, J.P. (2012): Climate-driven or human-induced: Indicating severe water scarcity in the Moulouya river basin (Morocco). *WATER* 4(4), 959-982.

in recent decades, water resources have reached or already exceeded physical limits in many locations worldwide due to steadily increasing consumption rates (Molden 2007; Alcamo et al. 2008; Bates et al. 2008). Already in 1995, more than one billion people lived in water stressed watershed (Arnell 2004). This number is estimated to increase significantly in the coming decades (Bates et al. 2008). Respective scenarios range significantly, however, until 2050 the amount of population living with a maximum per capita renewable water resource of less than 1.000 m^3 could transgress a threshold of more than 6 billion (Bates et al. 2008 referring to Arnell 2004 and Alcamo et al. 2007). Vulnerability thus depends not only on climate change but in particular on an adequate water management of scarce resources under growing pressures.

A commonly accepted definition on water scarcity does not exist (Rijsberman 2006). Rijsbermann (2006) describes water scarcity as follows: "*When an individual does not have access to safe and affordable water to satisfy her or his needs for drinking, washing or their livelihoods we call that person water insecure. When a large number of people in an area are water insecure for a significant period of time, then we can call that area water scarce."* Water scarcity in this sense depends of the "*defined"* and "*satisfied needs of people*", if environmental water needs are taken into account, on the amount of water that "*is made available*" and *"temporal and spatial scales*" (Rijsberman 2006).

White (2012) defines water scarcity *„as the lack of access to adequate quantities of water for human and environmental uses*". However, the true nature of water scarcity is as complex as the physical flows and dynamics of the resource itself (Rijsberman 2006). Global freshwater scarcity induced by rapidly increasing demand requires solutions, thus representing a particular challenge for science and water governance (Hoekstra et al. 2012).

Mainly since the past two decades, different approaches have been concerned with the capturing of relevant aspects of pressures on water resources and with the characterization and measurement of water scarcity (Savenije 2000; White 2012). The description of water scarcity by using more or less complex indicators involves difficulties and uncertainties, thus there is no consensus on a standardized measurement White (2012).

A particular weakness of current indicators is the focus on water withdrawal instead of actual water consumption (Hoekstra 2002). Further, many indicators do not include environmental flow requirements and temporal variation. Thus, they are not comprehensive tools for the assessment of water scarcity situations, but, however, support the indication of disequilibrium of water abstraction and water availability.

The most common approaches are the Falkenmark Water Stress Index (Falkenmark 1989), the Social Water Stress Index (SWSI) (Ohlsson 2000), and the Water Resources Vulnerability Index (Criticality Ratio) (Alcamo et al. 2000), the Physical and Economical Scarcity Indicators (Molden 2007), and the Water Poverty Index (Sullivan et al. 2003) (see Table 3 for a comparison of the approaches).

The original concept, the Falkenmark Index from 1989, concentrated solely on blue water[28] availability, leaving aside green water (Rijsberman 2006). The Falkenmark Index is often criticized for being too simplistic, as:

- It does not differentiate between countries regarding their specific water stress thresholds (one country might be able to handle a 500 m^3 per capita annual availability; another might be experiencing severe water problems at that level);
- It focuses on natural freshwater availability only and does not include man-made freshwater sources (e.g., desalinization) or the accessibility of water;
- It does not consider regional differences of the water use of countries (e.g., urban areas often have higher consumption rates than rural areas) (Molden 2007; Rijsberman 2006; White 2012; Savenije 2000; Gleick et al. 2002; Brown and Matlock 2011) .

However, Falkenmark et al. (1989) added the social perspective of water resource vulnerability to current approaches addressing the challenges of water management under increasing pressure.

[28] 'Blue water' refers to the amount of rainfall directly exceeding the soil's storage capacity forming the total surface water runoff groundwater recharge, equivalent to the natural water resources (Falkenmark et al. 1995).

Table 3: Comparison of most popular approaches to measure water scarcity (based on Rijsberman 2006, Gleick et al. 2002, and Brown and Matlock 2011).

Index	Approach and benefits	Limitations
Falkenmark Water Stress Index (Falkenmark 1989)	• Total annual renewable water resources available to the population (per cap/year freshwater availability) • Determines thresholds for minimum per capita water requirements • Data most often available as well on regional or smaller scales • Easy to apply and intuitively understandable	• Focus on blue water stress only, omits green water. • Excludes main drivers for water scarcity, e.g., demand, efficiency, management and lifestyles. • Societal adaptive capacity is not included. • Assumes that all countries globally use or need the same amount of water for development.
Social Water Stress Index (Ohlsson 2000)	• Builds on the Falkenmark indicator and applies the UNDP's Human Development Index (HDI) to depict the social dimension of water scarcity. • Contextualizes water stress with a low social adaptive capacity.	• The HDI does not include ecological factors and focuses mainly on economic criteria [50]. • The HDI does not depict intra-national differences, as the data applied is country-based only.
Water Resources Vulnerability Index (criticality ratio) (Alcamo et al. 2000)	• Withdrawal-Ratio of human water use to total renewable water resources. • Comparison of country-specific water demand and availability. • Scarcity: proportion of total withdrawals relative to total available resources.	• Role of non-natural resources (e.g., desalinization), recycled or re-used water is not considered. • Omits behavioural change as a reaction towards lowering water capacities, e.g., the implementation of new technologies.
Physical and Economical Scarcity Indicators (Molden 2007)	• Accounts for all renewable water resources available for primary supply under future scenarios of improved water management policies, e.g., infrastructure development and irrigation efficiency. • Physical scarcity: countries being unable to meet future demands *despite* future adaptive capacity (e.g., investments in water infrastructures). • Economical scarcity: countries unable to meet future water demand *without* investments in water infrastructures despite sufficient renewable resources.	• Measuring of indicator is very complex and time-consuming. • Data requirements difficult to meet, thus it's mainly based on expert judgments. • Omits ability to adapt by virtual water imports (food) or water saving devices. • Partly green and blue water are summed up, providing too high potential availability values. • Country-based aggregated analysis.
Water Poverty Index (Sullivan et al. 2003)	• Determines water security at household and community level based on income and wealth. • Measures and aggregates five dimensions: level of access to water; water quantity, quality and variability; water used for domestic, food, and productive purposes; capacity for water management; environmental aspects.	• Focuses on limitations of the Falkenmark Index. • Comprehensive amounts of data required. • Approach of high complexity. • Lacks intuitive understanding. • Suited for smaller rather than national scales.

The introduction of the green water[29] concept by Falkenmark in 1995 represented a milestone regarding the evaluation of available freshwater resources and water use efficiency (Rijsberman 2006; Willaarts et al. 2012).

The importance of green water is often underestimated, considering that global food production for the most part relies on rain-fed irrigation (up to 60%, including grazing for meat production or forests for wood production) (Savenije 2000). However, most water scarcity indices build upon and complement each other, trying to overcome presumed limitations and to increase the predictive validity (White 2012). The majority of approaches affirms a crucial role towards the (re)adjustment of water management and water governance in order to react adequately upon a seriously deteriorating water situation (Rijsberman 2006; Gleick et al 2002). Next to the criticism regarding some indicators for being too simplistic, in particular addressing the Falkenmark Index, there is as well a critique that sophisticated approaches can be too complex for practitioners and decision-makers (Rijsberman 2006). For the latter, simple approaches may be more appropriate to raise awareness regarding the prior causes of a deteriorating water situation.

The Falkenmark Index is a comprehensible tool to raise awareness regarding the finiteness of blue water resources necessary for food production, taking into account that green water significantly changes the picture of the potential water availability. However, the optimal use and exploitation of rainwater requires a re-oriented water strategy and institutional changes. Thus, as a first step, on the basis of the Falkenmark Index, it can be very well depicted that building on blue water without efficiency increase leads to a problematic impasse.

[29] 'Green water' refers to the fraction of rainfall infiltrated and stored in the soil, supporting primary productivity of natural and agricultural systems through evapotranspiration; thus, it is crucial for biomass production and rain-fed agriculture (Falkenmark 1995; Willaarts et al. 2012).

3.4 Sustainable tourism[30]

To achieve long-term success the degradation of natural resources in a way that other economic activities are negatively affected or become impossible must be avoided. That is, sustainable tourism *"must aim at development of tourism in such a way that avoids damage to the environment, economy and culture […]. It requires simultaneous considering of lots of criteria including infrastructure, competitiveness and supply, socioeconomic, land use/tourist facilities and service to meet the concept of sustainable development"* (Monavari et al. 2012).

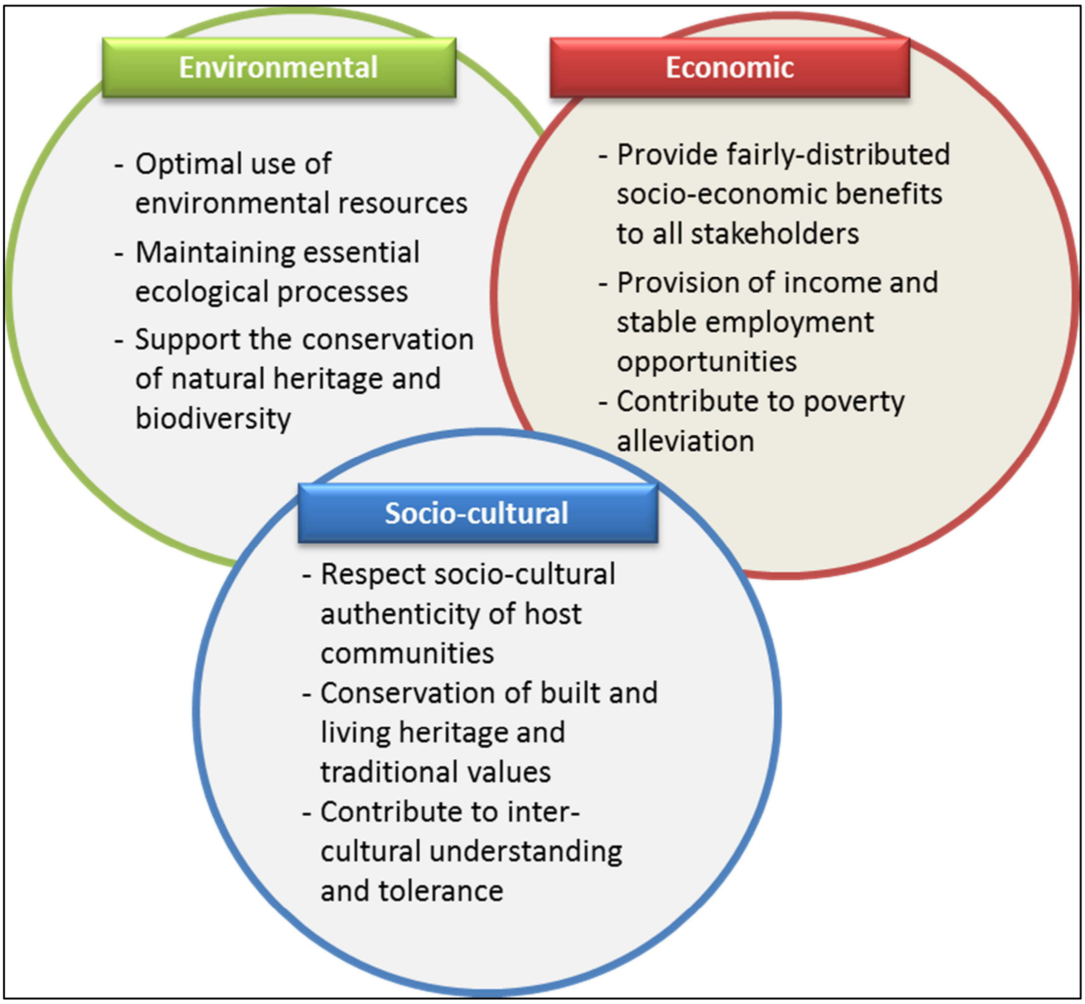
In this sense, tourism can support a sustainable development if it takes into "*full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities*" (UNEP/UNWTO 2005) (Figure 15).

The ecological perspective is an objective of primary importance in most approaches for a sustainable tourism development (Schmied et al. 2009). For example, Müller and Flügel (1999) refer to the need of an intact nature and resource protection, which must be ensured by the reduction of the ecological impact by tourism activities. Baumgartner (2000) defines the "*ecological dimension*" as "*most important source for a touristic development*" (Schnell et al. 2002). Examples for the definition of ecological criteria are the reduction of resource consumption (e.g. water), or the avoidance of negative impacts on biodiversity (Schmied et al. 2009; Baake et al. 2002).

In general, a course towards achieving a more sustainable tourism is an inclusive and continuous process (UNEP/UNWTO 2005). The development of adequate sustainability criteria and a regular monitoring of the implementation need to be steered by public institutions, e.g. planning authorities, to ensure the sustainability compliance of tourism businesses (Wöhlcke 1993).

[30] Text passages of this chapter are partly derived from Tekken, V. and Stoll-Kleemann, S.: Resource pragmatism vs. resource reality: sustainable tourism development in north-eastern Morocco. Submitted manuscript to *Tourism Management Perspectives*.

Figure 15: Aspects of a sustainable tourism development (based on UNEP/UNWTO 2005).



3.5 'Balanced' Sustainability[31]

The publication of the concept "Limits to Growth" by the Club of Rome in 1972 resulted from an intense discourse regarding the conflict of resource use and good environmental quality under the paradigm of economic growth (Meadows et al. 1972; Lee 2011). Continued and expanded by the Brundtland Report (1987) the agreed definition of sustainable development was then based on the two concepts of needs (in particular the essential needs of the world's poor, to which overriding priority should be given) and limitations (the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs), taking into account the perpetual conflict between ecological conservation and economic development (WCED 1987).

Today, the terms 'sustainable' and 'responsible' are commonly used in the context of socio-economic development. However, the meaning of sustainability has become fuzzy and is increasingly used as a rhetorical justification of anthropocentric development (Wöhlcke 1993). One reason might be the difficulty of meeting the criteria of a strong sustainability (ecocentric paradigm), which is in total contrast to a resource-based development (anthropocentric paradigm). Anthropocentrism aims at the decoupling of economic growth and the use of resources or materials (Simonis 1990). From a development perspective this conflict of targets needs a balanced concept of quality-oriented growth which should include frugality, efficiency, repair, recycling, material substitution, and structural change (Steurer 2001) (see Table 4 for sustainability paradigms and their classification).

Depending on the development pathway, environmental damage can be lessened by compliance with regulatory frameworks, and by an efficient implementation of legal restrictions (Steurer 2001). However, the harmonization between economic growth on the

[31] Text passages of this chapter are partly derived from: Tekken, V. and Stoll-Kleemann, S.: Resource pragmatism vs. resource reality: sustainable tourism development in north-eastern Morocco. Submitted manuscript to *Tourism Management Perspectives*.

one hand and safeguarding environmental quality on the other will lead to a reduced speed of growth: ecologic-economically optimized development pathways differ from economically-oriented development pathways (Steurer 2001).

Table 4: Paradigms of sustainability (based on Steurer 2001).

Weak sustainability (anthropocentric paradigm)	Balanced sustainability (eco-anthropocentric paradigm)	Strong sustainability (eco-centric paradigm)
- focus on maintaining and enhancing growth and prosperity - resource and growth optimism: welfare maximization and economic growth are seen as solution to environmental problems - natural capital is fully substitutable by human or real capital - conventional cost-benefit-analysis - decrease of natural capital is sustainable if compensated by growing capital in other sectors - harmonious interaction between growth and environment - pro- growth strategy with moderate environmental policies - representatives: neo-classical	- prosperity increase induced by policies for environmental protection/conservation - natural capital is partly substitutable - environment-friendly growth is possible - ecological consumption patterns and their efficiency is supported by technologies, policies and markets - environmentally extended cost-benefit-analysis - representatives: social scientists; growth optimizers	- healthy environment as basis of all other sustainability dimensions - growth pessimism: economic growth is not compatible with the preservation of natural capital and environmental quality - contra cost-benefit analysis - environmental protection needs restriction of economic growth1 - natural capital must be preserved, cannot be substituted or replaced through man-made assets - sustainable growth based on natural capital not possible - representatives: ecological economics, ecologists

Steurer (2001) determines criteria for a weak (anthropocentric), a strong (ecocentric) and a balanced (eco-anthropocentric) sustainability. In terms of intergenerational justice, a balanced sustainability is the only appropriate strategy to ensure a qualitative growth (Steurer 2001).

4 Methodological approach

The chosen research design is a vulnerability assessment approach. Vulnerability assessments have emerged over the past decade as appropriate frame of analysis to assess the impact and scope of different drivers causing socio-ecological vulnerability in the context of climate change (see chapter 3.1 in this thesis).

The underlying hypothesis is that regional climate change aggravates existing water scarcity in north-eastern Morocco, which is currently pressured by an inadequate demand-supply ratio (water deficit situation). From this general aim the research questions were derived and partly refined by sub-questions during the process of research. The main research questions are:

(i) What are climate change impacts that could potentially interfere with regional development plans in north-eastern Morocco?

(ii) What is the main cause for the increasing water scarcity in the area of the Moulouya river basin: increasing water demand or climate change?

(iii) How and to what extent does luxury tourism development add to the existing water problems in north-eastern Morocco?

(iv) How sustainable is the current tourism-based development pathway in north-eastern Morocco?

4.1 Research phases and analysis process

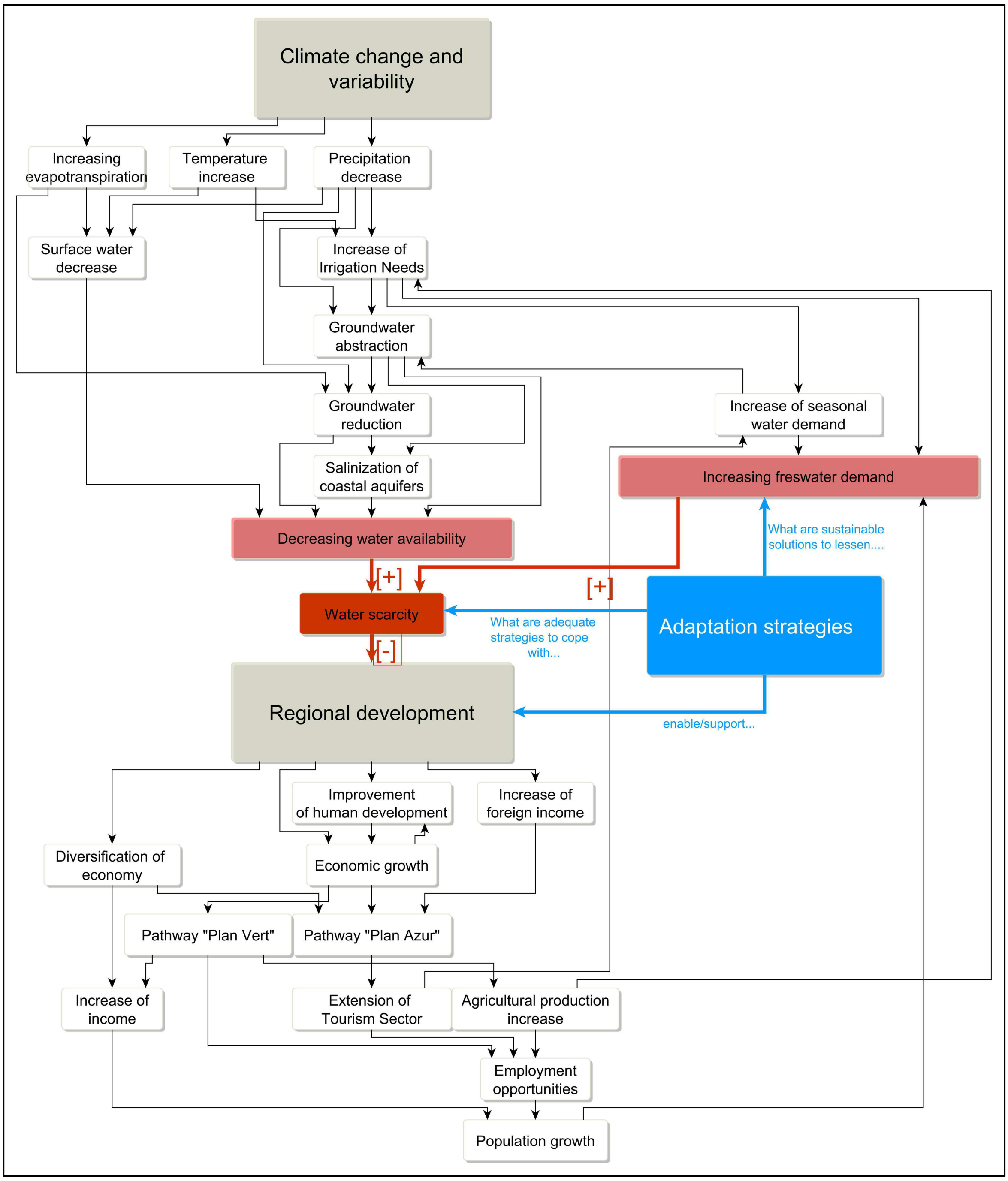
A structured analysis approach was developed and followed under the inclusion of the interim results of the respective preceding research phases. This thesis combines approaches from human and physical geography under disciplinary consideration of hydrological, socio-economic, and demographic perspectives.

In the ***first research phase*** the overall research question guiding the analysis was: "*What are climate change impacts that could potentially interfere with regional development plans in north-eastern Morocco?"* In this early stage of research, a factual overview of the problem context was achieved. Results from interviews with regional decision-makers of the coastal provinces Nador and Berkane in the region l'Oriental in north-eastern Morocco have shaped the research hypothesis and supported the definition of the research objectives. According to interviewees, information is required to understand the regional effects and impacts of climate change in the region, in particular in order to draw up adaptation strategies that are needed to minimize the risks for the regional population. Further, research needs in the particular context of *regional* climate change and the already problematic water situation were emphasized by regional decision-makers and Moroccan project partners during the respective interviews. Therefore, the hydrological and water management entity of the Moulouya river basin was specified as an appropriate geographical area for analysis.

For the overall research process a framework then was developed referring to the different research components of analysis and to depict cause-effect-relationships (Figure 16).

The methodological approach in this phase included a comprehensive literature review and data research. This was followed by the statistical analysis of regional climate trends observed in the Moulouya river basin over the 20th century (see chapter 4.2 in this thesis). Key vulnerabilities of climate change were determined by referring to exogenous and endogenous vulnerability parameters. Climate scenarios were compiled to estimate near-term water supply and demand under climate influence. *Intermediate results of the first research phase* revealed a continuing drying trend in the region, indicated by decreasing precipitation and increasing temperatures over the 20th century. Scenarios for near-term water demand and supply indicate severe water shortages and an increasing water deficit. The question how this would interfere with the fulfilment of basic water needs in the region, and with the water-intense development plans was under evaluation.

Figure 16: Theoretical research framework with analysis components and cause-effect-relationships considered in this thesis.



This question has led to ***second research phase***, guided by the research question "*what is the main cause for the increasing water scarcity in the area of the Moulouya river basin: increasing water demand or climate change?"* The respective research approach addressed three sub-questions. In a first step it was analysed, how the observed regional climate trends will affect the per capita water availability. The analysis based on three indicators for decreasing regional water availability: precipitation decrease, temperature increase and higher evapotranspiration rates. Climate trends are analysed for 1971-2005 (ref. baseline 1936-1970) and the regional water situation is depicted by calculating the Climatic Water Balance (CWB), used as an indicator for potential water availability.

The regional climate signal was statistically derived from the mean historical trend and linearly extrapolated for 2006-2040. The second sub-question focused on the role of population growth for regional water availability. The analysis of physical drivers is supplemented by the socio-economic driver population growth. A linear trend is derived based on current demand and supply figures coupled with regional climate and population trends. The potential per capita water availability, the per capita demand-supply gap at 500 m^3/1.000 m^3, and the influence of population trends on the potential per-capita availability are calculated. The third sub-question focused on the adequacy of common approaches to measure water scarcity: what are minimum thresholds, what data is needed for the calculation and how can 'water scarcity' be characterized.

The intermediate results show an accelerating decrease of the minimum per capita water availability, mainly caused by increasing demand due to population growth and aggravated by climate change. The expected severe limitations of water availability in the very near-term have led to the ***third research phase***, guided by the research question: "*How does luxury tourism development add to the existing water problems in north-eastern Morocco?"* Water scarcity as shown and referenced in the preceding research phase is a critical limit for development, if not responded by an adapted water management. In north-eastern Morocco, luxury tourism has an overarching role in the context of socio-economic development. The analysis of regional economic and demographic data shows, that the opportunities of the tourism sector to support the regional development process are promising. But luxury tourism is water-intense: golf and garden areas need a continuous water supply, large public and private pool areas need freshwater, and the per capita need of tourists in 5-star hotels is estimated higher than the average tourist water demand. The seasonal water demand analysis for the newly-built tourism complex in the north-east of the case study area, Mediterranean Saidia, shows an increasing demand in particular in the summer season. This is in conflict with the subsequent beginning of the agricultural growing season in autumn, if the quantities of stored volumes are not sufficient. Agriculture is still the major employer in the region, thus the water supply is essential. In contrary, tourism facilities need much less water and could be managed by internal water demand management and be supplied by internal water circuits.

The question, if and how water supply is considered in regional development plans guided the final and ***fourth research phase***: *"How sustainable is the current tourism-based development pathway in north-eastern Morocco?"* Regional tourism development plans are analysed with emphasis on sustainable solutions for the critical water situation guided by the sub-question *"How is existing water scarcity addressed in regional development plans?"* Aspects of sustainable tourism are outlined and a literature-based inventory of problems and pressures for socio-economic development in north-eastern Morocco is compiled. At the end of the research phase recommendations for a sustainable water management are outlined with a focus on particular demand management in the context of regional tourism development.

4.2 Methods applied

For the analysis of causes of regional vulnerability and limits for regional development in the case study region a portfolio of different methods was applied. The overall approach of this thesis is grounded in an integrative and applied approach, under inclusion of methods from human and physical geography under disciplinary consideration of hydrological, socio-economic, and demographic perspectives.

4.2.1 Literature review

A thorough study and review of secondary literature, regional reports, regional environmental and sectoral policies, and statistics on climate change and socio-economic structures and problems has been undertaken in order to collect information on regional climate change and supplementary data for water demand of tourists and of associated tourism infrastructures. The literature research revealed a repeated contextualization of water scarcity, climate change and pressures from human usage and demand in Mediterranean North Africa. As an overall result a comprehensive literature archive was compiled with region-specific literature and data focusing on climate change, water problems and socio-economic development in north-eastern Morocco.

4.2.2 Statistical time series analysis of regional and sub-regional precipitation and temperature development 1901-2005 in the Moulouya river basin[32]

In order to detect regional climate characteristics and to derive trends a time series analysis was conducted for the climate-relevant parameters temperature and precipitation. The relative long-term trend (1901-2005) of the spatial-temporal climatology was analysed using a linear trend method of minimum squares.

Significance testing of precipitation trends was performed by an independent two-sample t-test for the seasonal time series DJF (December, January, February), MAM (March, April, May); JJA (June, July, August); SON (September, October, November) for 1971-2005 (reference baseline 1936-1970). The assessed data records span 35 years, considered appropriate to deliver a valid statistical mean, as the minimum time series for precipitation should not be below 30 years (classical period, as defined by the World Meteorological Organization WMO).

[32] Text passages of this chapter are partly derived from: Tekken, V. and Kropp, J.P. (2012): Climate-driven or human-induced: Indicating severe water scarcity in the Moulouya river basin (Morocco). *WATER* 4(4), 959-982.

4.2.3 *Trend analysis of Potential Evapotranspiration (Pot.ET) and Climatic Water Balance (CWB)*[33]

The Pot.ET substantially determines the CWB and indicates the extent of evapotranspiration under the assumption of a continuously wet surface, based on the empirical relationship between potential evapotranspiration and mean temperatures (Thornthwaite 1948). Changes in evapotranspiration rates are an important indicator for water stress situations. Increasing evapotranspiration may substantially impair run-off rates and soil moisture. To identify a long-term annual and monthly trend the Thornthwaite formula (1948) was applied. The Thornthwaite formula is a temperature-based Pot.ET model and requires only few meteorological variables for its calculation: mean monthly temperatures over the annual cycle and the average daylight hours. The Thornthwaite method is often criticised for its limited applicability due to minimum input variables, and due to estimation inaccuracies. However, at a given insufficient data situation newer approaches are currently not applicable, as input data needs to be more accurate. Based on the prior results of precipitation and temperature trends and the Pot.ET the CWB is calculated for 1936-1970 and 1971-2005 to indicate a long-term trend change for each month. The CWB denotes the difference of the average monthly precipitation (P) minus the potential evapotranspiration (CWB = P - Pot.ET), in order to indicate annual precipitation deficits and interannual shifts of relevant precipitation periods (i.a. for groundwater recharge).

4.2.4 *Regional population trend: linear trend projection*[34]

The projected population trend for Morocco at medium term was derived from United Nations Population Division (2011). The UN population growth rate was then applied to the regional population based on values from 1995 to deduce estimates for population development until the year 2040. The data of regional population was taken from the official Moroccan 2004 population census (Royaume du Maroc 2005).

[33] Ibid.

[34] Ibid.

4.2.5 Analysis of regional water availability

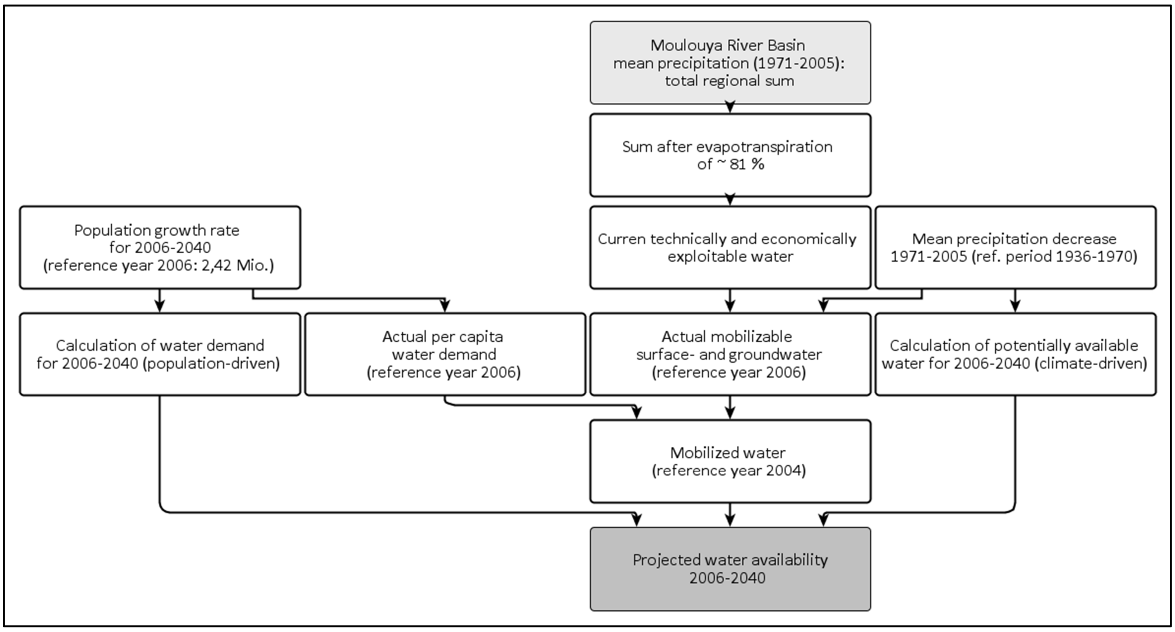
As a baseline, in order to assess the dimension of the problematic water situation in the case study area, threshold values of the Falkenmark Water Stress Index (water resource to population index) are referred to as indicators for regional water stress levels (Falkenmark 1989). Falkenmark compiled and classified the per capita water usage in multiple countries and deduced social water stress levels as the fraction of the total annual renewable water resources available for human usage (Table 5) (Falkenmark 1989; Falkenmark and Widstrand 1992). The index is widely used to indicate water stress and to emphasise the interrelationship between limited water per capita water availability and implications for development. Falkenmark categorizes water conditions, and describes index thresholds with regard to water resource management problems (Falkenmark and Widstrand 1992). As the index focuses on the (minimum) human water availability needs as a basic requirement for development, it can thus serve as a landmark for the adaptation needs of water management, depending on the water needs of development trajectories (Vörösmarty et al. 2005).

Table 5: Water stress levels and definitions (based on Falkenmark 1989; Gleick et al. 2002; Falkenmark and Widstrand 1992).

Water availability (per capita in m^3)	Level of water stress	Water resource management problems and constraints
> 1,700	Occasional or local water stress	No or limited problems
1,700- 1,000	Regular water stress	Heavy pressures on water resources, general management problems
1,000 – 500	Chronic water scarcity	Chronic water shortages/limitation to economic development and human health and well-being
< 500	Absolute water scarcity	Beyond availability limit; beyond the water barrier of manageable capability, main constraint to life

To estimate the potential development of regional per capita water availability under climate change and population growth a calculation framework was developed (Figure 17). Under the inclusion of rainfall losses from evapotranspiration, currently mobilizable water and actual water demand, projected water availability is calculated for 2006-2040.

Figure 17: Calculation framework for the estimation of per capita water availability 2006-2040 in the Moulouya river basin



4.3 Regional Data

Data gaps on water availability are common in North African countries, where instrumental coverage and the compiling of long-term records and data series are not well established (Taylor et al. 2009). One of the main objectives of the project ACCMA was to broaden the empirical regional data basis to enable adequate decision-making under climate change. Small-scale climate assessments or projections as possible basis for the development of adequate adaptation strategies are not available for Morocco so far.

A major problem in the region is water scarcity; however, statistical information on freshwater availability is largely unavailable (Eurostat/European Commission 2009). A lack of observational data and sustained time series is a key characteristic affecting all hydrological systems in Africa (Taylor et al. 2009). This is also the case for the Moulouya river basin, where empirical data on water demand and availability is neither available nor accessible or of very fragmented nature (Eurostat/European Commission 2009). Reference values for regionally mobilizable water (groundwater considered to be potentially usable) and water demand are taken from Snoussi (2004) and Imassi (2007) as well as Moulouya basin-specific population data for 2004. Data on exploitable natural water resources and mobilized groundwater resources for Moulouya river basin were obtained from FAO/AQUASTAT (2012, 2005) and UN-Water/Africa (2006).

Another problem arose from the unavailability of comprehensive instrumental long-term meteorological data records for the analysis of historical climate trends due to the low spatial density of meteorological stations. Therefore, a consecutive monthly climate proxy data series for temperature and precipitation for 1901–2005 was taken from the gridded and interpolated climatology at a 0.5° × 0.5° scale of the Climate Research Unit, CRU TS2.1 (New et al. 2002). For precipitation, the corrected and homogenized “CRU/PIK” data set was used (Österle et al. 2003). For the purpose of a detecting a historical trend in the cases study area, the “CRU/PIK” precipitation data so far provides the best applicable data under acknowledgement of the generally very limited regional water data situation.

The last population census for Morocco was conducted in 2004[35]. Therefore, to achieve an approximate picture, population trends and projections were scaled down from national population dynamics at a medium variant obtained from UN Population Division (2011), combined with the official population census of Morocco of 2004 (Royaume du Maroc 2005).

Following regional data was used:

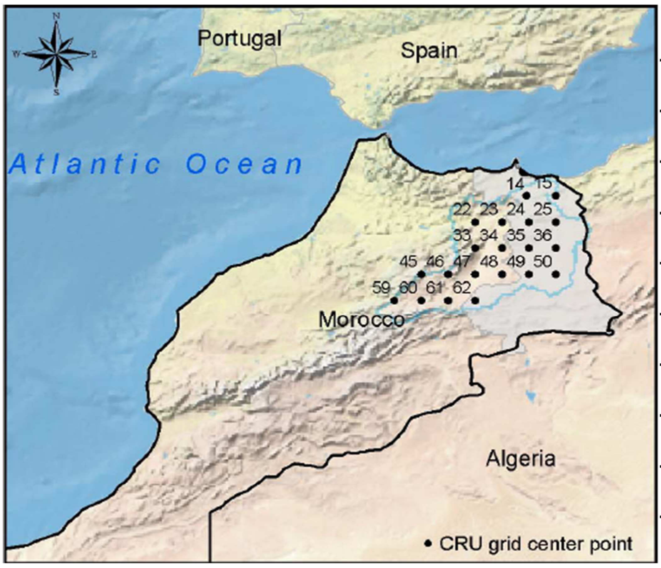
- *Historical climate data (1901-2005)*: for the long-term trend detection of regional climate trends in the area of the Moulouya River Basin the CRU TS2.1 (New et al. 1999; Mitchell and Jones 2005) interpolated, aggregated historical temperature and precipitation data set on a 0.5°x0.5° grid scale was used (Figure 18), corrected and homogenized (called there after CRU/PIK) by Österle et al. (2003). For the purpose of a small-scale historical trend observation of past climate the CRU/PIK data series

[35] Data source: Haut Commissariat au Plan du Maroc Web Page. Recensement Général de la Population et de L’habitat 2004. Available online: http://hcp.ma/Recensement-general-de-la-populaiton-et-de-l-habitat-2004_a633.html (last accessed December 2012).

so far provides the best applicable data under acknowledgement of a generally very limited data situation.

- *Mobilizable water*: reference values for regionally mobilizable water and demand are based on values taken from Snoussi (2004) and Imassi (2007) as well basin-specific population numbers; official data on exploitable natural water resources and mobilized groundwater resources for Moulouya River Basin were extracted from (FAO/AQUASTAT 2005, 2012; UN-Water/Africa (2006).
- *Population growth:* application of extrapolated projections of national population dynamics at medium variant from United Nations Population Division (2008, 2011), and official population census Morocco from 2004 (Royaume du Maroc 2005).
- *Water demand of tourists: r*eference values for irrigation needs of golf courses under semi-arid conditions (Kent et al. 2002), reference values for individual daily water demand of tourists from Diaz et al. (2007), Kent et al. (2002), Gössling (2005, 2012) and WWF (2001), applied for the case study area.

Figure 18: Case study area Moulouya river basin with CRU grid cell numbers, latitudes and longitudes of each point for spatially aggregated climate data (own illustration).



Longitude/Latitude (CRU grid cell number)	Longitude/Latitude (CRU grid cell number)
-2,75/34,75 (CRU 14)	-4,75/33,25 (CRU 45)
-2,25/34,75 (CRU 15)	-4,25/33,25 (CRU 46)
-3,75/34,25 (CRU 22)	-3,75/33,25 (CRU 47)
-3,25/34,25 (CRU 23)	-3,25/33,25 (CRU 48)
-2,75/34,25 (CRU 24)	-2,75/33,25 (CRU 49)
-2,75/34,25 (CRU 25)	-2,25/33,25 (CRU 50)
-3,75/33,75 (CRU 33)	-5,25/32,75 (CRU 59)
-2,25/33,75 (CRU 34)	-4,75/32,75 (CRU 60)
-2,75/33,75 (CRU 35)	-4,25/32,75 (CRU 61)
-2,25/33,75 (CRU 36)	-3,75/32,75 (CRU 62)

5 Summary and Synthesis of research articles

5.1 Summary of articles

Article I[36] gives an overview regarding current and potential future problems under targeted development pathways and climate change over the 20th century in the Moulouya river basin in north-eastern Morocco. The article outlines the specific problems of the region that is classified as a Mediterranean climate change hotspot and it links to problems regarding water availability if historical climate trends will continue. In particular near-coastal areas in the case study region might be severely affected by the combined impacts of climate change and sea level rise. Seasonal and annual changes of temperatures and precipitation are assumed to cause severe water problems in particular for rain-fed agricultural production and for the tourism sector currently in the process of expansion. In the low-lying and fertile areas of the basin with intensive agriculture currently ca. 77 % of agricultural areas are irrigated. Further, the agricultural sector employs ca. 30 % of the total labour force in the region. Government-induced development plans aim at stimulating economic growth, mostly by an accelerated extension of the agriculture and tourism sector.

Endogenous (system-inherent climate shifts) and exogenous (defined as anthropogenic influence on a system) parameters are differentiated to depict the specific human influence on regional vulnerability. In order to find out about the extent of potential pressures in the region CRU/PIK long time data series for seasonal precipitation and temperature (1901-2005) was applied to evaluate historical trends in regional climatic variability. Economic growth projections delineate that under aggravating regional climate conditions the water situation will be worsening and represent a limiting factor for economic development and growth if improvement of water infrastructures and management is not initiated. Further, calculations show that water demand for tourism is marginal compared to water needs for

[36] V. Tekken, L. Costa and Kropp, J.P. (2009): Assessing the regional impacts of climate change on economic sectors in the low-lying coastal zone of Mediterranean Morocco. *Journal of Coastal Research* SI 56, 272-276.

irrigated agriculture. Agriculture is the main water consumer. However, to avoid seasonal water shortfalls, adaptation is mandatory for regional and national decision makers. The analysis depicted that economic development plans for north-eastern Morocco are limited by clear environmental constraints, in particular with regard to water resources and water availability. This indicates high socio-economic vulnerability to regional climate variability. Detrimental impacts on the water budget and with this severe limitation of water availability are thus very likely, if not responded appropriately. Small-scale regional climate assessments with emphasis on socio-economic vulnerability are important for regional stakeholders and decision-makers to outline and implement appropriate water demand management responses. The degree of vulnerability can only be influenced by the establishment of region-adequate adaptation strategies.

Article II[37] is concerned with the primary causes of the critical water situation in north-eastern Morocco. The analysis contrasts the human influence (indicators: population growth, water demand) on decreasing freshwater availability with the potential impacts of a changing regional climate (indicators: precipitation, temperatures, evapotranspiration). Climate change in terms of a decreasing natural water budget combined with water-based development objectives and population growth will enhance the pressures on water resources. A decreasing availability will have negative impacts, as the socio-economic dependency on natural water availability in the region is very high. A main purpose of the analysis was to emphasize the need for societal and institutional responses.

The methodological approach includes a description the most popular approaches to measure water scarcity, their respective benefits and limitations: the Falkenmark Water Stress Index, the Social Water Stress Index (SWSI), the Water Resources Vulnerability Index (Criticality Ratio), the Physical and Economical Scarcity Indicators, and the Water Poverty Index. The simplest and intuitively understandable – in particular by stakeholders – is the Falkenmark Index (FI). Thus, in order to assess the dimension of the problematic water

[37] V. Tekken and Kropp, J.P. (2012): Climate-driven or human-induced: Indicating severe water scarcity in the Moulouya River Basin (Morocco). *WATER* 4(4): 959-982.

situation in the case study area, threshold values of the FI as indicators for regional water stress levels are used in the article. Data for the demand-availability gap calculations were obtained from FAO/AQUASTAT (2005, 2012), and UN-Water/Africa (2006), UNPD (2011) and from the last official Moroccan population census in 2004. Further, the precipitation/temperature data for the regional climate analysis was obtained from Climate Research Unit, UK. Within the data set CRU TS2.1, 20 data points located in the area of the Moulouya river basin were chosen to detect climate trends of the past decades (1971-2005 with reference period 1935-1970).

The analysis found a severe imbalance between potential water availability and minimum per capita water needs. In general, the water budget will not at all be sufficient to serve the targeted path to socio-economic development. Additional pressures, such as increasing siltation rates of existing dams of the Moulouya River, already cause high costs for maintenance (Snoussi 2004). Given that water availability represents the key resource to achieve development targets, institutional capabilities and policies need to address the serious degradation. Further, financial and technical support is urgently required (Sullivan and Huntingford 2009; Qadir et al. 2010). Once a certain threshold of water degradation is exceeded, the compensatory costs for alternative water resources might by far exceed the costs of promptly taken measures to adjust regional water capacities. Finally, the ecological value of water resources is inter alia expressed in the designation of the River Moulouya deltaic plains as RAMSAR wetlands. Not only is the regional water supply at risk, but also a unique ecosystem and wildlife habitat of international importance. The degree of impacts associated with climate change impacts and population growth can be lowered by the prioritization and prompt implementation of water efficiency measures that also include innovative approaches, such as *green water*, crucial for rain-fed food production, the water footprint or the virtual water trade approach to valorise water. With this article it is intended to encourage a discourse that contributes to the development of a region-adequate and integrated adaptation plan that accounts for both, human and climatic pressures on water resources. However, climate change should only be regarded as an *additional pressure* but not as the originator of the critical water situation. Water infrastructures must be readjusted, or the expansion of water intense sectors will lead to an exceeding of capacity thresholds, thus to an overexploitation or *"collapse"* of water resources (Ludwig et al. 1993). As our calculations indicate, the current water situation represents already a "*main constraint to life*" (Falkenmark 1989). The main adjustable parameter is the mitigation of human pressure on resources, thus requiring an enhanced awareness that the human factor is the root cause for regional water scarcity.

Article III[38] analyses the additional water demand in north-eastern Morocco caused by the recent establishment of a large-scale luxury tourism sector in the coastal zone.

Recently, the Moroccan government launched a programme to push forward the development of rural areas in the country, mainly to tackle poverty and to create employment opportunities. The main objective is to turn tourism into the second most important economic sector of the country, to create 470.000 direct jobs and one million indirect jobs through 2020, to increase revenues from foreign tourism expenditures, and to shift Morocco among the top 20 holiday destinations worldwide.

The "Plan Azur/Vision 2020" focuses on the establishment of seven large scale luxury tourist destinations located at the country's Atlantic and Mediterranean coastal zones. All newly constructed tourist destinations include luxury standard facilities, including 5-star hotels and private villas with amenities such as pools, restaurants, spas, large garden areas, golf courses and partly marinas. One out of the seven coastal tourist destinations listed in the "Plan Azur/Vision 2010" is located in the most north-eastern Mediterranean part of Morocco, in the low-lying coastal zone between the deltaic plain of the Moulouya river and the city of Saidia, at the border of Algeria. A major problem the region has to cope with is the aggravating water scarcity situation. The regional water balance is increasingly under pressure not only by decreasing precipitation amounts and a high interannnual precipitation variability, but as well due to the significant reduction of groundwater

[38] Tekken, V., Costa, L. and Kropp, J.P. (2013): Increasing pressure, declining water and climate change in north-eastern Morocco. *Journal of Coastal Conservation* (online first), doi: 10.1007/s11852-013-0234-7.

recharge rates. If this current trend continues, reduced rainfall will severely aggravate the regional freshwater deficit. Currently, the regional water demand–supply ration is merely balanced, with little scope for an additional water consumer, like water-intense luxury tourism. However, coastal tourism in north-eastern Morocco is a growing sector and has a paramount role for socio-economic development.

In this analysis, the amount of additional water demand is exemplarily assessed for the large-dimensioned Saidia tourism resort; including the monthly, seasonal and total annual tourist per capita water need under inclusion of irrigated golf courses and garden areas.

Further, long-term climate trends are included in the analysis to detect significant regional climate variation that could potentially impinge on the water situation. The results show that regional climate change is observable in terms of a lengthening of the annual dry summer season. This has implications for the irrigation needs of the hotel/accommodation facilities and must be included in the regional water budgeting. Further, in the summer season the additional water demand is high, and must be ensured to guarantee high standard of luxury tourism. An additional pressure is the growing population in the area leading to further water demand. "Business-as-usual-solutions", e.g. the extension of existing river dams or groundwater abstraction will not solve the problem due to a severely reduced water capacity, salinized aquifers and increasing siltation of water basins. Thus, the region is at double risk from increasingly dry climate conditions, and further due to increasing water demands. Even without rainfall decreases in the near future, the water situation can only be improved by modifications of current water management routines, by the implementation of adequate water recycling, and by non-conventional water production.

Article IV[39] aims to identify if and how sustainability is anchored in the government-induced tourism concept for north-eastern Morocco, with a particular emphasis on adequate water availability. Without an effective implementation of region-specific

[39] Tekken, V. and Stoll-Kleemann, S. (submitted manuscript): Resource pragmatism vs. resource reality: sustainable tourism development in north-eastern Morocco. *Tourism Management Perspectives*.

sustainability criteria tourism development will be hampered by severe water supply problems. Several studies and research indicate the aggravation of the problematic water situation. However, the article emphasizes, that despite an increasing awareness and the existence of scientific evidence ecologically responsible tourism has not made sufficient progress in Morocco.

Based on the sustainability paradigms of Steurer (2001), determining criteria for a weak (*anthropocentric*), a strong (*ecocentric*) and a balanced (*eco-anthropocentric*) sustainability, the current development pathway of north-eastern Morocco is classified. Key aspects that need to be met to adopt a sustainable strategy for coastal tourism development are outlined and contrasted to those explained in the “Moroccan chart of sustainable development” (Royaume du Maroc, 2006) and the concept for regional tourism development “Plan Azur 2010/Vision 2020” (Royaume du Maroc, 2010; Roudies, 2010). Based on a literature review, criteria for environmental and socio-economical sustainability are compiled as recommendations for a resource-realistic establishment of the regional tourism sector. Finally, we recommend criteria for a balanced sustainability, which could support sustainable growth under a strong regional development pressure.

A neglect of the current critical resource (water) situation is detected which is crucial regarding the aim to establish a luxury tourism sector. We considered “*balanced sustainability*” as an appropriate intermediate way between strengths and weaknesses of sustainability concepts (Steurer 2001). In fact, the respective assessment depends very much on the particular case, but for north-eastern Morocco seems to be true that tourism development needs to be supported by appropriate public policies and management. The current absence or inadequacy of institutional, legal, and other policy instruments encourages economic growth at the expense of the environment. High ecological risks, such as critical water shortage, must be prevented. Compliance with high environmental standards ensures the long-term availability of resources, which is apparently not the main interest of tourism businesses. A balance is needed between the interests of facilitators of socio-economic development and environmental protection under the responsibility of public authorities. The transformation process of the regional economy currently is resource pragmatic, as neither resource threshold values are defined, nor measures for an effective and appropriate water management. The resource reality is already critical: there is scientific evidence for severely limited water availability. New practices and standards regarding the management of nature are needed, that go beyond mere rhetoric. Thus, the success or failure of socio-economic development in north-eastern Morocco, facilitated by luxury tourism, remains first and foremost a matter of governance structures.

5.2 Synthesis of results with regard to the research objectives

This thesis followed five research objectives in order to assess the socio-economic vulnerability to climate change in north-eastern Morocco in the context of water stress and tourism development.

Research objective 1: Changes in regional climate patterns in the hydrological unit of the Moulouya river basin over the recent past using historical meteorological data

Regional climate trends in the Moulouya river basin are observable (Article I), indicating an extension of the dry annual period at a concomitant temperature increase and precipitation decrease. The semi-arid situation is a limiting factor for regional water availability, and could even be exacerbated if the detected long-term (1901-2005) will proceed. Areas of intensive agricultural production in the low-lying river plains of the Moulouya might be at double risk: coastal zones are increasingly affected from groundwater salinization and further due to increasing irrigation needs due to dryer conditions (Snoussi 2004; Carneiro et al. 2010). For the coastal zones, on a sub-basin-scale analysis, the precipitation decrease shows the highest declines (Article III). This is problematic, as in the region rain-fed agriculture is important for industrial and subsistence agriculture. Further, tourism development in the area is dependent on rainfall for large golf and garden areas. Any decrease or shift of precipitation will enhance the irrigation needs (Article III).

Research objective 2: Influence of population growth and water-intensive human activities on regional per capita water availability based on population projections and development pathways

By the means of the Falkenmark Index the water stress level for the Moulouya region was classified as 'chronical' or 'absolute' water scarcity measured in the per capita availability (Article II). The index refers to water needs for development, and to deduce social water stress levels. In Moulouya, the combination of climate change causing dryer conditions, and further enhancing water demand caused by population growth, will lead to an increasingly problematic water situation. A severe water deficit is very likely, leading to a per capita water availability below 500 m^3, which represents *"a main constraint to life"* (Falkenmark 1989). Natural water resources are fundamentally at risk if water demand increases, and as the current technical capacities to support water are inadequate.

Research objective 3: Increasing seasonal water demand in the particular context of regional luxury tourism development

Coastal areas in the Mediterranean are tourist hot-spots. In many areas tourism has enhanced economic growth, regional development, and led to an increase and the diversification of regional employment (Article III). Guaranteed continuous water supply is an important success factor for tourism. The estimation of additional seasonal water demand in the context of the establishment of luxury tourism in north-eastern Morocco varies between seasons and tourist occupancy rate (Article III). It can be expected by an additional annual water demand of ca. 8 million m^3, which is dwindling small compared to the amount need by the agricultural sector: 975 million m^3 assumed an irrigated area of ca. 150.000 ha (Imassi 2007) (Article I). Agriculture is the largest consumer of freshwater, and it currently employs most of or the working population in the area. In this context, the region's socio-economic vulnerability mostly depends on the water supply of the agricultural sector.

Research objective 4: Adequacy of regional development strategies under aggravating water scarcity

The Moroccan development plans “Plan Azur” and “Plan Bleu" presuppose water availability despite increasingly poor water conditions. Pressures on water resources are very high due to inadequate water management, a lack of technology and increasing water demand by population growth. The governmental strategies to extend the coastal tourism, focusing on water-intense luxury tourism, do not take into account the increasingly problematic water scarcity situation in the region (Article III). The regional water balance is in deficit and a significant reduction of groundwater resources is observable (Döll 2009). An inventory of water–related problems and associated pressures (Article IV) contrasting the climate-induced influence and the human–induced influence on water resources reveals that pressures resulting from an inadequate human resource management significantly contribute to the aggravating situation. Tourism development as economic diversification strategy can only be successful and sustainable if water supply is guaranteed; thus water-saving instruments must be integral parts of any extension strategy.

Research objective 5: Recommendations for a sustainable regional water management

Considering the growing water demand and the decreasing water budget, it is important to strengthen water conservation, to improve water efficiency and to take innovative approaches aimed at ensuring a sufficient supply of water (Article II). Wastewater collection and treatment currently plays only a minor role in Morocco (less than 10 % of used water). The potential of wastewater resource exploitation is a neglected feature in the public water budget calculations. The regional water management has not yet taken sufficient advantage of existing technological possibilities. Given the aggravating water situation and the underlying two-fold causes, three main strategies are considered reasonable and achievable:

(1) Increase of regional water efficiency: the modernization of water infrastructures (no-open channel water transport, no gravity irrigation), the inclusion of ‘blue’ water in

calculations of water supply, innovative water collection measures, using the opportunities of virtual water trade (Articles II,IV);

(2) Modernization of the regional water management: monitoring of the water situation and climatic variability, participatory approaches to engage the local population and to create awareness;

(3) Implementation of legally-binding regulations for the public administration, supported by national water policies.

6 Conclusions

The specific risk of climate change lies in its rapid pace, which causes considerable difficulties for most of the world's ecosystems. With this, the living conditions of billions of people on this planet are deteriorating. The human influence on this phenomenon is scientifically recognized, and necessitates addressing the causes. However, the sharp reduction of the amount of greenhouse gases that harm the climate is compulsory. The anthropogenic climate change is accompanied by an over-exploitation of natural resources. Therefore, it is crucial to develop a reconsidered modus operandi regarding the responsible and sustainable handling of resources. In particular water-scarce regions which are under increasing pressure resulting from population growth, economic development, urbanization, and changing consumption and lifestyles will experience severe water problems if no adequate strategies are implemented. Additionally, in low-lying coastal areas, sea-level rise will contribute to an aggravating situation due to saltwater intrusion into coastal aquifers, inundation, beach erosion, and sediment loss. However, the respective influence of human-driven and climate-induced impacts on a deteriorating situation has to be clear in order to delineate adequate adaptation strategies. Human interferences such as the overexploitation and degradation of natural resources play a substantial role for the adaptive capacity of ecosystems. Thus, the human influence has made many natural systems vulnerable and sensitive to climate change. All too often little or no consideration has been given to the fact that natural resources are the key for human activities, economic development and societal progress. This negligent handling does not only lead to the disappearance of natural habitats but as well threatens or destroys the foundation of human existence in many parts of the world.

This thesis delineates the role of climate change as an *aggravating* but not as causal factor for an increasing socio-economic vulnerability towards water scarcity in north-eastern Morocco. This is of particular importance as vulnerable countries or regions will have to allocate funds to supporting adaptation to climate change. Developing countries have a limited capacity to cope with additional pressures, thus undermining growth opportunities (Dasgupta and Baschieri 2010). This is also true for Morocco, where population growth, high unemployment rates, urbanisation, high water demand, and environmental degradation collide with recently observed variability of climate patterns (Varis and Abu-Zeid 2009; Knippertz et al. 2003; Tekken et al. 2009). Recently, the coastal areas in north-eastern Morocco are in the focus of national socio-economic development initiatives (Royaume du Maroc 2005, 2010). Poverty rates shall be reduced and economic opportunities be increased by the extension of the agricultural and tourism sector. In particular the tourism sector is aimed to contribute to a diversification of employment structures, as large proportions of the working population are employed in the climatically sensitive sector agriculture. Due to the semi-arid situation in the region, agriculture is highly dependent on irrigation. Water-intense tourism is vulnerable to climate change in terms of likely occurrence of water shortfalls. Sufficient water availability is the key requirement for the implementation of regional development plans. Large-scale luxury tourism is water-intense and will contribute to rising regional water demand. Continuous water supply must be guaranteed; water shortfalls will not be tolerated at high-level tourist sites. At the moment, the regional water demand–supply ratio is balanced, with little scope for an additional water consumer. Thus, at the one hand the tourism sector needs to adapt to a chronic water deficit situation, and on the other hand it contributes to it.

Without major changes in resource management and adequate adaptation initiatives regional development will nearly be impossible. However, the most effective vulnerability reduction, as a *basis for adaptation* to climate change, often takes place at a local scale (Schipper and Pelling 2006). To inform decision-makers about vulnerability-creating mechanisms in their region it is necessary to evaluate and differentiate between the influencing factors of existing pressures on a reasonable scale. This thesis aims to contribute to the process of outlining region-adequate water management strategies for the facilitation of socio-economic development. By the means of an integrated analysis the vulnerability to increasing water scarcity was empirically investigated. Climate trends in the hydrological unit of the Moulouya river basin in north-eastern Morocco reveal changing patterns that have high potential aggravating the already critical water situation.

Four main reasons are identified for an aggravating water situation indicating towards an increasing socio-economic vulnerability:

The *first reason* is the expansion of the agriculture-based economy, that is increasingly dependent on supplementary irrigation due to low precipitation amounts and further due to increasingly recurrent drought situations and. The transition from a small-holder-characterised agronomy into large management schemes intensifies the production and makes if more efficient. However, the formerly abstraction of water from dispersed sources is now being replaced by the intensive and selective water abstraction from groundwater aquifers in near coast areas. The situation is particular precarious, as approximately 40 % of the regional employees work in the primary sector. Given this situation, water represents the key resource not only for agricultural production but as is as well crucial for the regional socio-economic situation.

The *second reason* is as well economic, as it is caused by Moroccan national development plans to diversify the regional economic structure and to generate jobs by the establishment of large-scale coastal luxury tourism sector. Facilities such as golf courts, large garden and pool areas are highly water-consuming and represent a further burden for the regional water situation, as the all-year supply has to be guaranteed. Due to increasing salinization of near-coast groundwater aquifers, freshwater is obtained from the river Moulouya. The Moulouya river is the only freshwater provider in the region, thus an increased abstraction does as well lead to a reduced natural groundwater recharge.

The t*hird reason* is rooted in the social structure of the region. In Morocco, the coastal areas experience rapid urbanization processes. This has several causes: the hope for employment opportunities (e.g. in the tourism sector), aggravating livelihood conditions in the countryside due to increasing water scarcity, changing lifestyles of the younger people. The concentration of population in urban areas does also lead to increasing local water demand, thus overstraining water resources if adequate water infrastructures (e.g. water treatment, water recycling) are not in place. The demand often exceeds the supply and impairs the natural water regeneration rate.

Changing regional climate patterns are the *fourth reason* for an aggravating water situation. The shift of seasonal precipitation combined with increasing temperatures has an impact on evapotranspiration rates, groundwater replenishment and thus plays a significant role for the regional water cycle.

To conclude, it is essential to develop future-adequate concepts for rural and urban water management and governance "*to ensure that the accelerating speed of human expansion does not push us past the Planetary Water Boundary*" (Falkenmark 2011).

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Annex A: Research Articles I-IV

Originally published as:

Tekken, V., Costa, L., Kropp, J.P. (2009): Assessing the regional impacts of climate change on economic sectors in th e low-lying coastal zone of Mediterranean East Morocco. *Journal of Coastal Research (SI 57)*: 272-276.

http://e-geo.fcsh.unl.pt/ICS2009/_docs/ICS2009_Volu me_I/272.276_V.Tekken_ICS2009.pdf

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Journal of Coastal Research	SI 56	pg - pg	ICS2009 (Proceedings)	Portugal	ISSN

Assessing the regional impacts of climate change on economic sectors in the low-lying coastal zone of Mediterranean East Morocco

V. Tekken†, L. Costa † and J.P. Kropp†
†Potsdam Institute for Climate Impact Research
14473 Potsdam, Germany
vera.tekken@pik-potsdam.de

ABSTRACT

Tekken, V., Costa, L. and Kropp, J.P., 2009. Assessing the complex impacts of climate change on economic sectors in the low-lying coastal zone of Mediterranean East Morocco. Journal of Coastal Research, SI 56 (Proceedings of the 10th International Coastal Symposium), pg – pg. Lisbon, Portugal, ISBN

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

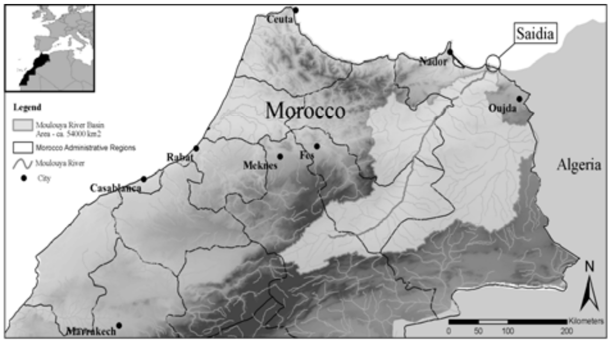

Figure 1: Moulouya River Basin, Morocco

extension of the tourist sector in the near future. Both economic sectors are profoundly water consuming. Water therefore is the 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

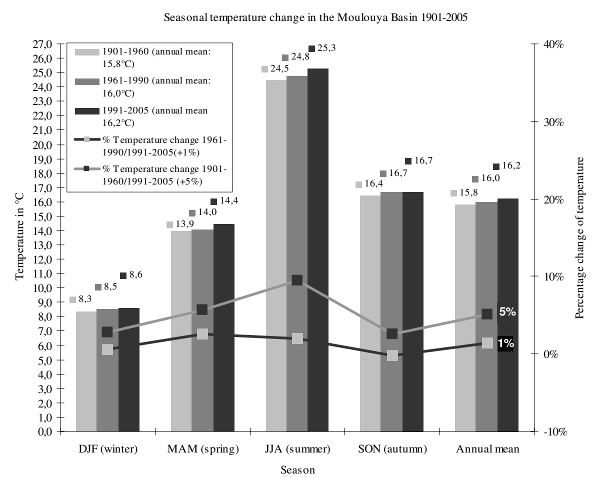

Figure 2: Seasonal temperature change in the Moulouya Basin 1901-2005.

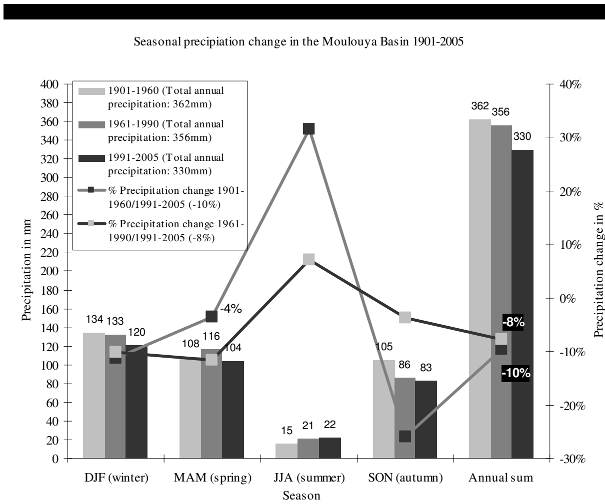

Figure 3: Seasonal precipitation change in the Moulouya Basin 1901-2005.

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) 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.

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

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 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.

ACKNOWLEDGEMENT

We would like to thank the IDRC International Development Research Centre (Canada) for funding the research project ACCMA "Adaptation to Climate Change in Morocco".

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Originally published as:

II

Tekken, V., Kropp, J.P. (2012): Climate-driven or human-induced: Indicating severe water scarcity in the Moulouya river basin (Morocco). *Water* 4(4): 959-982.

DOI: 10.3390/w404095

Water **2012**, *4*, 959-982; doi:10.3390/w4040959

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water

ISSN 2073-4441

www.mdpi.com/journal/water

Article

Climate-Driven or Human-Induced: Indicating Severe Water Scarcity in the Moulouya River Basin (Morocco)

Vera Tekken [1,]* and Jürgen P. Kropp [2,3]

[1] Department of Geography and Geology, University of Greifswald, Friedrich-Ludwig-Jahn-Str.16, D-17487 Greifswald, Germany

[2] Potsdam Institute for Climate Impact Research, Telegraphenberg A31, D-14412 Potsdam, Germany; E-Mail: kropp@pik-potsdam.de

[3] Department of Geo- and Environmental Sciences, University of Potsdam, Am Neuen Palais 10, D-14469 Potsdam, Germany

* Author to whom correspondence should be addressed; E-Mail: vera.tekken@uni-greifswald.de; Tel.: +49-(0)3834-86-4689; Fax: +49-(0)3834-86-4681.

Received: 28 September 2012; in revised form: 15 November 2012 / Accepted: 16 November 2012 / Published: 3 December 2012

Abstract: Many agriculture-based economies are increasingly under stress from climate change and socio-economic pressures. The excessive exploitation of natural resources still represents the standard procedure to achieve socio-economic development. In the area of the Moulouya river basin, Morocco, natural water availability represents a key resource for all economic activities. Agriculture represents the most important sector, and frequently occurring water deficits are aggravated by climate change. On the basis of historical trends taken from CRU TS 2.1, this paper analyses the impact of climate change on the per capita water availability under inclusion of population trends. The Climatic Water Balance (CWB) shows a significant decrease for the winter period, causing adverse effects for the main agricultural season. Further, moisture losses due to increasing evapotranspiration rates indicate problems for the annual water budget and groundwater recharge. The per capita blue water availability falls below a minimum threshold of 500 m^3 per year, denoting a high regional vulnerability to increasing water scarcity assuming a no-response scenario. Regional development focusing on the water-intense sectors of agriculture and tourism appears to be at risk. Institutional capacities and policies need to address the problem, and the prompt implementation of innovative water production and efficiency measures is recommended.

Keywords: North Africa; Moulouya river basin; climate change; population growth; regional development; water availability; water management; water scarcity

1. Introduction

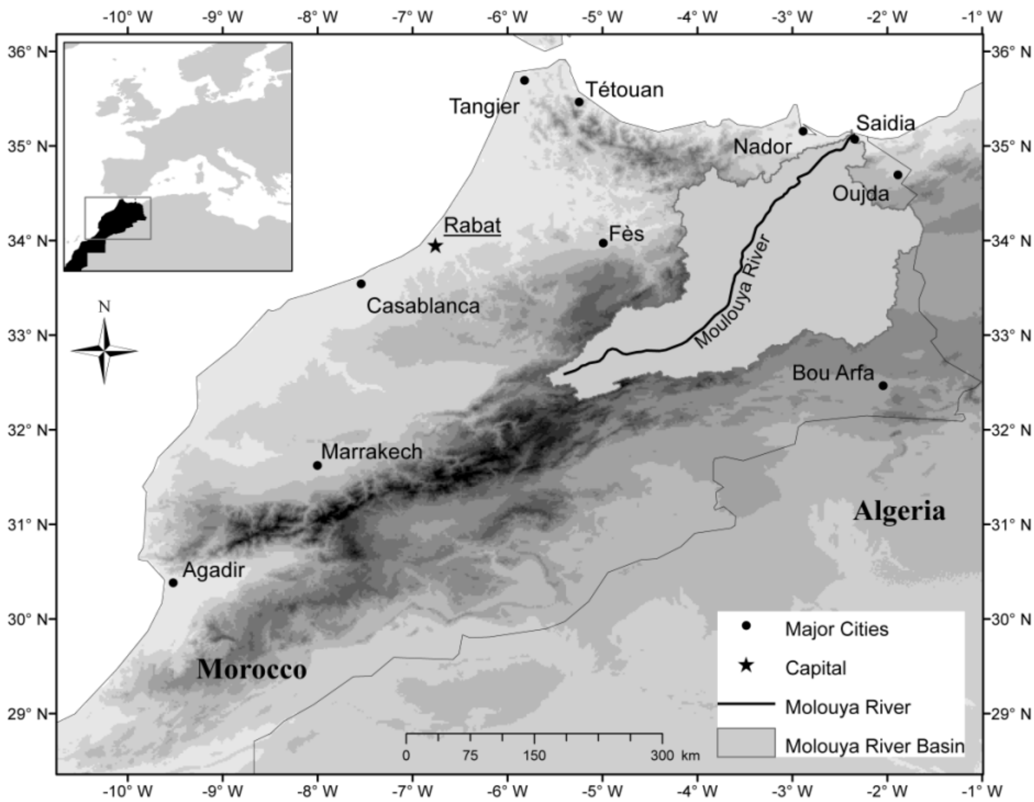
Globally, water resources are increasingly under pressure [1]. The rapidly accelerating exploitation of natural water resources caused by population growth, the intensification of agricultural production, and changing lifestyles associated with an increase of consumption represent the key reasons to cause severe environmental degradation [2–5]. Many populations are aware of the limited carrying capacities of the resources they use, but the complexity of challenges arising from increasing demands and associated environmental impacts does not allow for simplistic solutions [2,6]. Therefore, only minor progress is achieved when fostering economic growth while guaranteeing environmental sustainability [1,7]. Currently, most countries follow the paradigm of economic growth to ensure food security, employment and societal progress. The excessive exploitation of natural resources still represents the standard procedure to achieve socio-economic development. In this context, water plays a key role: the access and the ability to harness water has always been the prerequisite for human progress throughout history [8–10]. Increasingly, in recent decades, water resources have reached or already exceeded physical limits in many locations worldwide due to steadily increasing consumption rates [11–13]. Despite this growing demand at already critical water states, the lack of awareness and inaction, respectively, exacerbates the water situation [14]. The inadequate and excessive usage of available water resources is now threatening development, as any kind of economic activity requires a certain amount of water [3,9]. Next to (existing) technical know-how, an effective water resource management depends on supporting and enabling governance structures and on the enforcement of policy frameworks [15]. But, strategies for the protection of water resources and to safeguard future availability taken to date are still insufficient to account for challenges that result from the water demand of growing populations [4,16].

Additionally, water resources are particularly pressured by recent climate change in terms of interannual shifts of precipitation patterns, decreasing precipitation amounts and increasing temperatures [12]. Thus, the combination of growing water demand and increasingly limited water availability will lead to severe water supply problems if not compensated by innovative approaches [3,12,17].

One region seriously affected by increasing water scarcity is semi-arid North Africa [4,8]. As part of the Middle East and North Africa (MENA) countries, it is among the driest regions of the world, with only 1% of the world's freshwater resources [5]. More than 20 years ago, Falkenmark [8] drew attention to the "*massive water problem*" in the region, stressing the natural finiteness of water resources and the absence of proactive approaches in order to avoid severe consequences. Falkenmark identified the human negligence of the negative feedback mechanisms of the physical environment, caused by the human exploitation of water resources, as the root cause for an alarming increase of regional water scarcity [18]. Further, North Africa has been classified as being a "*key hotspot*" of climate change, thus implying a further aggravation of the already critical water situation [4,19,20]. Due to the currently high economic dependency on the sufficiency of water, increasing water scarcity can lead to development failure (*cf.* the Millennium Development Goals) [9].

In the case study region of this analysis, the Moulouya river basin in north-eastern Morocco (Figure 1), water scarcity has long been a problem [21]. The average annual precipitation is markedly below 400 mm and is strongly concentrated in the cooler half of the year. Despite limited availability, water represents the core resource for the regional economy, which is predominantly agriculture-based [22]. The agricultural sector employs approximately 40% of the regional population and currently consumes *ca.* 87% of mobilized water resources (groundwater and surface water), thus, the socio-economic situation depends to a large extent on sufficient water availability [22,23]. Precipitation is the main hydrological variable, as non-conventional water production plays only a minor role and groundwater resources show alarming rates of degradation, e.g., salinization [22,24]. Due to the fragile water situation, climate change pronounced as decreasing or shifting precipitation will create additional pressures in particular for the fulfillment of agricultural water needs [22,25]. Problems will occur if governmental plans fostering regional development by placing emphasis on the extension of the water-consuming sectors of agriculture ("Plan Maroc Vert": production increase) and tourism ("Plan Azur": expansion of luxury tourism at the coastlines) do not include water compensation and efficiency measures [26,27]. At present, development objectives do not explicitly consider the problematic water situation as a critical barrier for the realization of targeted economic pathways [28]. Additionally, further pressures on water resources, such as regional population growth and population shifts towards urbanizing coastal areas, will amplify water demands. Hence, water is at the core of regional development processes, while at the same time its availability is highly insecure [19,22].

Figure 1. The Moulouya river basin located in North-Eastern Morocco.



The following analysis focuses on relevant drivers for regional water scarcity in the Moulouya river basin. Currently, water management is mainly based on blue water availability (blue water: the amount of rainfall directly exceeding the soil's storage capacity forming the total surface water runoff groundwater recharge, equivalent to the natural water resources) [29]. Innovative approaches, such as the inclusion of green water (refers to the fraction of rainfall infiltrated and stored in the soil, supporting primary productivity of natural and agricultural systems through evapotranspiration; thus, it is crucial for biomass production and rain-fed agriculture), into the regional water budget calculation are not yet pursued vigorously enough [29,30]. However, the main purpose of the article is to increase awareness, that adequate and innovative water management is essential for the region's development and, further, to deliver an argument for promptly needed investments in water technologies. A set of quantitative indicators for climatic and human-caused pressures is used to assess the potential per capita water availability for 2005–2040. The use of indicators to determine the extent of a problematic situation is a frequently used tool in environmental assessments [10]. For this purpose, the Water Poverty Index (WPI) would represent a comprehensive tool to support effective water management [31]. The link between water demand and availability can reveal certain unsustainable patterns of water usage and, thus, support effective water management [31]. However, the lack of regional data represents a major constraint on the application of the WPI. Therefore, as a starting point of analysis and as a guiding framework, the "*levels of water stress*", as defined by the Falkenmark Index, are used as threshold values for the minimum water availability needed for development. Several approaches analyze water scarcity, and the original Falkenmark Indicator is criticized for its simplicity. Therefore, the most popular approaches are described and discussed regarding whether they prove adequate for the purposes intended by this analysis. Climate trends are analyzed for 1971–2005 (reference baseline 1936–1970), and the regional water situation is depicted by calculating the Climatic Water Balance (CWB), used as an indicator for potential water availability. The analysis of physical drivers is supplemented by the socio-economic driver of population growth. A linear trend is derived based on current demand and supply figures, coupled with regional climate and population trends. The potential per capita water availability, the per capita demand-supply gap at 500 m^3/1000 m^3, and the influence of population trends on the potential per-capita availability are calculated.

Regional decision-making relies on area-specific information; hence data on drivers indicating adverse effects to water availability is important. A major problem for decision-making and the adjustment of water management strategies is the lack of understandable information on local climate trends regarding water availability. The Moulouya river basin, similar to many river basins worldwide, is already overexploited [21,22,32]. Thus, the results of this analysis aim to contribute to the stock-taking of regional climate information, with particular focus on the regional water situation. The main causes for the increasingly problematic water situation are highlighted. Potential adjustments of water usage behavior with regards to the adequacy of current water-based development pathways are discussed, and potential adjustments are emphasized.

2. Contextual Background

2.1. The Case Study Area—Moulouya River Basin in North-Eastern Morocco

The Moulouya river basin represents the spatial delimitation for the analysis of the regional water situation. The Basin represents a natural geographical and hydrological unit, and the regional water management operates in this frame [21].

The basin surface area covers *ca.* 54,000 km^2 and is the largest river basin in North Africa [21,33]. The river itself has a length of *ca.* 600 km, supplies the region with freshwater and, thus, determines environmental conditions and human activities from its source in the High Atlas Mountains to its low-lying river mouth at the Mediterranean shoreline near the city of Saidia (Figure 1). The area belongs to the driest regions in Morocco, with an irregular average annual rainfall of 330 mm [33,34]. The climate regime can be classified semi-arid: warm temperate climate with winter precipitation [35]. Along its course, the Moulouya River is partly dammed to ensure regional all-year water supply, mainly for agricultural production. The main agricultural production areas can be found in the north-eastern part of the basin, with irrigation schemes supplied by river freshwater (gravity and sprinkler irrigation) [21,36]. Water storage is mainly secured by a large dam in the Moulouya hinterland (Mohammed V, in operation since 1967). Increasing sediment accumulation and the subsequent loss of storage capacity represents a severe problem for the future functionality of the Moulouya dams [21,36]. This is one reason for a dramatically deteriorating water situation. Further, groundwater resources have already reached capacity limits due to intensive withdrawal and decreasing groundwater recharge rates [21,37]. In the coastal zones, groundwater salinization caused by saltwater intrusion poses a serious problem for water quality and is a further limitation of freshwater resources [21,37]. The River Basin's deltaic plain is a designated Ramsar (RAMSAR Convention on Wetlands) site, emphasizing the ecological importance, its sensitivity to disturbances and its worth to be protected [38].

With an average total renewable per capita water availability of less than 500 m^3/year, water scarcity in the Moulouya river basin represents not an exceptional, but a common situation [21]. However, the particular influence of climate change and population growth on the overall regional water availability has not yet been assessed to the best knowledge of the authors [22]. The awareness regarding the regional vulnerability to water scarcity and water shortage situations is very high, and water management is a policy priority in Morocco [22]. As a reaction towards increasing water demand large-scale water infrastructures were built, e.g., large dams and reservoirs [39]. Under changing climate conditions, these solutions might no longer be sufficient, due to high losses of renewable water resources, e.g., due to higher evapotranspiration rates, groundwater recession and reduced run-off [40,41].

2.2. Measuring Water Scarcity—Indicators, Approaches, Limitations and Critique

Water represents a key limiting factor *for* food production, while water scarcity is mainly caused *by* food production [19]. The true nature of water scarcity is as complex as the physical flows and dynamics of the resource itself [19]. Global freshwater scarcity induced by rapidly increasing demand requires solutions, thus representing a particular challenge for science and water governance [42]. Mainly since the past two decades, different approaches have been concerned with the capturing of relevant aspects of pressures on water resources and with the characterization and measurement of water scarcity [43,44]. The description of water scarcity by using more or less complex indicators involves difficulties and uncertainties, thus there is no consensus on a standardized measurement [43].

A particular weakness of current indicators is the focus on water withdrawal instead of actual water consumption [45]. Further, they do not include environmental flow requirements and temporal variation.

Thus, they do not represent a comprehensive tool for the assessment of water scarcity situations, but, however, support the indication of disequilibrium of water abstraction and water availability.

The most common approaches are the Falkenmark Water Stress Index [8], the Social Water Stress Index (SWSI) [46], the Water Resources Vulnerability Index (Criticality Ratio) [47], the Physical and Economical Scarcity Indicators [11] and the Water Poverty Index [31] (see Table 1 for a comparison of approaches).

Table 1. Comparison of most popular approaches to measure water scarcity based on [19,48,49].

Index (year)	Approach and benefits	Limitations
Falkenmark Water Stress Index (1989) [8]	• Total annual renewable water resources available to the population (per cap/year freshwater availability). • Determines thresholds for minimum per capita water requirements. • Data most often available as well on regional or smaller scales. • Easy to apply and intuitively understandable.	• Focus on blue water stress only, omits green water. • Excludes main drivers for water scarcity, e.g., demand, efficiency, management and lifestyles. • Societal adaptive capacity is not included. • Assumes that all countries globally use or need the same amount of water for development.
Social Water Stress Index (2000) [46]	• Builds on the Falkenmark indicator and applies the UNDP's Human Development Index (HDI) to depict the social dimension of water scarcity. • Contextualizes water stress with a low social adaptive capacity.	• The HDI does not include ecological factors and focuses mainly on economic criteria [50]. • The HDI does not depict intra-national differences, as the data applied is country-based only.
Water Resources Vulnerability Index (criticality ratio) (2000) [47]	• Withdrawal-Ratio of human water use to total renewable water resources. • Comparison of country-specific water demand and availability. • Scarcity: proportion of total withdrawals relative to total available resources.	• Role of non-natural resources (e.g., desalinization), recycled or re-used water is not considered. • Omits behavioral change as a reaction towards lowering water capacities, e.g., the implementation of new technologies.
Physical and Economical Scarcity Indicators (2007) [11]	• Accounts for all renewable water resources available for primary supply under future scenarios of improved water management policies, e.g., infrastructure development and irrigation efficiency. • Physical scarcity: countries being unable to meet future demands *despite* future adaptive capacity (e.g., investments in water infrastructures). • Economical scarcity: countries unable to meet future water demand *without* investments in water infrastructures despite sufficient renewable resources.	• Measuring of indicator is very complex and time-consuming. • Data requirements difficult to meet, thus it's mainly based on expert judgments. • Omits ability to adapt by virtual water imports (food) or water saving devices. • Partly green and blue water are summed up, providing too high potential availability values. • Country-based aggregated analysis.
Water Poverty Index (2003) [31]	• Determines water security at household and community level based on income and wealth. • Measures and aggregates five dimensions: level of access to water; water quantity, quality and variability; water used for domestic, food, and productive purposes; capacity for water management; environmental aspects.	• Focuses on limitations of the Falkenmark Index. • Comprehensive amounts of data required. • Approach of high complexity. • Lacks intuitive understanding. • Suited for smaller rather than national scales.

The original concept, the Falkenmark Index from 1989, concentrated solely on blue water availability, leaving aside green water [19]. The Falkenmark Index is often criticized for being too simplistic, as:

- It does not differentiate between countries regarding their specific water stress thresholds (one country might be able to handle a 500 m^3 per capita annual availability; another might be experiencing severe water problems at that level);
- It focuses on natural freshwater availability only and does not include man-made freshwater sources (e.g., desalinization) or the accessibility of water;
- It does not consider regional differences of the water use of countries (e.g., urban areas often have higher consumption rates than rural areas) [11,19,43,44,48,49].

The introduction of the green water concept by Falkenmark [29] in 1995 represented a milestone regarding the evaluation of available freshwater resources and water use efficiency [19,30]. The importance of green water is often underestimated, considering that global food production for the most part relies on rain-fed irrigation (up to 60%, including grazing for meat production or forests for wood production) [44]. However, most water scarcity indices build upon and complement each other, trying to overcome presumed limitations and to increase the predictive validity [43]. The majority of approaches affirms a crucial role towards the (re)adjustment of water management and water governance in order to react adequately upon a seriously deteriorating water situation [19,48].

Next to the criticism regarding some indicators for being too simplistic, in particular addressing the Falkenmark Index, there is as well a critique that sophisticated approaches can be too complex for practitioners and decision-makers [19]. For the latter, simple approaches may be more appropriate to raise awareness regarding the prior causes of a deteriorating water situation. Further, as is the case for the Moulouya river basin, water management currently relies on sufficient blue water availability. The Falkenmark Index is a comprehensible tool to raise awareness regarding the finiteness of blue water resources necessary for food production, taking into account that green water significantly changes the picture of the potential water availability. However, the optimal use and exploitation of rainwater requires a re-oriented water strategy and institutional changes. Thus, as a first step, on the basis of the Falkenmark Index, it can be very well depicted that building on blue water without efficiency increase leads to a problematic impasse.

Indicating Water Stress with the Falkenmark Index (FI)

As a baseline, in order to assess the dimension of the problematic water situation in the case study, threshold values of the Falkenmark Water Stress Index (resource to population index) are referred to as indicators for regional water stress levels [8]. Falkenmark compiled and classified the per capita water usage in multiple countries and deduced social water stress levels as the fraction of the total annual renewable water resources available for human usage (Table 2) [8,51]. The index is widely used to indicate water stress and to emphasize the interrelationship between limited water per capita availability and implications for development. Falkenmark [51] categorizes water conditions, and describes index thresholds with regard to water resource management problems. As the index focuses on the (minimum) human water availability needs as a basic requirement for development, it can thus serve as a landmark for the adaptation needs of water management, depending on the water needs of development trajectories [52].

Table 2. Water stress levels and definitions, based on [8,48,51].

Water availability (per capita in m^3)[a]	Level of water stress	Water resource management problems and constraints
>1700	Occasional or local water stress	No or limited problems
1700–1000	Regular water stress	Heavy pressures on water resources, general management problems
1000–500	Chronic water scarcity	Chronic water shortages/limitation to economic development and human health and well-being
<500	Absolute water scarcity	Beyond availability limit; beyond the water barrier of manageable capability, main constraint to life

Note: [a] refers to renewable and usable water.

3. Methodology

3.1. Data

Data gaps on water availability are common in North African countries, where instrumental coverage and the compiling of long-term records and data series are not well established [53]. Ideal data would be spatially well-resolved and show continuity [48]. Water usage data is especially hard to find; agricultural water use or groundwater withdrawals are rarely measured. This is also the case for the Moulouya river basin, where empirical data on sector-comprehensive water demand and availability is neither available nor accessible or very fragmented [54]. To nevertheless enable the assessment of potential implications for the regional water situation, statistical data was obtained from several sources. Missing measured data for the case study area were filled by a consecutive monthly climate proxy data series for temperature and precipitation for 1971–2005 (reference baseline 1936–1970) from the gridded and interpolated climatology at a 0.5° × 0.5° scale of the Climate Research Unit, CRU TS2.1 [55,56]. Out of this, 20 data points covering the margins of the Moulouya river basin were chosen. For precipitation, the corrected and homogenized "CRU/PIK" data set was used [57]. For the purpose of a small-scale historical trend, the "CRU/PIK" precipitation data so far provides the best applicable data under acknowledgement of the generally very limited regional water data situation.

Reference values for regionally mobilizable water (groundwater considered to be potentially usable) and water demand are taken from Snoussi [21] and Imassi [58] as well as Moulouya basin-specific population data for 2004. Data on exploitable natural water resources and mobilized groundwater resources for Moulouya river basin were obtained from FAO/AQUASTAT [24,59] and UN-Water/Africa [60]. The last population census for Morocco was conducted in 2004 [23]. Therefore, to achieve an approximate picture, population trends and projections were scaled down from national population dynamics at a medium variant obtained from United Nations Population Division [61], combined with the official population census of Morocco of 2004 [62]. However, current extrapolations of population dynamics involve uncertainties and do not capture accelerating coastal urbanization trends. The latter is essential to estimate local water demand in urbanizing areas and to adjust infrastructure capacities accordingly.

3.2. Indicators for Regional Water Availability in the Moulouya River Basin

In order to describe the blue water situation in Moulouya, to determine drivers for regional water stress and to project foreseeable problems regarding per capita water availability, the following gradual analysis steps are performed: a trend analysis of the mean annual and seasonal regional precipitation for 1971–2005 (reference baseline 1936–1970); a trend detection of the potential evapotranspiration (Pot.ET) for 1971–2005 as calculation baseline for the regional CWB (denoting the potential blue water availability); and the projection of the regional supply gap as a result of the imbalance between per capita water demand and natural water availability for 2005–2040 (linear trend extrapolation based on the current mobilization rate and the regional population trend). Calculations are performed for each of the 20 CRU data grid point in the basin, then seasonally or monthly aggregated.

3.2.1. Precipitation and Temperature Trends

The relative long-term trend (1936–2005) of the spatial-temporal climatology was analyzed using a linear trend method of minimum squares. The region is characterized by a high inter-annual variability, very dry summer and wet winter periods. Potential shifts and/or a decline of winter precipitation would be detrimental for the agricultural cultivation period, which starts in autumn and ends with the harvesting period in spring [59]. Precipitation for rain-fed production is thus needed between autumn and spring, and the cultivation period is adjusted accordingly. Significance testing of precipitation trends was performed by an independent two-sample t-test for the seasonal time series: DJF (December, January, February); MAM (March, April, May); JJA (June, July, August); and SON (September, October, November) for 1971–2005 (reference baseline 1936–1970). The assessed data records span 35 years, considered appropriate to deliver a valid statistical mean, as the minimum time series for precipitation should not be below 30 years (classical period, as defined by the World Meteorological Organization WMO).

3.2.2. Potential Evapotranspiration (Pot.ET) in the Moulouya River Basin

In north-eastern Morocco, winter rainfall is crucial for the water balance. Precipitation is not equal to later water availability from run-off or groundwater. The influence of temperature on evapotranspiration is essential; cooler temperatures can impede moisture losses and, thus, have the potential to partly compensate for declining rainfall budgets. The Pot.ET substantially determines theCWB and indicates the extent of evapotranspiration under the assumption of a continuously wet surface, based on the empirical relationship between potential evapotranspiration and mean temperatures [63]. Changes in evapotranspiration rates are an important indicator forwater stress situations. Increasing evapotranspiration may substantially impair run-off rates and soil moisture. Here, to identify a long-term annual and monthly trend the Thornthwaite formula [63] was applied. The Thornthwaite formula is a temperature-based Pot.ET model and requires only few meteorological variables for its calculation: mean monthly temperatures over the annual cycle and the average daylight hours. The Thornthwaite method is often criticized for its limited applicability due to minimum input variables and due to estimation inaccuracies. Given a sufficient data situation, newer approaches can deliver more accurate results [64]. Based on the CRU data points with temperature and rainfall as the only variables, a parameterization according to the FAO-standard method, the Penman-Monteith formula, lacks necessary input data (air temperature, relative humidity, wind velocity and net radiation) [64]. Here, the Pot.ET after Thornthwaite is intended to function as an input variable for the calculation of the regional Climatic Water Balance. To increase its validity, the correction factor for mean daylight values is adjusted according to the geographical coordinates of the river basin.

In Equation (1), Pot.ET is the potential evapotranspiration in mm per month; C is the daylight coefficient (mean possible duration of monthly sunlight in the latitudes of Moulouya river basin; T_m is the mean monthly temperature; I is the heat index and depends on 12 mean monthly temperatures (Equation (2)); and α (Equation (3)) is a function of the heat index for semi-arid locations [63,65].

$$\text{Pot.ET} = 16\, C \left(\frac{10\, T_m}{I} \right)^{\alpha} \tag{1}$$

$$I = \sum_{i=1}^{12} i \left(\frac{T_{\alpha i}}{5} \right)^{1.5} \tag{2}$$

$$\alpha = (67.5 \times 10^{-8} I^3) - (77.1 \times 10^{-6}\, I^2) + (0.0179\, I) + (0.492) \tag{3}$$

3.2.3. The Climatic Water Balance (CWB) in the Moulouya River Basin

Based on the prior results of precipitation and temperature trends and the Pot.ET, the CWB is calculated for 1936–1970 and 1971–2005 to indicate a long-term trend change for each month. The CWB denotes the difference of the average monthly precipitation (*P*) minus the potential evapotranspiration (CWB = P − Pot.ET) in order to indicate annual precipitation deficits and interannual shifts of relevant precipitation periods (e.g., for groundwater recharge).

3.2.4. Regional Population Trend

Population growth represents a main driver for water stress, if not accompanied by measures for capacity increase [31]. The projected population trend for Morocco at medium term was derived from United Nations Population Division [61] and scaled down based on regional population data taken from the official Moroccan 2004 population census [62]. The UN population growth rate was applied to the regional population based on values from 1995 to deduce estimates for population development until the year 2040.

3.2.5 Calculation of Regional Per Capita Water Availability for 2006–2040

The detected trend for the regional CWB serves as the basis of calculation to statistically derive the trend for future water availability (projection period 2006–2040) by applying a linear regression based on the comparison of the periodical values (1971–2005 with 1936–1970 as reference baseline). Reference values for the per capita mobilizable blue water (technically and economically exploitable) and per capita water demand (baseline 2004) are included to assess the potential deficit or surplus under the driving forces of population growth and climate change [21,66]. The combination of population and climate trends delivers projections for the potential per capita availability or the extent of water scarcity, respectively.

The calculation is based on the linear trend of the CWB of 1971–2005/1936–1970 as total mobilizable surface- and ground-water (blue water) in relation to the regional population growth. Two water scarcity levels are taken into account: available water at a hypothetical average regional water demand of 500 m^3 and 1000 m^3, respectively.

4. Results

4.1 Climate Impacts on the Water Regional Budget

Relevant precipitation for the regional water budget falls between September and May. An annual decrease of *ca.* 7% is observed for 1971–2005 (reference baseline 1936–1970) (Figure 2). The mean values of the periodical standard deviations (SD) related to mean precipitation show no significant modification. Thus, the probability of an abnormal precipitation situation is quite low. The regional climate regime is undergoing an established precipitation loss, in particular in the cooler half of the year. Water accumulation in the summer months is greatly reduced due to high evapotranspiration rates. Negative trends between October and March are considered to be detrimental for the annual water balance, for groundwater replenishment, as well as for the winter-based agricultural cultivation period. Losses cannot be compensated by precipitation increases in summer. For the basin area, a consecutive decrease of mean monthly precipitation is found in the rain relevant months between October and January and further in April, with a highly significant trend for the winter season DJF (−21%) (Figure 3, Table 3). Thus, next to an overall negative annual precipitation trend, the hydrological important winter season underwent a significant moisture loss. Further, the formerly typical gradual precipitation increase between September and December (precipitation maximum) has weakened substantially.

Table 3. Significance testing (two-sample *t*-test) of seasonal precipitation change in the Moulouya river basin.

Season	DJF	MAM	JJA	SON
Seasonal mean in mm 1971–2005 (reference baseline 1936–1970)	145 (124)	110 (111)	18 (20)	89 (83)
Trend (change)	−21%	0	2%	−6%
Statistical significance (α = 0.05)	0.024	0.77	0.13	0.096
Significance level	Highly significant	not	not	Slightly significant

Sources: Downscaled precipitation data for basin area based on [55,57]; basin area [33,36].

Figure 2. Mean annual precipitation in the Moulouya river basin: long-term trend and periodical change 1971–2005 (reference baseline 1936–1970).

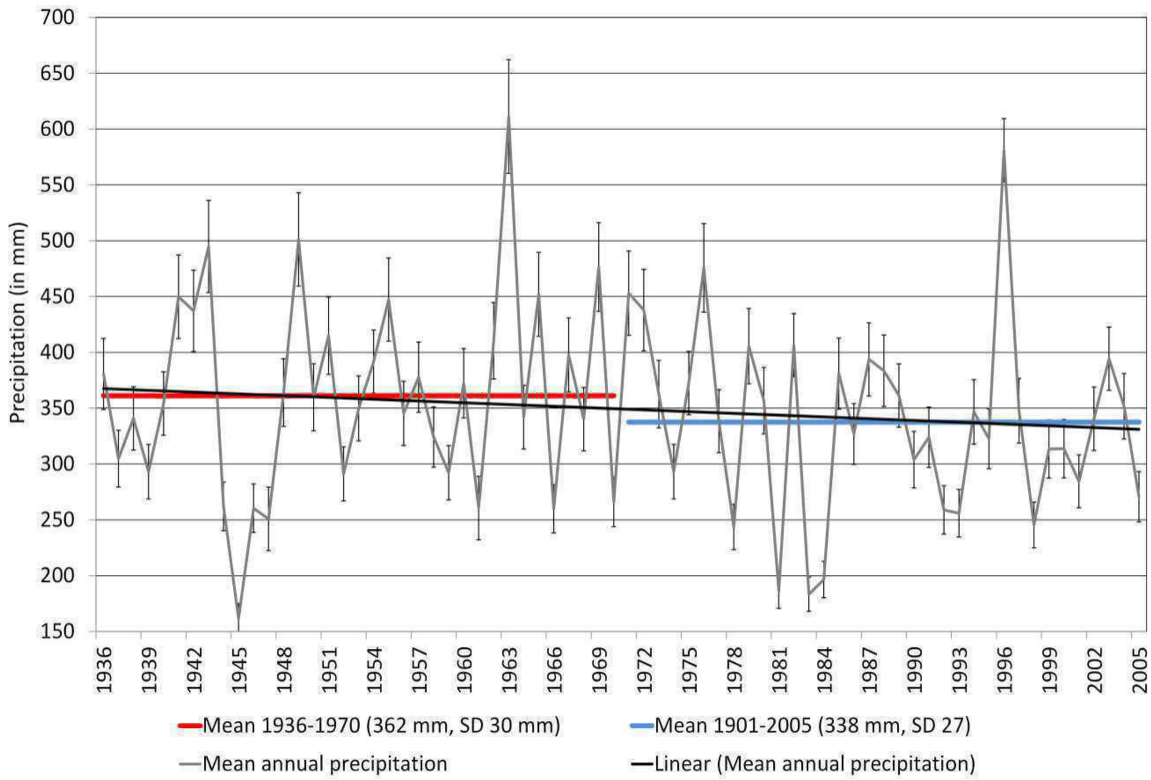
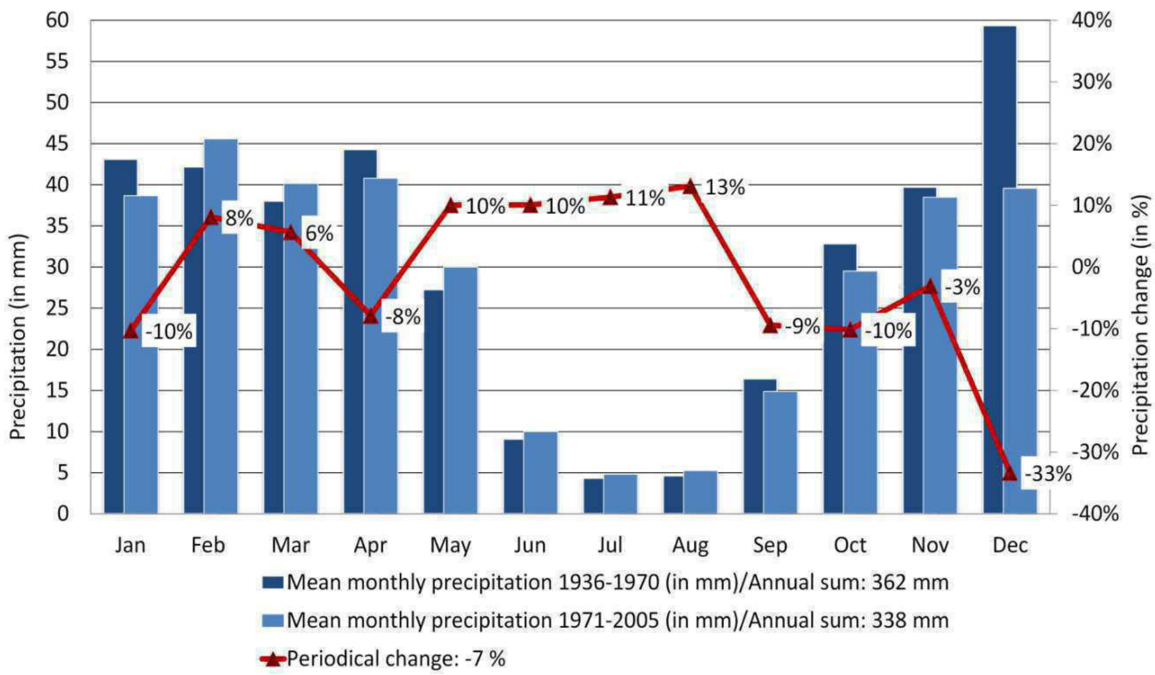
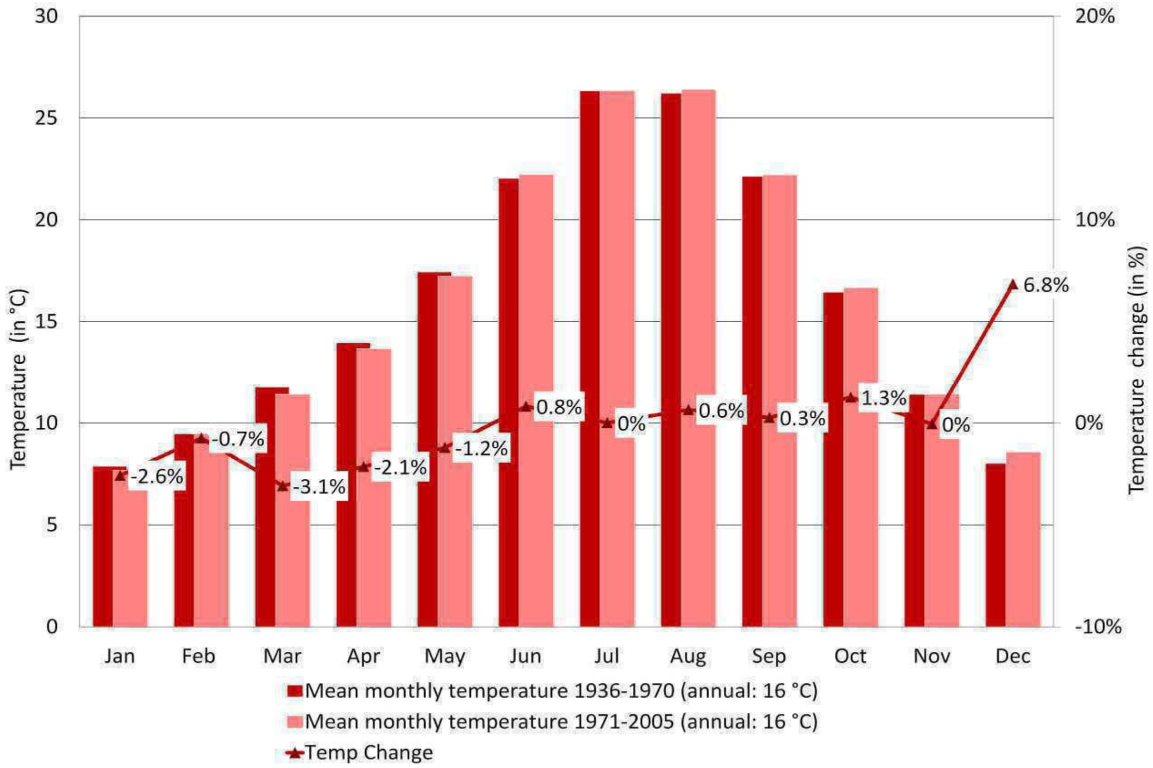


Figure 3. Mean monthly precipitation change and periodical change in the Moulouya river basin 1971–2005 (reference baseline 1936–1970) and the monthly difference in %.



The temperature parameter is essential for the calculation of the Pot.ET; increasing temperatures impede moisture losses and lead to the decline of water budgets. In Moulouya river basin, the annual temperature progression shows a gradual increase between January, reaching the maximum in June/July, and decrease thereafter, with the lowest temperatures in December/January. While the mean annual temperature remains nearly unchanged (16 °C), a significant increase can be observed for the month December (+6.8%) (Figure 4). This trend can impinge on the winter water amount and cause lower recharge rates.

Figure 4. Mean monthly temperatures and periodical change in the Moulouya river basin 1971–2005 (reference baseline 1936–1970) and the monthly difference in %.



The Pot.ET calculated after Thornthwaite [63] revealed a gradual increase from January onwards reaching its maximum in July, and it's minimum between December/January (Figure 5). In general, increasing temperatures lead to higher Pot.ET rates given an unchanged amount of water or moisture to evaporate. In the case of precipitation decrease, the Pot.ET lowers accordingly, if temperatures are not increasing. The annual sum of Pot.ET remains unchanged in the case study area, while a decrease is observed in the first half of the year and an increase thereafter. The significant higher monthly temperature in December (+6.8%) causes an annually exceptional increase of the Pot.ET rate (+12%) and indicates a strong loss of moisture.

The mean monthly change of the regional CWB for 1971–2005 (reference baseline 1936–1970) is calculated based on the difference of the sums of Pot.ET (Figure 6). Results show the annual distribution of precipitation surpluses or deficits, indicating the month of positive water budgets and the historical change. As is normally the case in this climate zone, a situation of water deficiency is common during the hot summer months between June and September (deficit period). Surpluses of precipitation (precipitation > potential evapotranspiration) can be found in the remaining months (surplus period). The potential annual water availability reduces considerably from 184 mm down to 161 mm (−13%), mainly between October and January (Figure 6). This statistically significant negative trend for the winter period outbalances the increases of other months.

Figure 5. Change of mean monthly evapotranspiration rate (Pot.ET after Thornthwaite) in Moulouya river basin 1971–2005 (reference baseline 1936–1970) and the monthly difference in %.

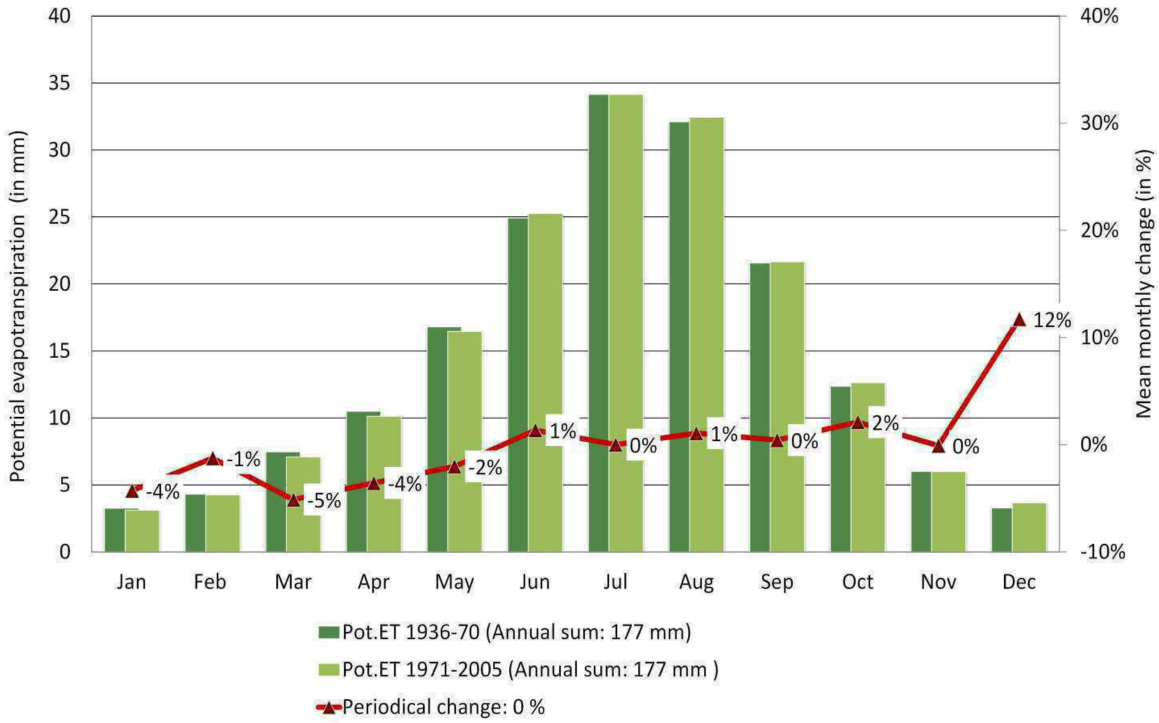
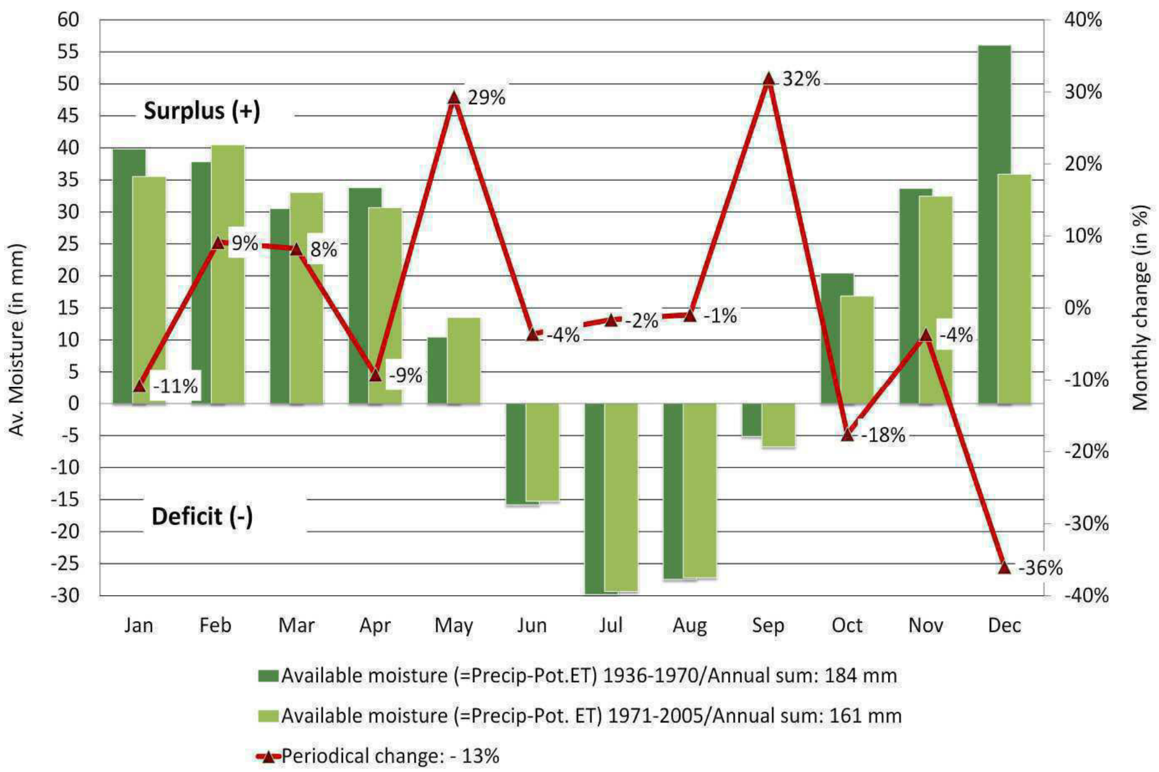


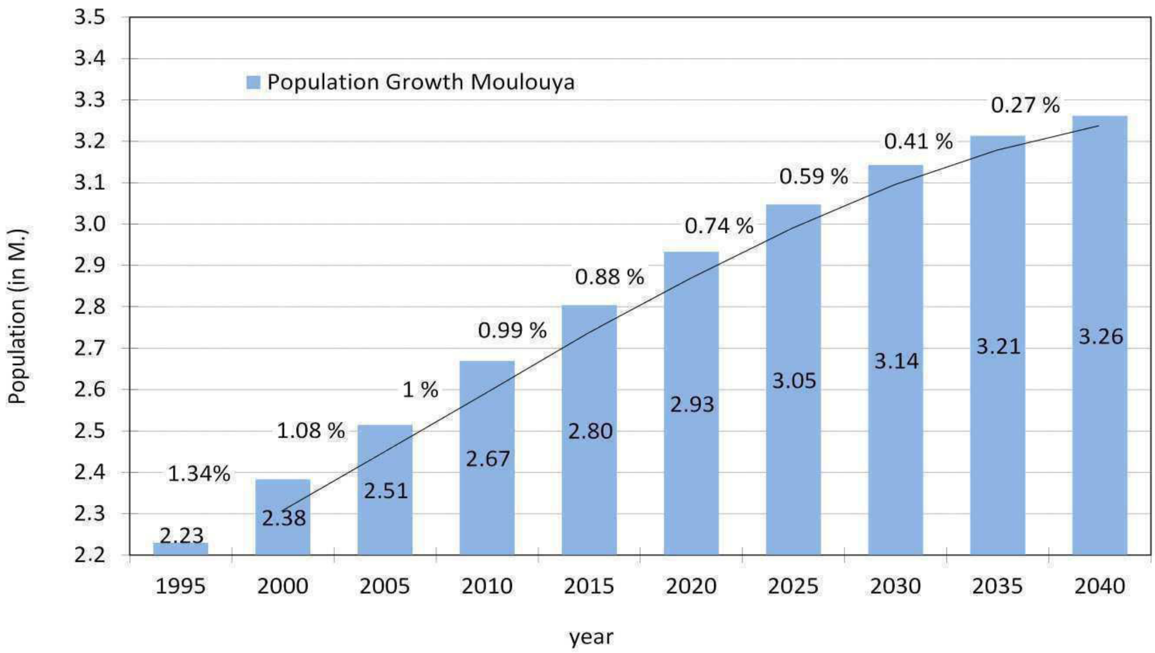
Figure 6. Change of mean monthly CWB in the Moulouya river basin 1971–2005 (reference baseline 1936–1970) and the monthly difference in %.



4.2 Impacts for Regional Per Capita Water Availability

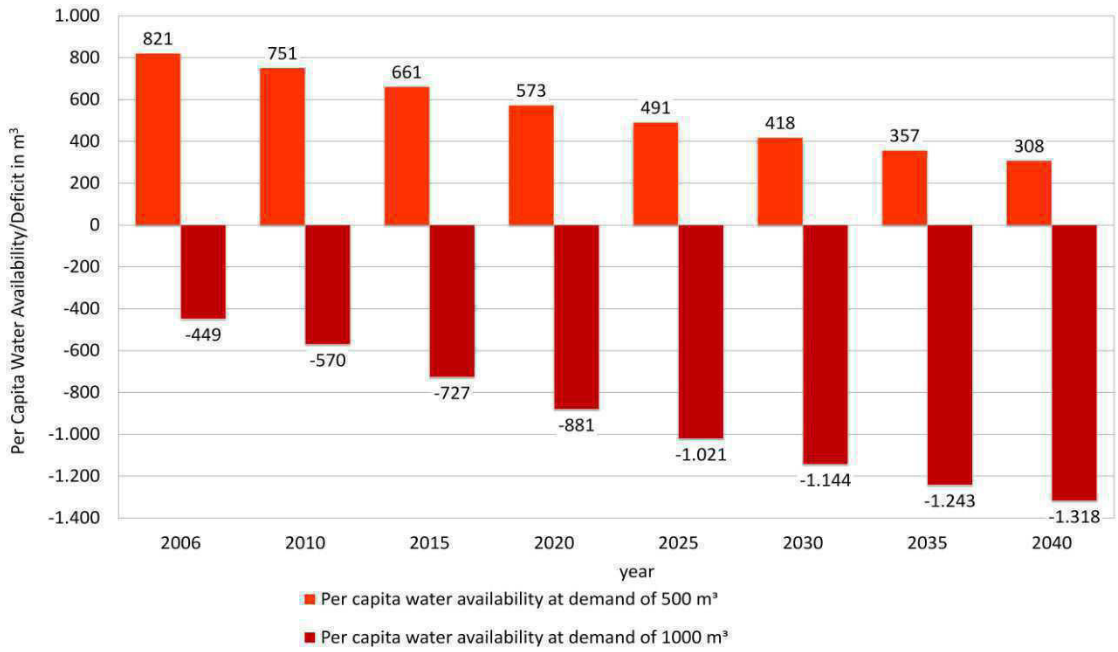
The peak of projected population growth in Morocco will be reached in 2020 [61]. The national population development projection at a medium variant is transferred to the case study area, based on regional population figures (Figure 7). Even under a weakening population growth scenario, the region will have to supply a considerable amount of additional water to consumers. Further, additional growth can be expected due to hinterland migration towards the urbanizing coastal areas.

Figure 7. Population projections for the Moulouya river basin (1995–2040). Values in bars refer to the potential population in the respective 5-year segments based on the UN population growth rate for Morocco [61].



Under the inclusion of regional population projections and potential water availability, two scenarios are derived for 2006–2040 to depict the human water supply situation if no compensatory measures are taken (Figure 8). According to Falkenmark per capita water availability between 1000 m^3–1700 m^3 denotes "*regular water stress*" [51]. Below a 1000 m^3 per capita availability, a situation of "*chronic water scarcity*" marks a critical barrier for any economic activity and seriously limits economic development [51]. The real situation is alarming: the already markedly below-average regional supply capacity (442 m^3 per capita in 2006) does not fit the actual demand (508 m^3 per capita in 2006) [21]. Under the assumption of a decreasing CWB reinforced by pressures resulting from population growth, the regional per capita availability of blue water will fall below the critical value of 500 m^3, even under an average low-demand assumption of 500 m^3. Assuming a minimum water demand of 1000 m^3, the overall availability will predominantly range in negative margins. Figure 8 shows the per capita water availability at an average water demand of 500 m^3 and 1000 m^3, respectively. Both values indicate considerable problems for development (Table 2), while a per capita availability of lower than 500 m^3 denotes—according to Falkenmark [8,18,51]—that socio-economic development is virtually impossible without capacity improvements of water infrastructures and water usage behavior. The combined trends of the regional CWB and population growth show the risk of severe water deficits or total shortfalls for both scenarios. This is not only problematic for human supply and agricultural production, but could as well be detrimental for the natural environment (e.g., increases of droughts, increase of wild fires, canopy loss, increasing erosion). These figures point out that relying on blue water resources only will not suffice to achieve the targeted development objectives.

Figure 8. Scenarios for per capita water deficit/availability for 2006–2040 at two demand rates.



5. Discussion

The very limited data availability and quality for the case study area poses a challenge for adequate water management and for decision makers. Discussions with stakeholders in the context of the ACCMA (Adaptation to Climate Change in Morocco) project revealed that climate change is feared to additionally enhance the pressure on water resources. Further, there was broad consensus that the current routines of water usage need to be improved and to become more efficient. This is particularly because regional development targets are concentrated on the expansion of water-intense sectors, namely agricultural production and luxury tourism at the coastline (city of Saidia, Figure 1). Insufficient blue water availability thus limits regional development and economic growth unless appropriate counteraction. As there is a discernible human influence on the scarcity situation, an important aspect of this analysis was to emphasize the human influence on the increasing scarcity of water availability. The water problem is not a novel phenomenon; but still water infrastructures are insufficient to fulfill the increasing demand. Under climate change and population growth, the need to innovatively restructure and adapt water management is a crucial task. Otherwise, the deterioration in living conditions caused by massive water scarcity may give rise to, inter alia, new migration streams or water conflicts.

The stepwise analysis of the increasingly problematic water situation in the area of the Moulouya river basin focused on two main drivers: regional climate change and population growth. Indications of climate change refer to changing average weather conditions within a considerable period of time (35 years). The assessment of historical climate trends shows a deterioration of the water situation. The CWB was used as a core indicator for declining water availability and calculated on the basis of aggregated climate data taken from CRU TS2.1 and "CRU/PIK" data sets. For the analysis of climate drivers we have found:

- A mean annual precipitation decrease for 1971–2005 (−7%);
- A significant decrease of winter precipitation (−21%);
- A slightly significant drying trend for autumn 1971–2005 (−6%);
- A significant temperature increase for December 1971–2005 (+6.8 °C); and
- A 13% decrease of the regional CWB for 1971–2005.

Thus, there is a clear indication of decreasing winter precipitation, which is a vitally important hydrological variable for the overall regional water balance. The resulting consequences can be serious reduced productivity and yields in the agricultural sector, and the possibility of revenue losses in the newly established tourism sector in case water capacities will run short. Combined with population projections for the region, we assume:

- A very likely increase of regional water demand due to population growth;
- A reinforcing trend of the critical per capita water supply situation (below 500 m^3); and
- A very likely establishment of a permanent water deficit situation.

Insufficient water availability is a principal obstacle to achieving regional development objectives. A per capita availability of below the 500 m^3 threshold represents a "*main constraint to life*" [8,48,51]. Considering the per capita water deficit projected for the region, there is no other option than to implement innovative water production techniques (e.g., desalinization) [67] combined with an efficiency increase (waste water treatment, modern sewerage systems) to create stable conditions for water supply for human consumption or irrigation. Regional water policies have to be adjusted accordingly to safeguard future water demands. Further, development targets have to take into consideration limited resource capacities and competitive water sectors. The planning of large tourism facilities, which require an all-year continuous water supply (e.g., for garden and golf areas, and pools), such as in the coastal zone of Saidia (Figure 1), must be equipped with internal water treatment systems. The agricultural sector is the largest regional water consumer, with withdrawal rates of about 87% [59]. Under dryer conditions and rising temperatures in the agriculturally important winter period, supplementary irrigation will be indispensable. If water for irrigation cannot be guaranteed, the loss of cultivated land will be a consequence with complex socio-economic impacts, such as productivity losses, spread of poverty and increasing migration processes [68].

Implications for Regional Water Management

Regional stakeholder workshops with farmers and local decision makers in the context of the ACCMA project revealed high awareness regarding the problematic water situation. Particular problems referred to include the increase of water supply problems, increasing dryness and an associated reduction in agricultural productivity with the result of economic stagnation. The detected climate trends of this analysis support these perceptions and observations. However, it delivers a strong argument for a water resource management that takes into account both the aggravating climate conditions and the improvement of natural resources management, including water-use efficiency.

Currently, in many MENA countries, policy changes most often are a result from severe water crisis, affecting a critical mass of the population [4]. The Moroccan development plans "Plan Azur" and "Plan Bleu" presuppose water availability despite increasingly poor water conditions in some of the targeted regions [26,27]. Considering the growing water demand and the decreasing water budget, it is therefore important, above all, to strengthen water conservation, to improve water efficiency and to take innovative approaches aimed at ensuring a sufficient supply of water [4]. For example, water resources in the Moulouya basin suffer from degradation due to water pollution of industrial and agricultural origin [33]. Wastewater collection and treatment plays only a minor role in Morocco (less than 10%), and accurate data on wastewater volumes produced are not available [33]. The potential of wastewater resource exploitation is a neglected feature in the public water budget calculations of the regional water management, even if wastewaters in the Moulouya basin are partially used by farmers for irrigation, in particular in drought periods [69]. As well, taking into consideration the increasing urbanization rate in the lower basin area and the implementation of large tourism facilities, to relieve the pressure on blue water resources, regional water management could strengthen the focus on urban water reuse, e.g., by wastewater treatment plants located close to the place of use, and could further stipulate small-scale water cycles for water-intensive industrial production or tourism facilities. As regards water efficiency and to address water scarcity in agriculture, the potential of green water exploitation should be included as an essential part of the overall regional water resource calculations [19,44]. However, temporal variation and irregularity of rainfall leads to different amounts of available water and limits the possibilities of rain-fed agriculture [21]. Blue water will thus be essential for irrigation during low-precipitation periods [21].

To avoid water shortages in times of water demand peaks, and to avoid the usage of water from resources already under pressure, the Integrated Water Resource Management strategy in the region (effected by Agence du Bassin Hydraulique de Moulouya, see [70]) could consider a water management concept that focuses on the optimal valorization of water resources [45,71]. For example, the incremental value per m^3 water deployed in the tourism sector might result in higher net gain than the same amount of water used for crop production. The emerging concepts of virtual water trade and the water footprint can support decision-making in water-short regions/countries by linking water consumption and production with a market-oriented approach for improving water demand management and by the identification of areas with inefficient water use [42,45]. It is thus imperative to improve the skills of water managers to adjust to future challenges and to pursue innovative trajectories for a sustainable water demand and supply management, instead of focusing on large-scale technical solutions as key objective in water scarce regions [4,19,44,48]. However, to be effective, water-resource related management strategies must consider specific local circumstances and should be in line with superordinate water policies and within a supportive political framework [15,48].

6. Conclusions

The analysis looked at different aspects to indicate the vulnerability of the Moulouya river basin to increasing water scarcity. Based on the simple and intuitively understandable Falkenmark Index and its water stress thresholds, the region's exposure to water stress are analyzed and depicted. Climate change in terms of a decreasing natural water budget combined with water-based development objectives and population growth will enhance the pressures on water resources. A decreasing availability will have negative impacts, as the dependency on natural water availability in the region is very high. A main purpose of the analysis was to emphasize the need for societal and institutional responses. The degree of impacts associated with climate change impacts and population growth can be lowered by the prioritization and prompt implementation of water efficiency measures that also include innovative approaches, such as *green water*, crucial for rain-fed food production, the water footprint or virtual water trade approach to valorize water.

However, natural resources are fundamental to the physical and economic survival of the region's population. Despite existent awareness, local technical capacities for efficient water usage are inappropriate [67]. Further, climate trends revealing the significant increase of dryer winters and autumns, coinciding with the cultivation period, are expected to severely interfere with the agricultural production. Very recently, the tourism sector represents an additional regional water consumer, causing seasonal demand peaks in the high summer season. This might lead to problems for the start of the following cultivation period in autumn, if water originally stored for this purpose is depleted.

Development targets can only be achieved if water conservation measures are implemented as a reaction towards increasing demand rates caused by population growth and the expansion of water-intense sectors. The analysis found a severe imbalance between potential water availability and minimum per capita water needs. The per capita blue water availability will fall markedly below the 500 m^3 thresholds in the near term. The minimum per capita need of 1000 m^3 in order to push economic development is considered as being impossible to be achieved on the basis of blue water [51]. Dry winters and an increased evapotranspiration rate will limit the natural water recharge and lead to a reduced annual water budget. In general, the water budget will not at all be sufficient to serve the targeted course of socio-economic development. Additional pressures, such as increasing siltation rates of existing dams of the Moulouya River, already cause high costs for maintenance [21]. This supports the argument that water management based on blue water resources only is not an appropriate measure of cost-effective water management. Given that water availability represents the key resource to achieve development targets, institutional capabilities and policies need to address the serious degradation, and financial and technical support is urgently required [68,69]. Once a certain threshold of water degradation is exceeded, the compensatory costs for alternative water resources might by far exceed the costs of promptly taken measures to adjust regional water capacities. Finally, the ecological value of water resources is inter alia expressed in the designation of the River Moulouya deltaic plains as RAMSAR wetlands. Not only is the regional water supply at risk, but also a unique ecosystem and wildlife habitat of international importance.

Acknowledgments

This work was supported by the project "ACCMA—Adaptation to Climate Change in Morocco" as part of the program "Adaptation aux Changements Climatiques en Afrique (ACCA)" of the International Development Research Centre Canada (IDRC) and the UK Department for International Development (DFID). The authors would like to gratefully thank Susanne Stoll-Kleemann (University Greifswald) and three anonymous reviewers for their valuable and constructive comments on this manuscript.

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Originally published as:

Tekken, V., Costa, L., Kropp, J.P. (2013): Increasing pressure, declining water and climate change in north-eastern Morocco. *Journal of Coastal Conservation.*

DOI: 10.1007/s11852-013-0234-7

J Coast Conserv
DOI 10.1007/s11852-013-0234-7

Increasing pressure, declining water and climate change in north-eastern Morocco

Vera Tekken · Luis Costa · Juergen P. Kropp

Received: 7 August 2012 / Revised: 10 December 2012 / Accepted: 4 January 2013

Abstract The coastal stretch of north-eastern Mediterranean Morocco holds vitally important ecological, social, and economic functions. The implementation of large-scale luxury tourism resorts shall push socio-economic development and facilitate the shift from a mainly agrarian to a service economy. Sufficient water availability and intact beaches are among the key requirements for the successful realization of regional development plans. The water situation is already critical, additional water-intense sectors could overstrain the capacity of water resources. Further, coastal erosion caused by sea-level rise is projected. Regional climate change is observable, and must be included in regional water management. Long-term climate trends are assessed for the larger region (Moulouya basin) and for the near-coastal zone at Saidia. The amount of additional water demand is assessed for the large-dimensioned Saidia resort; including the monthly, seasonal and annual tourist per capita water need under inclusion of irrigated golf courses and garden areas. A shift of climate patterns is observed, a lengthening of the dry summer season, and as well a significant decline of annual precipitation. Thus, current water scarcity is mainly human-induced; however, climate change will aggravate the situation. As a consequence, severe environmental damage due to water scarcity is likely and could impinge on the quality of local tourism. The re-adjustment of current management routines is therefore essential. Possible adjustments are discussed and the analysis concludes with management recommendations for innovative regional water management of tourism facilities.

Keywords North-eastern Morocco · Climate change · Coastal zone · Luxury tourism · Water demand · Adaptation

V. Tekken (✉) · L. Costa · J. P. Kropp
Potsdam Institute for Climate Impact Research,
Telegrafenberg A31,
14473 Potsdam, Germany
e-mail: vera.tekken@pik-potsdam.de

L. Costa
e-mail: luis.costa@pik-potsdam.de

J. P. Kropp
e-mail: kropp@pik-potsdam.de

J. P. Kropp
Department of Geo-and Environmental Sciences, University of Potsdam,
Am Neuen Palais,
D-14469 Potsdam, Germany

Introduction

Many coastal areas in the Mediterranean are increasingly under pressure from the combined effects of an accelerating concentration of human activities and due to changing climate conditions (Gössling 2002; IPCC 2007; Jones and Phillips 2011; Phillips and Jones 2006; UNEP/PAP 2009).

Particularly over the recent decades, the tourism sector in the Mediterranean underwent a strong growth trend (Benoit and Comeau 2005; Rico-Amoros et al. 2009). Tourism has enhanced economic growth, regional development, and led to an increase and the diversification of regional employment (Belloumi 2010; Katircioglu 2009; Klein et al. 2004). Thus, it has become a very important and successful economic sector in many northern Mediterranean countries, but at the same time, it represents the principal reason for the transformation and overexploitation of coastal environments and their resources (Jones and Phillips 2011; UNWTO 2008; Belloumi 2010; UNEP/MAP-Plan Bleu 2009). And its development is still very dynamic; projections see a steady increase of visitors by up to 136 million in 2025 in particular due to the expansion of the tourism sector in the southern Mediterranean countries (Benoit and Comeau 2005).

Recently, the Moroccan government launched a programme aiming to push forward the development of rural areas in the country and in particular to tackle poverty (Royaume due Maroc 2008). One main pillar of the national economic development plan is the extension of the tourism sector

Published online: 19 January 2013

(Royaume du Maroc 2008). The "Plan Azur/Vision 2010" focuses on the establishment of seven large scale luxury tourist destinations located at the country's Atlantic and Mediterranean coastal zones (Royaume du Maroc 2008). The aim is to raise Morocco to be among the top 25 holiday destinations worldwide until 2010 (Lalou 2011). Further, the "Plan Azur/Vision 2010" intends to create ca. 48.000 new jobs, and thus strengthen the socio-economic development (Royaume du Maroc 2010). All newly constructed tourist destinations include luxury standard facilities, including 5-star hotels and private villas with amenities such as pools, restaurants, spas, large garden areas, golf courses and partly marinas. Luxury tourism is considered to avoid mass tourism and to set quality standards (Royaume du Maroc 2008; Roudies 2010). The ambitious plans are only partly realized to date, however, as 2010 has passed, the "Plan Azur/Horizon 2010" is followed by the revised and complementary development plan "Vision/Horizon 2020" (Royaume du Maroc 2010; Roudies 2010). Here, next to the coastal sites currently being established as major tourist destinations, further parts of the country are to be included in the tourism expansion strategy to raise new bed capacities up to ca. 200.000 by 2020 (Royaume du Maroc 2010). This renewed objective aims to turn tourism into the second most important economic sector of the country, to create 470.000 direct jobs and one million indirect jobs until 2020, to increase revenues from foreign tourism expenditures, and to shift Morocco among the top 20 holiday destinations (Royaume du Maroc 2010).

One out of the seven coastal tourist destinations listed in the "Plan Azur/Vision 2010" is located in the most north-eastern Mediterranean part of Morocco, in the low-lying coastal zone between the deltaic plain of the Moulouya river and the city of Saidia, at the border of Algeria.

A major problem the region has to cope with is the aggravating water scarcity situation (Tekken and Kropp 2012). The regional water balance is increasingly under pressure not only by decreasing precipitation amounts and a high interannnual precipitation variability, but as well due to the significant reduction of groundwater recharge rates (Döll 2009; Moustadraf et al. 2008). If this current trend continues, reduced rainfall will severely aggravate the regional freshwater deficit (Anfuso and Nachite 2011). Still, water withdrawals are the major source of freshwater in Morocco (Benoit and Comeau 2005). But despite steadily increasing demands and alarming signals of overexploitation, water policies, planning and management focus mainly on opportunities to enhance withdrawals (Benoit and Comeau 2005). The amounts of produced water from non-conventional resources or wastewater reuse are still negligible (Benoit and Comeau 2005).

Current development trajectories, focusing on coastal tourism development, will lead to population growth and thus further enhance pressures on natural resources, in particular on water. Since the current average per capita water availability rate ranges below the critical benchmark of 1.000 m^3 per year, water scarcity is a normal situation (Snoussi 2004; Tekken and Kropp 2012). Falkenmark (1989) has addressed the issue of an alarming water situation in North Africa more than two decades ago; however, she defined a per capita water availability of less than 1.000 m^3 per year as "chronic water scarcity" and associated severe limitations to economic development, human health and well-being (Gleick et al. 2002; Falkenmark and Widstrand 1992). Not surprisingly, sufficient water availability is the key requirement for the implementation of regional development plans. Large-scale luxury tourism is water-intense and will contribute to rising regional water demand. Continuous water supply must be guaranteed; water shortfalls will not be tolerated at high-level tourism sites. At the moment, the regional water demand–supply-ratio is balanced, with little scope for an additional water consumer. Thus, at the one hand the tourism sector needs to adapt to a chronic water deficit situation, and on the other hand it contributes to it.

A further risk for the realization and success of tourism development in the region is the physical vulnerability to accelerated sea level rise (Snoussi et al. 2009). Rising sea levels are observed in the Alboran Sea in the southern Mediterranean, and affecting the low-lying north-eastern littoral of Morocco (Anfuso and Nachite 2011; Cazenave et al. 2001). Scenarios are projecting a trend continuation (Snoussi et al. 2009). This involves a high risk of coastal hazards such as flooding and inundation, and sea water intrusion into near-coast groundwater aquifers (Anfuso and Nachite 2011; Snoussi et al. 2009). As regards tourism development in north-eastern Morocco, built infrastructures at the low-lying fringe of the coastal zone are at high risk of being impaired by coastal erosion (Snoussi et al. 2009). Respective experiences have already been made in the 1990s when coastal erosion led to beach and tourist infrastructure loss in Tangiers (northern Morocco), and, eventually, to the substantial loss of foreign income from tourism (Benoit and Comeau 2005).

Thus, for the coastal area of north-eastern Morocco, the combination of climate change towards even dryer conditions, of littoralization due to the concentration of economic activities, of increasing local water demand under scarcity conditions, of the high economic dependency on water availability, and of the impacts of coastal erosion, constitutes severe risks for the successful realization of tourism-based socio-economic development.

However, tourism in at the coastline of north-eastern Morocco is a growing sector and has a paramount role for socio-economic development (Anfuso and Nachite 2011). Thus, it is all the more important to develop sustainable management strategies that account for the particular local vulnerability of tourism to climate change and sea level rise (Jones and Phillips 2011). So far, increasing water scarcity in many regions is primarily driven by increasing demand, such as changing lifestyles, increasing population, urbanization, agricultural intensification, insufficient water infrastructures and the establishment or further extension of water intense economic sectors. Often this leads to a very punctual water abstraction, causing a spatial overexploitation of natural water resources. Influencing factors must be considered carefully to avoid harming consequences from severe water scarcity or even the failure of economic plans.

Starting point for the following analysis is the sub-regional analysis of recent climate change in the Moulouya river basin. The detection of respective trends, increase of temperatures and decrease of precipitation, indicates an aggravation of the water situation. Further, for the low-lying area of the north-eastern coast a climate diagram was compiled in order to detect modifications regarding the length of the local dry period. This would imply a further enhancement of water needs in the high tourist season. Facilities of luxury tourism resorts such as recently established in Saidia require continuous all-year irrigation for golf and garden areas and a secured water supply for tourist water needs (Diaz et al. 2007; Kent et al. 2002; Gössling 2005). The amount of needed water depends on the tourist season, and on the number of tourists and the hotel/accommodation occupancy. Accordingly, we exemplarily assess the potential water demand of the new tourist facilities in Saidia, as a baseline to estimate seasonal water demands and their peaks. By the calculation of the golf/garden area irrigation needs and the tourist per capita water demand per day resolved monthly and seasonally, we derive the additional water demand impact caused by the Saidia resort.

Given the already scarce regional water situation, we discuss possible measures to improve the situation and conclude with management recommendations for regional water planning under scarcity conditions.

Case study area–Saidia tourism resort in north-eastern Morocco

The large-scale tourist resort in Saidia is located at the low-lying coastline of north-eastern Morocco, in the most northern part of the administrative region l'Oriental and its province Berkane. The resort covers an area of 713 ha with a beach line of 14 km and is built closely to the Moulouya river's estuary, a unique wetland and salt marshes ecosystem, of high aesthetic value and habitat for many endemic species (RAMSAR Convention on Wetlands of International Importance).

North-eastern Morocco is climatologically classified as semi-arid and characterised by dry summers and winter rainfall (Luterbacher et al. 2006; Xoplaki et al. 2006; Imassi 2007). The river Moulouya is the most important water provider in north-eastern Morocco (Snoussi 2004). Its basin stretches between 32–35°N and 2–6°W, with a hydrological drainage area of ca. 54,000 km^2 (Snoussi et al. 2002; Imassi 2007) (Fig. 1).

The hydrological situation is characterized by recurring periods of physical water scarcity, but increasingly in the last decades, as well by human-caused water scarcity (Carneiro et al. 2008; Snoussi 2004). Due to growing regional water demand groundwater abstraction has already reached levels of overexploitation, causing saline intrusion in the low-lying coastal aquifers (El Yaouti et al. 2009; Anfuso and Nachite 2011; Snoussi et al. 2007). This has a tangible effect on the agricultural production in littoral areas (Snoussi et al. 2008; Skim 2007). In recent decades changing climate patterns have been observed, mainly an annual decrease of precipitation with signals for a changing seasonality (Imassi 2007; Tekken et al. 2009).

Methods and data

Sub-regional climate trends in north-eastern coastal Morocco

As a first step, for the area of the Moulouya river basin as major hydrological entity, precipitation and temperature changes are assessed for 1991–2005 (with reference period 1961–1990) for trend detection. Consistent long-time and instrumental data series for Morocco are currently not available (Taylor et al. 2009). Such, climate data was taken from the CRU TS2.1 climatology (Climate Research Unit Norwich, UK), a global gridded data set developed to replace missing or inconsistent meteorological values (New et al. 2002). A local climate diagram for the location of the Saidia tourist resort was compiled to determine locally-characteristic annual humid and dry seasons (after Walter and Lieth 1960). The values of the two closest coast-located CRU grid cells at a 0.5°x0.5° scale, named CRU14 (Lon -2.75/Lat 34.75) and CRU15 (Lon -2.25/Lat 34.75) (Fig. 2), were averaged and analyzed for the period 1991–2005 (with reference period 1961–1990) to detect a shift or duration change of the dry summer period.

Estimating the tourist water demand for Saidia tourism

The Saidia resort area spans 713 ha, thereof a 210 ha sprinkled 18-hole golf course. The quantities of irrigation water demand (in m^3/ha/year) for the golf course area were calculated based on estimates for semi-arid Mediterranean areas (proxy values were taken from the climatically comparable island of Mallorca, Spain, see Kent et al. 2002). The amounts of

Fig. 1 The Moulouya river basin in Morocco; location and area extent

irrigation water demand range between 3.5 and 5 mm/m^2 (values taken from Kent et al. 2002 referring to Aramburu and Escribano 1993, and Markwick 2000). We presumed seasonal variation in irrigation needs due to rainfall conditions, differentiated three annual seasons and calculated the monthly required amount (in m^3) for the Saidia golf course area (210 ha) thereafter:

- 3.5 mm/m^2 at lower range of irrigation need in months with relatively high rainfall amounts: low season;
- 4.25 mm/m^2 at medium range for months with medium rainfall amounts: medium season; and
- 5 mm/m^2 at highest range of irrigation needs in the hot and dry summer months: high season (Table 1).

The estimation takes into account the variation of water demand influenced by the season-dependant number of tourists, the occupancy rate and the targeted bed capacity for Saidia hotels/accommodations.

Water consumption of tourists was calculated under consideration of the planned resort bed capacity of 28.000, equivalent for tourist overnight stays (Royaume du Maroc 2001). Differences in the seasonal occupancy rates are assumed to influence the overall water demand. In the lower season the tourist per capita water demand is decreasing, while golf areas need continuous irrigation. However, for the colder half of the year, it is assumed that rainfall can partly compensate for the needed irrigation of golf areas, and irrigation needs might be lowered due to smaller evapotranspiration rates in the cold season (Tekken and Kropp 2012). The daily per capita water consumption of tourists is estimated at highest range due to luxury standards and water-intense facilities at 0,9 m^3 (value assumptions on daily water consumption taken from WWF 2001 and Gössling et al. 2012). High and low range and average monthly consumption was calculated considering the seasonal hotel occupancy rate. Results of both calculations, the amounts of needed irrigation water for golf courses' maintenance of 210 ha and the high assumptions on touristic water demand per capita are aggregated to obtain an ensemble value for monthly water demand and information regarding seasonal peaks of water demand.

Results

Regional climate trends

Climate change is a global and long-term process that cannot be reversed or halted easily. However, the regional or local impacts differentiate widely. In water scarce regions with increasing water demands, climate change can contribute significantly to a lowering water availability. In combination with the human influence critical thresholds of water resources are at high risk of being exceeded (Tekken and Kropp 2012). Any

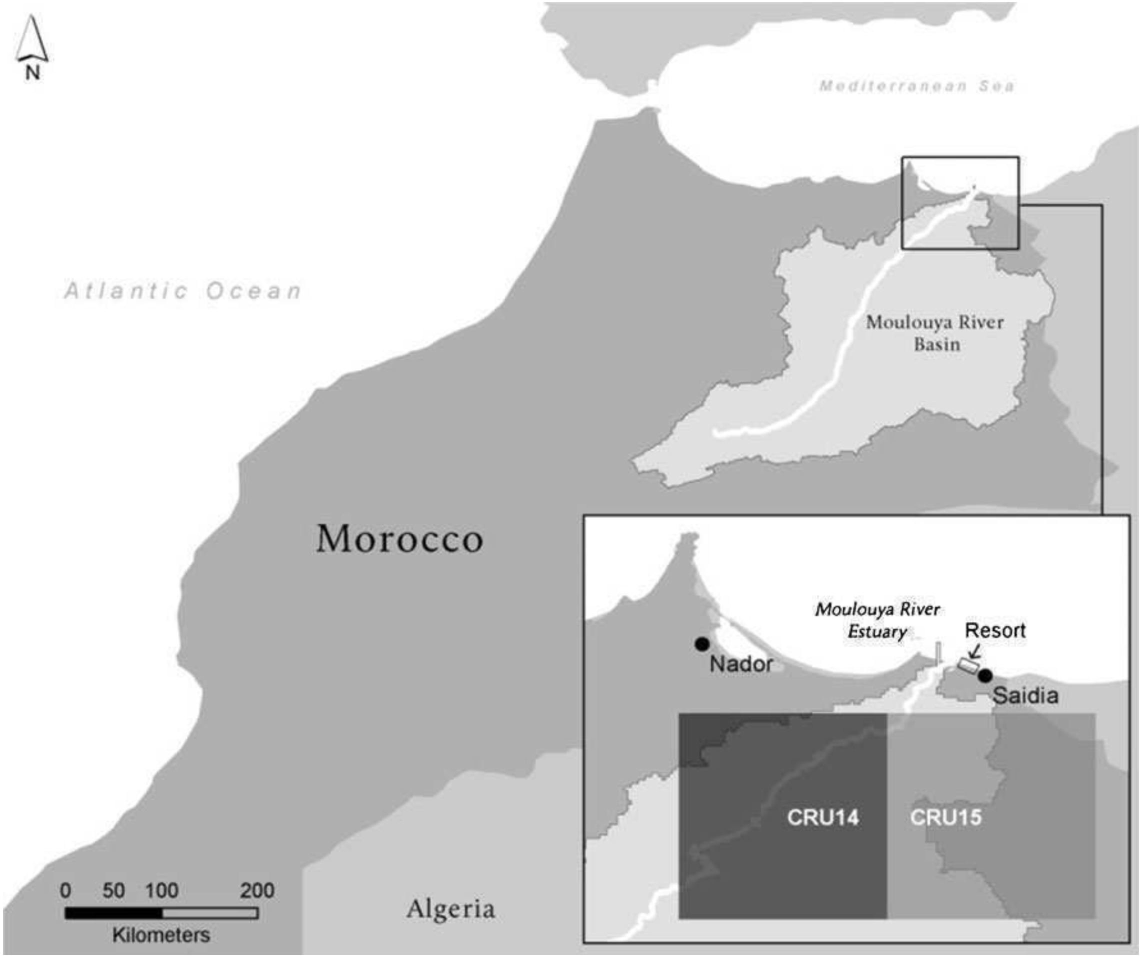

Fig. 2 Data points for analysis of local climate trend in Saidia and location of resort area

signal of an aggravating situation is thus important and must be included in readjustments of water demand management.

Here, by means of a sub-regional analysis of recent climate change the critical situation in north-eastern Morocco is illustrated. From an average annual precipitation amount of 356 mm in the climate reference period 1961–1990 precipitation has lowered by about 26 mm to 330 mm in 1991–2005 (Fig. 3a). The main decreases are observed for the rainfall-relevant months in the colder period between October and April. In combination with an increasing temperature variability and a warming trend (+2 °C, Fig. 3b), and assuming the climate influence on the hydrological situation, these findings reveal that the region might be facing an increasingly problematic freshwater water situation.

Shifting climate patterns in Saidia, north-eastern Morocco

Precipitation and temperature of the data points CRU14 (LON -2.75/LAT 34.75) and CRU15 (LON -2.25/LAT 34.75) were calculated for monthly means, averaged and depicted in a climate diagram to indicate a potential climate shift pointing towards dryer conditions (Fig. 4). The mean annual precipitation sum has significantly decreased by ca. 62 mm/year (Fig. 5a) while the mean annual temperature shows an increase of 0,2 °C/year (Fig. 5b). The annual dry season, previously (period 1961–1990) starting in May and lasting until October, has lengthened by ca. 1 month, starting already in April (Fig. 4). This can cause a critical situation for the water supply during the tourist season in summer, when the water

Table 1 Calculation baseline for monthly, seasonal and annual water demand by Saidia tourism

Classification of tourist seasons	Potential seasonal occupancy	Tourists (bed capacity: 28.000 beds)
• Low season (Jan–Mar, Nov–Dec)	low: 25 %	12.600
• Medium (Apr–May, Sep–Oct)	medium: 50 %	25.200
• High (Jun–Aug)	high: 100 %	28.000

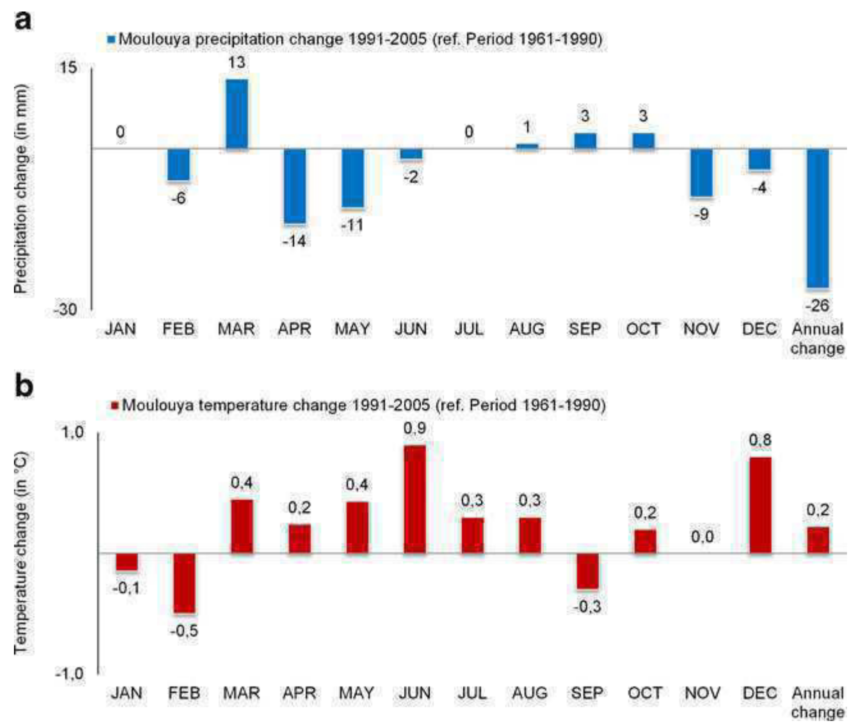

Fig. 3 **a** Precipitation variability for the Moulouya river basin in north-eastern Morocco for 1991–2005 (with ref. period 1961–1990). **b** Temperature variability for the Moulouya river basin in north-eastern Morocco for 1991–2005 (with ref. period 1961–1990)

demand is higher than usual. Further, a continuous temperature increase can be observed in the warmest time of the year when precipitation amounts are negligible (summer months June, July and August). If this trend manifests in the near future, it can be assumed that water demand of tourist facilities in the high season will rise considerably due to high irrigation needs of tourist facilities. In general, decreasing rainfall amounts in the case study area will seriously aggravate the already critical regional water situation (Imassi 2007). Since near-coast aquifers are salinized and no additional non-conventional water resources are produced, the main freshwater stems from the Moulouya river and from stored waters of upriver dams (Snoussi et al. 2008).

Water demand for the local tourism sector in Saidia

The establishment of a water intensive tourism sector requires continuous annual freshwater supply to maintain facilities and for tourists' demand (Kent et al. 2002). Golf courses and gardens must be irrigated all-season, although

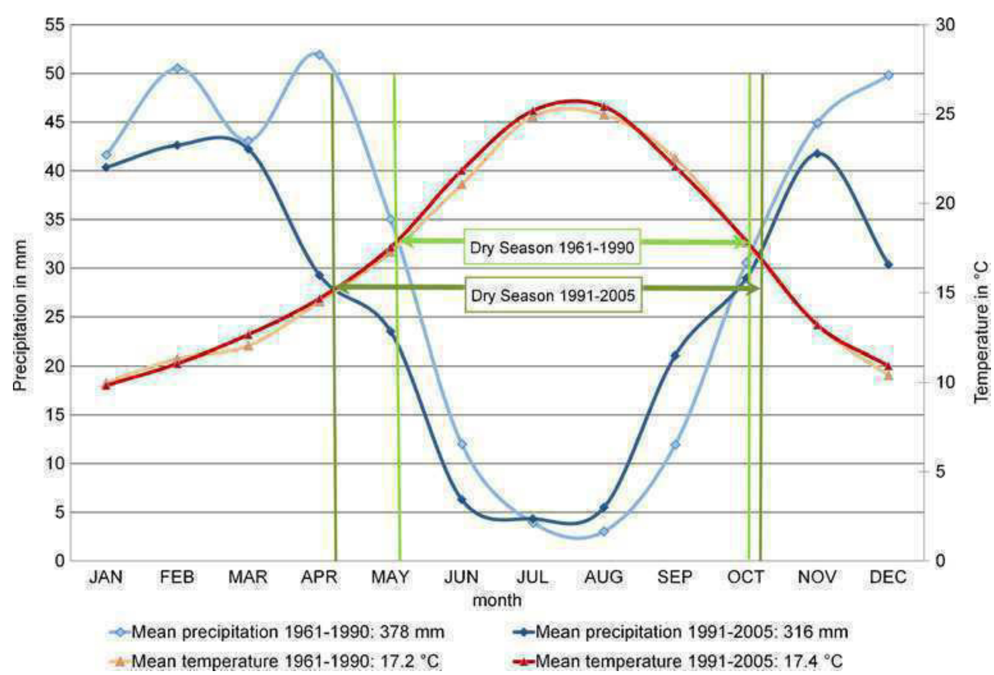

Fig. 4 Lengthening of the dry season: Climate diagram for Saidia, north-eastern coastal Morocco. Averaged values of CRU14 (LON -2.75/LAT 34.75) and of CRU15 (LON -2.25/LAT 34.75) for 1991–2005 (with ref. period 1961–1990)

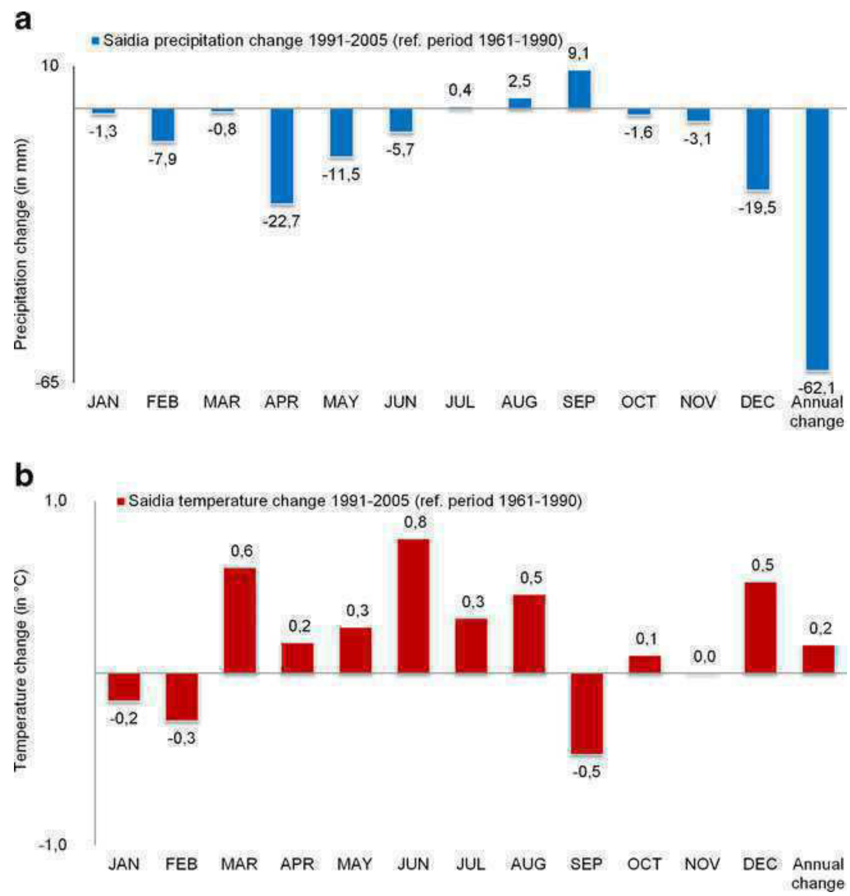

Fig. 5 **a** Precipitation change in Saidia, north-eastern Morocco for 1991–2005 (with ref. period 1961–1990). **b** Temperature change in Saidia, north-eastern Morocco for 1991–2005 (with ref. period 1961–1990)

in the colder period of the year (October to April) irrigation might partly be compensated by rainfall. However, the latter might only be possible, if the area would have respective assets, e.g. a rainfall drainage system that allows rainwater harvesting, storage and appropriate usage. Of course, the compensating capability of rainfall for the irrigation of golf areas is very limited. Regional rainfall is of torrential characteristic, meaning that the irrigating function of rainfall is practically non-existent. Another reason for concern is the local temperature increase between March and August. This trend coincides considerably with decreasing precipitation in the same months. As a result, higher evapotranspiration rates can be assumed, thus impinging on the overall water budget but as well on the amount of water needed for golf course/garden irrigation. We assume an additional annual water need of 5 million m^3 per year; however, an extended dry season might maximize the irrigation needs (Fig. 6). Further, most tourist visits in the area take place in the summer season (June, July, August), with gradual decreases in spring and autumn, and reduced quantities of visits in the winter season. Estimates on overnight stays are season-dependent. The amount of tourist per capita water use can vary greatly; we assume an annual water demand of 3 million m^3(Fig. 6). As a last step, the tourist per capita water demand and the irrigation water needed for the golf/garden areas were aggregated. As expected, peak water demand will occur in the most frequented months in the high summer season (June, July and August). The additional water amount for the supply of Saidia tourist facilities–under consideration of seasonality–totals to an annual additional water need of 8 million m^3 (Fig. 6)

Discussion and conclusions

Many studies discuss the implications of a growing tourism sector for the natural environment of the Mediterranean coast (Anfuso and Nachite 2011; Rico-Amoros et al. 2009; WWF 2001; Loukissas and Skayannis 2001): There is a general consensus that the provision of continuous water supply and the strong seasonal peak of visitors leads to an overexploitation of water resources, that cannot be compensated by the natural replenishment of aquifers (e.g. Garcia and Servera 2003; Stefano 2004; Kent et al. 2002). This could then prove to be very problematical, as the main economic activities in north-eastern Morocco are based upon the availability of water: irrigated agriculture and, increasingly, tourism.

This analysis of regional climate change and variability as indicators for an aggravating water situation revealed a worrying trend of a warming and drying situation. The regional

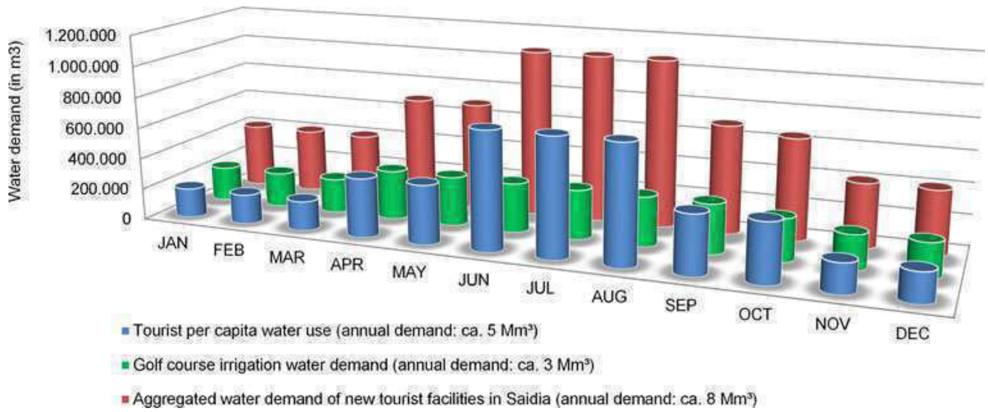

Fig. 6 Estimated monthly tourist per capita tourists, golf/garden irrigation demand, and annual sum of additional water needs for Saidia tourism facilities

economy focuses on the extension of water-intense tourism, water availability is essential for a successful realization. Water supply for tourism facilities must be ensured for all seasons and further at any time for tourists' demand. Problems could evolve if the additional tourism water demand interferes with other usages, such as irrigated agriculture, domestic usage and industrial supply, and priorities need to be set.

Further, employment prospects in the tourism sector will attract people to move into the developing areas, thus adding to the demographic population growth trend (United Nations Population Database, http://esa.un.org/wpp/). A growing population increases water demand–how is that to be solved? And, for example, environmental damage due to the overexploitation of water resources is very likely; however, visitors shall be attracted as well by the unique and protected environmental site close to Saidia, the Moulouya river delta (RAMSAR site). Would the loss of unique environmental assets in turn impair the success of the tourism development ambitions? There is no doubt, that the realization of water-intense socio-economic development in the region requires an adapted water management. A first but essential step is the efficiency increase of water usage in general, e.g., improved irrigation methods, facility-based waste-water reuse, municipal and industrial water treatment for waste water reuse, and avoidance of open channel water transport for agricultural purposes (Araus 2004; Kadi 2004).

In Saidia, the additional annual water demand for tourism (8 million m^3) is dwindling small compared to irrigation water for agriculture (in 2005: 850 Mm^3) (Imassi 2007). However, continuous water supply for tourism must be ensured at all time in particular in the water scarce hot summer season, if tourism is expected to become a key economic sector in the region. Currently lacking non-conventional water production and waste-water reuse systems could serve as stabilizing factors, in particular in times of water shortages (Araus 2004). However, agriculture is still the largest consumer of freshwater resources, even if the share of rain-fed agriculture is considerably higher. Thus, under increasingly dry conditions, efficiency increase of irrigated and rain-fed agriculture is inevitable, supplemented by modern water technologies to secure regional water supply.

There is no longer any potential for the extension of large water dams along the river Moulouya. Existing dams suffer from high siltation rates and increasing capacity decline (Snoussi et al. 2002, 2007; Benoit and Comeau 2005). Due to high costs and relatively small amounts of water achievable, desalinization of brackish or sea water is not particularly common in Morocco (Benoit and Comeau 2005). However, the climate conditions in North Africa offer a great potential for innovative measures, e.g. using concentrated solar power (CSP) as energy sources for seawater desalinization (Trieb 2007; Trieb and Muller-Steinhagen 2008). The combination of CSP (Concentrated Solar Power) and desalinization would be an option to add to the needed mixture of water resources. However, the supply of tourism facilities by integrated desalinization plants would allow for greater water security. Instead, tourism currently enhances the imbalance between regional water demand and supply, and interferences with other water users are very likely.

However, the critical water situation is mainly human-caused, as the increasing water demand in the region has already exceeded sustainable limits which are impossible to compensate in an economically meaningful manner (Tekken and Kropp 2012). Even without having reached a point of collapse yet, water management in the region needs profound structural change regarding the sustainable use of water resources.

The combination of human-caused pressures and projected impacts resulting from climate change (e.g. sea-level-rise) might cause irreversible damages for the north-eastern coastline. Uncertainties regarding the magnitude of sea-level rise are high (Nicholls and Cazenave 2010). It therefore has to be carefully assessed, which are the most pressing impacts, and to be considered which solutions are appropriate to protect the natural environment *and* tourist infrastructures, as intact beaches are a prerequisite for the tourism sector (Jurado et al. 2009).

To conclude, the regional facilitator of socio-economic development in the region, the tourism sector, is at double risk from climate change: a clear trend towards dryer conditions with severe impacts for the local water situation, and further due to increasing sea levels, threatening near-coast infrastructures, in particular beaches. However, the critical water situation is predominantly human-caused and not climate-induced. Even without decreasing rainfall amounts in the future, the water situation can only be improved by modifications of current water demand management, by the extensive implementation of waste water reuse, and by non-conventional water production. Additional water demand from the tourism sector is small compared to the water demand for agricultural irrigation. Bottlenecks in the continuously required water supply of tourist facilities due to water shortfalls could turn out to be critical, if tourists are not coming back. Socio-economic development in the region is based on the extension of the tourism sector since the inception of the PLAN AZUR in Morocco. The local water availability in Saidia, but as well the supply of the regional agricultural irrigation schemes, depends on freshwater resources from the Moulouya river, thus posing an unforeseeable risk under the recent drying trend.

Acknowledgments The work was supported by the project "ACCMA–Adaptation to Climate Change in Morocco" as part of the program 'Adaptation aux Changements Climatiques en Afrique (ACCA)', financed by the International Development Research Centre Canada (IDRC) and the UK Department for International Development (DFID). The authors would like to thank Susanne Stoll-Kleemann (University Greifswald) and three anonymous reviewers for their valuable and constructive comments on this manuscript.

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Submitted manuscript (January 2013):

IV

Tekken V., Stoll-Kleemann, S.: Resource pragmatism vs. resource reality: sustainable tourism development in north-eastern Morocco. *Tourism Management Perspectives*.

Elsevier Editorial System(tm) for Tourism Management Perspectives
Manuscript Draft

Manuscript Number:

Title: Resource pragmatism vs. resource reality: sustainable tourism development in north-eastern Morocco

Article Type: Research Paper

Keywords: north-eastern Morocco; economic growth; natural resources; water; sustainable tourism; sustainability paradigms; governance

Corresponding Author: Mrs. Vera Tekken,

Corresponding Author's Institution: Ernst-Moritz-Arndt-University of Greifswald

First Author: Vera Tekken

Order of Authors: Vera Tekken; Vera Tekken; Susanne Stoll-Kleemann

Abstract: Concerning sustainable development often there is a large gap between vision and theory on the one hand and reality on the other. The coastal area of north-eastern Morocco, an environmental unique region, is in the focus of government-induced establishment of a large-scale tourism industry. Tourism is expected to considerably contribute to economic growth in formerly marginalized regions, aiming at a long-term sustainable socio-economic development. The regional population depends on the availability of natural resources as alternative income sources are very rare. The fragile ecosystem is at risk due to the pressures from tourism development, making the establishment and implementation of sustainability criteria increasingly important. Based on a region-specific problem-pressure inventory the current development pathway of north-eastern Morocco is classified based on the sustainability paradigms by Steurer (2001). Measures for a sustainable tourism development are recommended, taking into account antagonistic positions of a weak and strong sustainability.

Resource pragmatism vs. resource reality: sustainable tourism development in north-eastern Morocco

Vera Tekken[a], Susanne Stoll-Kleemann[a]

[a]*Department of Sustainability Science and Applied Geography, Institute for Geography and Geology, Ernst-Moritz-Arndt-University Greifswald, Germany*

Submitted: 27th January 2013

Abstract

Concerning sustainable development often there is a large gap between vision and theory on the one hand and reality on the other. The coastal area of north-eastern Morocco, an environmental unique region, is in the focus of government-induced establishment of a large-scale tourism industry. Tourism is expected to considerably contribute to economic growth in formerly marginalized regions, aiming at a long-term sustainable socio-economic development. The regional population depends on the availability of natural resources as alternative income sources are very rare. The fragile ecosystem is at risk due to the pressures from tourism development, making the establishment and implementation of sustainability criteria increasingly important. Based on a region-specific problem-pressure inventory the current development pathway of north-eastern Morocco is classified based on the sustainability paradigms by Steurer (2001). Measures for a sustainable tourism development are recommended, taking into account antagonistic positions of a weak and strong sustainability.

Keywords north-eastern Morocco; economic growth; natural resources; water; sustainable tourism; sustainability paradigms; governance

1. Introduction

As of recently, the Moroccan government strives to achieve short-term economic growth and long-term socio-economic development in peripheral areas of the country (Spilanis et al., 2012; Royaume du Maroc, 2001; Royaume du Maroc, 2010). This catch-up process of development of structurally weak regions aims to strengthen economic performance, to alleviate rural poverty, but as well to contribute to the sectoral diversification of the national economy. Up to now the focus has been on agricultural production, however, development opportunities in this sector are very limited owing to unfavourable cultivation conditions. Tourism is considered to be a promising sector to facilitate regional development, in particular due to the expected beneficial effects on direct and indirect employment opportunities, but as well due to the generation of foreign income (Spilanis et al., 2012; Royaume du Maroc, 2010). So far, tourism development of north-eastern Morocco lags behind other coastal areas in Mediterranean Europe, but also behind economically successful inside-country destinations, e.g. Tétouan in north-western coastal Morocco (Spilanis et al., 2012; Roudies, 2010). Therefore, within a short timeframe, mass tourism infrastructures have been established at the coastal zone. As a consequence thereof the landscape scenery undergoes significant changes, and human activities are increasing in coastal areas, leading to littoralization and further an increasing depletion of natural resources. In general, rapid growth of the tourism can involve adverse, human-driven impacts, e.g. urbanization, population growth, damage to natural habitats, and water degradation (Claudet and Fraschetti, 2010; Jurado et al., 2012). Positive effects, e.g. increase of employment opportunities, can be superimposed by negative impacts of human activities, e.g. resource overexploitation. The degree of adverse disturbances of the natural environments depends inter alia on their respective resilience level (Castellani et al., 2007). But, compared to the original intention of a socio-economic stabilization, resource overexploitation can enhance the tendency towards impoverishment in certain parts of the population, e.g. unless tourism revenues are used to pursue economic diversification, to strengthen social capital, and to adapt the resource management in order to prevent an exceeding of certain sustainability levels (Sheng, 2011).

Overall, the complex effects of a growing tourism sector require the investigation of a destination's ecological and social carrying capacity (Jurado et al., 2012; Spilanis et al., 2012; Castellani et al., 2007). The role of carrying capacity of tourist destinations for sustainable tourism, and to seek support for the operationalization of management recommendations has become an important research topic (Lee 2011; Sheng, 2011). Tourism, depending on the number of visitors at a place, has an effect on the quality of the environment and natural resources such as water (Castellani et al., 2007; Gössling et al., 2012).

Recurring water scarcity represents a severe problem for freshwater supply in north-eastern Morocco, however, while at the same time water availability represents a key resource for economic development (Alonso-Almeida, 2012; Snoussi, 2004; Tekken & Kropp, 2012). Currently the regional water management lacks anticipating coping strategies to guarantee a continuous water supply, e.g. waste-water reuse or an appropriate water demand management (Alonso-Almeida, 2012; Tekken & Kropp, 2012). This resource pragmatism (expectation of a constant availability of freshwater resources without the implementation of adequate compensation measures and effective water management) is in contrast to the regional resource reality (overabstraction of freshwater resources despite the transgression of critical limits; frequent water shortfalls) (Wöhlcke, 1993). In this context, criteria for a sustainable and in the long-term successful establishment of the tourism sector are necessary in particular to safeguard current and future water availability (Bogardi et al., 2012).

The aim of the present study is to identify if and how sustainability is anchored in the government-induced tourism concept for north-eastern Morocco, with a particular emphasis on adequate water availability. Without an effective implementation of region-specific sustainability criteria tourism development will be hampered by severe water supply problems. Several studies and research indicate the aggravation of the problematic water situation. However, the article wants to emphasize, that despite an increasing awareness and the existence of scientific evidence ecologically responsible tourism has not made sufficient progress in Morocco.

Based on the sustainability paradigms of Steurer (2001), who determines criteria for a weak (*anthropocentric*), a strong (*ecocentric*) and a balanced (*eco-anthropocentric*) sustainability, the current development pathway of north-eastern Morocco is classified. Key aspects needed to adopt a sustainable strategy for coastal tourism development are outlined and contrasted to those explained in the "Moroccan chart of sustainable development" (Royaume du Maroc, 2006) and the concept for regional tourism development "Plan Azur 2010/Vision 2020" (Royaume du Maroc, 2010; Roudies, 2010). Based on a literature review, criteria for environmental and socio-economical sustainability are compiled as recommendations for a resource-realistic establishment of the regional tourism sector. Finally, we recommend criteria of a balanced sustainability, which could support sustainable growth under a strong regional development pressure.

2. Contextual background – sustainable economic growth

The publication of the concept "Limits to Growth" by the Club of Rome in 1972 resulted from an intense discourse regarding the conflict of resource use and good environmental quality under the paradigm of economic growth (Meadows et al., 1972; Lee, 2011). Continued and expanded by the Brundtland Report (1987) the agreed definition of sustainable development was then based on the two concepts of *needs* (in particular the essential needs of the world's poor, to which overriding priority should be given) and *limitations* (the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs), taking into account the perpetual conflict between ecological conservation and economic development (WCED, 1987).

Today, the terms *sustainable* and *responsible* are commonly used in the context of socio-economic development. However, the meaning of *sustainability* has become fuzzy and is increasingly used as a rhetorical justification of *anthropocentric* development (Wöhlcke, 1993). One reason might be the difficulty of meeting the criteria of a strong *sustainability* (*ecocentric paradigm*), which is in total contrast to a resource-based development (*anthropocentric paradigm*). Anthropocentrism aims at the decoupling of economic growth and the use of resources or materials (Simonis, 1990).

Table 1 Paradigms of sustainability (after Steurer 2001)

Weak sustainability (anthropocentric paradigm)	**Balanced sustainability (eco-anthropocentric paradigm)**	**Strong sustainability (ecocentric paradigm)**
• focus on maintaining and enhancing growth and prosperity • resource and growth optimism: welfare maximization and economic growth are seen as solution to environmental problems • natural capital is fully substitutable by human or real capital • conventional cost-benefit-analysis • decrease of natural capital is sustainable if compensated by growing capital in other sectors • harmonious interaction between growth and environment • pro- growth strategy with moderate environmental policies • representatives: neo-classical	• prosperity increase induced by policies for environmental protection/conservation • natural capital is partly substitutable • environment-friendly growth is possible • ecological consumption patterns and their efficiency is supported by technologies, policies and markets • environmentally extended cost-benefit-analysis • representatives: social scientists; growth optimizers	• healthy environment as basis of all other sustainability dimensions • growth pessimism: economic growth is not compatible with the preservation of natural capital and environmental quality • contra cost-benefit analysis • environmental protection needs restriction of economic growth1 • natural capital must be preserved, cannot be substituted or replaced through man-made assets • sustainable growth based on natural capital not possible • representatives: ecological economics, ecologists

From a development objective this conflict of targets needs a balanced concept of quality-oriented growth which should include frugality, efficiency, repair, recycling, material substitution, and structural change (Steurer, 2001) (see Table 1 for sustainability paradigms and their classification). Environmental damage can be lessened depending on the development pathway, by compliance with regulatory frameworks, and by an efficient implementation of legal restrictions (Steurer, 2001). However, the harmonization between economic growth on the one hand and safeguarding environmental quality on the other will lead to a reduced speed of growth: ecologic-economically optimized development pathways differ from economically-oriented development pathways (Steurer, 2001). But, in terms of intergenerational justice, a balanced sustainability is the only appropriate strategy to ensure a qualitative growth (Steurer, 2001).

2.1 Aspects of a sustainable tourism

To achieve long-term success the degradation of natural resources in a way that other economic activities are negatively affected or become impossible must be avoided. That is, sustainable tourism *"must aim at development of tourism in such a way that avoids damage to the environment, economy and culture […]. It requires simultaneous considering of lots of criteria including infrastructure, competitiveness and supply, socioeconomic, land use/tourist facilities and service to meet the concept of sustainable development"* (Monavari et al., 2012, 1473).

In this sense, tourism can support a sustainable development if it takes into "*full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities"* (UNEP/UNWTO, 2005, 12) (Figure 1).

The ecological perspective is an objective of primary importance in most approaches for a sustainable tourism development (Schmied et al., 2009, 30). For example, Müller and Flügel (1999) refer to the need of an intact nature and resource protection, which must be ensured by the reduction of the ecological impact by tourism activities. Baumgartner (2000) defines the "*ecological* *dimension*" as "*most important source for a touristic development*" (Schnell et al., 2002, 5). Examples for the definition of ecological criteria are the reduction of resource consumption (e.g. water), or the avoidance of negative impacts on biodiversity (Schmied et al., 2009; Baake et al. 2002).

In general, a course towards achieving a more sustainable tourism is an inclusive and continuous process (UNEP/UNWTO, 2005). The development of adequate sustainability criteria and a regular monitoring of the implementation need to be steered by public institutions, e.g. planning authorities, to ensure the sustainability compliance of tourism businesses (Wöhlcke, 1993).

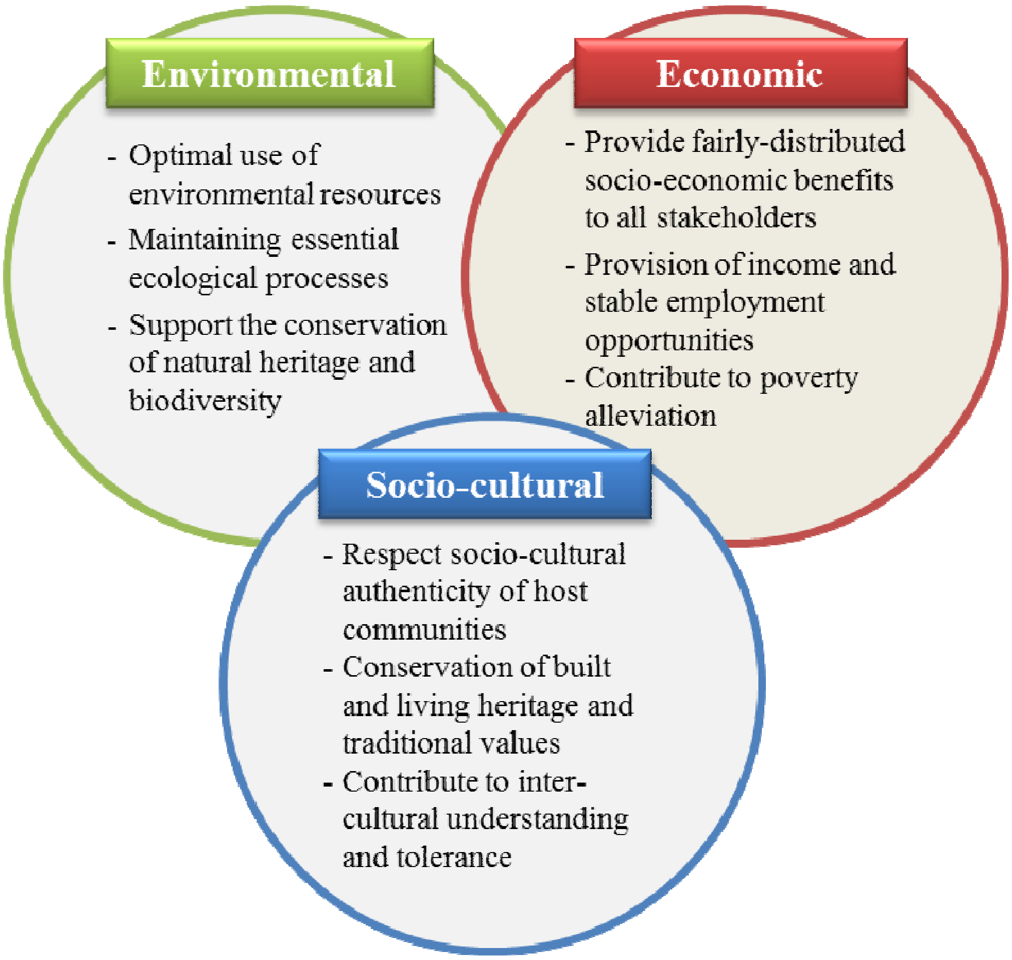

Figure 1. Aspects of a sustainable tourism development (based on UNEP/UNWTO, 2005).

2.2 *Tourism development in north-eastern Morocco*

The study area is localized in the low-lying coastal zone of north-eastern Morocco, close to the border with Algeria. Recently, due to political reasons but as well due to the assignment of economic potentials to rural areas, the Moroccan government intends to push socio-economic development by the establishment of large-scale coastal luxury tourism. The coastal zone has suitable beaches and a unique natural environment that is worth protecting (e.g., the delta of the local Moulouya river, which is listed under RAMSAR Convention on Wetlands http://www.ramsar.org). Located in a short distance tourist facilities have been constructed close to the beach area, including 5-star hotels, golf courses, pool areas, private villas, a marina, and beach promenades. The government-induced concept for regional tourism development "Plan Azur 2010/Vision 2020" aims to achieve a capacity of 27.000 hotel beds and private accommodation for national and international clientele (Royaume du Maroc, 2008, 2010; Roudies, 2010). This quick implementation harms the natural environment, in particular by the sealing of surface areas and the strong increase of local water demand. This human-induced shortage of water availability will lead to supply problems due to the absence of countervailing measures. During recent decades the region has been experiencing an increasing drying trend (Carneiro et al., 2010; Tekken & Kropp, 2009; Bzioui et al., 2010). The water situation has become more than temporarily critical, thus mainly caused by enhanced population growth, by water needs from of irrigated agriculture, but as well due to decreasing levels of groundwater and its degradation, e.g. due to salinization (Carneiro et al., 2008; Snoussi et al., 2007, 2008; Fetouani et al., 2008). The regional water balance is at risk (Tekken et al. 2009; Moustadraf et al. 2008). Increasing demand and the likely increase of water shortfalls constitute severe constraints for the realization of a successful local tourism industry (Bethune & Schachtschneider 2004). Water availability is crucial for tourism, thus it is all the more surprising that the growing water need is not yet part of regional water management strategies (Alonso-Almeida, 2012; Tekken & Kropp 2012).

3. Methodology

Sufficient water availability is a key success factor for the establishment of a luxury tourism industry. A literature-based inventory of water problems and associated pressures in north-eastern Morocco is compiled and contrasted with the main aspects expressed in governmental development plans. The region is at risk of a chronic water shortage, which should be taken into account considering the mainly resource-based development. By a qualitative comparison is it analysed if these local problems and impacts are adequately integrated into tourism development plans for the area, as those affirm to be "sustainable". Based on these statements the respective sustainability paradigm after Steurer (2001) is assigned to give a true view of the real situation and to identify mere rhetoric. To steer a balanced course for a sustainable tourism development, the divergent interests, environmental on the one hand, and socio-economic on the other are considered. Subsequently, recommendations are derived, which could support the achievement of an eco-anthropocentric development pathway.

4. Results

4.1 Inventory of water-related problems and pressures

The analysed literature shows that there is high awareness regarding human-induced water problems in the region (Table 2). Four problem categories are distinguished thereof three that focus the impacts of human activities on water resources (population growth & urbanization, overabstraction of freshwater, and lack of adequate resource management), and one category that addresses climate change as an exacerbating factor in the already difficult water situation (Table 2). There are overlaps in the referred literature, however, it can be stated that the extent of human activities is the principle reason for an increasingly challenging situation regarding future water supply. Climate change has the potential to intensify current water problems, primarily because of the absence of appropriate water infrastructures and management.

From a research point of view it has been sufficiently described, that the currently critical water resource situation is not properly addressed. The insufficient water situation poses immanent threats for the establishment of a successful tourism industry, and must be considered accordingly.

Table 2 Literature-based inventory of obstacles for socio-economic development in north-eastern: problems and associated pressures of the regional water situation.

Problem category	**Pressures**	**References**
Population growth & urbanization	• Rapid increase of water demand • Imbalance of water supply and demand • Inadequate water use patterns (seasonal overexploitation)	Bzioui et al., 2010; Kadi, 2004; Fetouani et al., 2008; Moustadraf et al., 2008
Overabstraction of freshwater	• Increasing water deficiency for natural and human environment • Lack of agricultural irrigation water • Salinization of groundwater • Reduced freshwater recharge • Sea water intrusion into coastal aquifers • Wetland degradation (RAMSAR site) • Water shortages	Bzioui et al., 2010; Carneiro et al., 2010; El Yaouti et al., 2009
Lack of adequate resource management	• Lack of financial means to modernize the water sector • Lack of measures to react upon the decrease of groundwater • Lack of innovative water production in addition to conventional water supply • Water planning does not include climate change impacts on the water cycle • Inadequate water supply infrastructures • Lack of drinking water • Health problems/bad water quality	Bzioui et al., 2010; Carneiro et al., 2010; Carneiro et al., 2008; Tekken et al., 2009; Tekken & Kropp 2012; Alonso-Almeida, 2012; Boelee & Laamrani 2003; Fetouani et al., 2008
Climate Change	• Drought frequency increase • Pressure on hydrological cycle • Precipitation decrease, temperature increase • Higher evapotranspiration rates • Increasing wind erosion (land loss) • Sea water intrusion into coastal aquifers • Coastal inundation due to sea-level rise • Siltation of river dams • Reduced river sediment transport	Bzioui et al., 2010; Kadi, 2004; Moustadraf et al., 2008; Snoussi et al., 2002; Snoussi et al., 2007; Snoussi et. al., 2008; Tekken et al., 2009; Tekken & Kropp, 2012

4.2 Analysis of regional tourism development plans

In the light of these concerns, the two main tourism development plans for the region are analysed in order to identify if concrete measures are anchored to reduce and counteract the environmental impact (Table 3). Both plans show neither clear criteria for defining targets regarding environmental quality and protection nor compulsory specifications and legally binding-instruments. The achievement of the priority objective "economic growth" by the establishment of tourism is based on the expectation of an infinite availability of water. However, current water shortages and an increasingly problematic situation are neither reflected in the "Moroccan Charter for Sustainable Tourism", nor in the "Plan Azur/Vision 2020". Measures that focus on wastewater reuse and water saving devices focus on the tourism infrastructures only, and enable companies to save money rather than contributing to an overall reduction of the water requirement. Luxury tourism is water intense (Gössling et al., 2012). Considering proportionate water savings by up to "*80 %*" in the facilities (Royaume du Maroc, 2008), still the additional water demand exceeds the capacity of regional water resources (Tekken et al., 2013). The description of sustainability aims, e.g. "*environmental friendliness*" or "[…] *the rational use of natural, scarce and precious resources* […]" lacks a commitment towards the specification of concrete water resources protection measures. Under the overarching policy aims to develop the tourism sector, the focus is mainly on "*employment generation*" and "*wealth generation*".

Table 3 Main objectives regarding sustainable tourism development in Morocco in the "Moroccan Charter for Responsible Tourism" (Royaume du Maroc, 2010) and "Plan Azur" (Roudies, 2010; Royaume du Maroc, 2008).

Institution	**Moroccan Committee of Responsible Tourism**	**Royaume du Maroc, Département du Tourisme**
Document title	Moroccan Charter for Responsible Tourism	Principes de Développement Touristique Durable Cas Marocain (Plan Azur)
Main mission statement	Based on UNWTO's[1] mission statement "…*to promote and to develop tourism as a tool for*	• New tourism policy announced by King Mohammed VI in 2001

[1] World Tourism Organisation UNWTO, URL:http://www2.unwto.org/ (last accessed January 2013).

	peace and international understanding, thereby fostering economic development and international trade" Key task: National body in charge of "*turning tourism into a major source of sustainable development, while at the same time looking after conservation of social and cultural values, the environmental heritage and the protection of the Moroccan identity"*	in order to establish a new profitable economic sector. Six areas are chosen, all located at the country's coastline with so far underdeveloped tourist potential • Place Morocco among the top tourism destinations worldwide[2]
Main statements regarding aims of tourism establishment and environmental aspects	• tourism as "*enabler for socio-economic development*" • "*employment generation*" • "*wealth generation*" • "*fostering* […] *synergies between different world cultures*" • "*environmental friendliness*" • "*It is the duty of all tourism development stakeholders to protect the environment and natural resources, with the aim to foster a sound economic growth, both on-going and sustainable, likely to meet the needs and aspirations of present and future generations*" • "*...rational use of natural, scarce and precious resources, especially water and energy* […] *will be given special weight and fostered by private and public members of the tourism industry*"	• Sector of national economic priority, contributing approx. 8% to GDP • Approx.10 million tourists by 2010 • Accommodation capacity of 230.000 beds in 2010 • All six areas focus on luxury tourism (e.g. golf courses) • 210.000 direct jobs • Realization by private companies (real estate and construction) Elements of sustainability: • controlled urbanisation, e.g. height limitations for buildings (landscape aesthetic) • respect for the coast • Reuse of treated wastewaters for irrigation, e.g. for golf and garden areas • Water-saving sanitary devices
Instruments for tourism-related sustainability	La Clef Verte Maroc[3]/Green Key Eco-label for tourist establishments (awarded by NGO FEE International, see http://www.green-key.org/[4] • implemented in Morocco in 2007 • environmental objectives: „*efficient use of natural resources*", and tourism facilities shall contribute to "*preserving resources and the environment*" • meant as an indicator of "*environmental management*"	• Definition of successive quality stages to ensure sustainable tourism: evaluation of quality standards, setting of standards, information and sensitization • Application of ISO norms for sustainable tourism (ISO TC 228) • Product labels for sustainable tourism

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[2] URL: http://www.resortmorocco.com/Morocco/plan-azur-2010.html (last accessed January 2013).
[3] URL: http://www.clefverte.ma/index.php/en/the-green-key/what-is-the-green-key.html (last accessed January 2013).
[4] FEE International (Foundation for Environmental Education) is a non-government, non-profit organization promoting sustainable development through environmental education. URL: http://www.green-key.org/ (last accessed January 2013).

4.3 The north-eastern Moroccan sustainability pathway

Steurer (2001) defines three categories of sustainability paradigms. The *anthropocentric paradigm* (weak sustainability) denotes that economic growth is given priority over environmental protection. Environment is protected as long as it is economically meaningful. Degradation of resources is accepted if economically meaningful. In Morocco, both tourism development plans emphasize a sustainable pathway, however, the economic interest stands in the foreground. Tourism is seen as "*enabler for socio-economic development*" and "*wealth generation*". The importance of sustainability is often stated, however, no criteria, policies or concrete measures are listed, which indicate a "real" sustainable pathway and the protection of resources.

The instruments "Green key" and "ISO norm TC 288" are rather marketing tools for tourism establishments and operators than effective environmental conservation measures. Such, despite the high risk of severe water shortfalls in the region, an adequate response is not yet formulated and determined.

Accordingly, there are no indications that development in north-eastern Morocco follows a strong sustainability pathway (*ecocentric paradigm*). Following a strong sustainability would mean, that making use of non-renewable resources is no option, thus natural resources are neither available for current nor for future generations (Grundwald & Kopfmüller, 2006). In contrary, a weak sustainability is characterized by the classification of natural resources in natural capital (air, soil, water, biodiversity, resources), and artificial capital (machines, constructions and buildings, knowledge, social structures and livestock) (Grunwald & Kopfmüller, 2006). Nature cannot be fully substituted, as any kind of economic activity depends on an ecosystem service (Grunwald & Kopfmüller, 2006). The opposing positions of weak ("quantitative growth") and strong sustainability (zero growth) both contradict the necessary harmonization of growth and environmental quality (von Hauff & Kleine, 2009). In north-eastern Morocco, economic growth will be limited very likely by restricted water availability and an overstrained environmental carrying capacity (Jurardo et al., 2012). Mass tourism affects the water resources by overabstraction, groundwater lowering and seasonal peaks of water demand (Garcia & Servara, 2003). Further the beach-dune system will be affected by erosion due to constructions and limited sediment transport due to climate change (Garcia & Servara, 2003; Snoussi et al., 2007). These examples represent a small selection of potential impacts for the region. However, current tourism development pathways do not adequately consider the limited capacities of water resources, nor do they define sustainable thresholds for resource exploitation. Standards to safeguard for an environmental stability in the short and in the long run are not set. Environmental stress in the area can lead to social inequity, land degradation, and severe problems with water availability, and an unequally distributed wealth generation. Her, balanced sustainability (*eco-anthropocentric paradigm*) represents a compromise. Economic growth and environmental protection are mutually conducive, if adequate technologies, policies and planning are implemented to allow an environment-friendly growth. Consumption patterns must consider current and future resource availability to secure resources in the long-term-term.

5. Discussion

In most developing countries the institutional enforcement of environmental protection is weak (Wöhlcke 1993). However, an effective environmental policy must be government-induced. The human economy is part of the biosphere and depends on resource availability (Daly 1999; Döring, 2004). Following the economic logic, investments should focus on the limiting factors of production (Döring, 2004). Thus, in the context of water scarcity in north-eastern Morocco, investments are needed in natural capital, in particular if natural resources are concerned above their physical carrying capacity (Döring, 2004).

The environmental burden of large-scale tourism must be considered, e.g. the impact on the seasonal proportion of freshwater supply to total available water resources (Jie et al. 2011; Gössling et al. 2012). Tourism must not be seen as the universal solution to solve all development problems and must not be at the expense of the environment (Arib, 2005).

The focus is on human beings and well-being, but the integration of the environment towards a resource-conserving development must be the primary objective in the sense of an „ecologically extended anthropocentrism" (von Hauf & Kleine, 2009, 35), corresponding to the paradigm of a balanced sustainability after Steurer (2001).

The main beneficiaries of tourism such as the resort destination in Saidia, north-eastern Morocco, are real estate companies (Spilanis et al., 2012). Experiences in other destinations reveal positive effects on employment, however, at the cost of high environmental damage (e.g. Tétouan) (Spilanis et al., 2012; Roudies, 2010). The high structural dependency on the success of the newly established tourism sector enhances the risk of detrimental socio-economic in case of a resource collapse (e.g. severe water shortage and seasonal water shortfalls in the tourist season). The problem lies within the fact that large-scale tourism is not integrated into a vulnerable environment, but that it has the potential to even aggravate the problematic water situation (Tekken & Kropp 2012).

In this sense, in order to complement regional tourism development plans by an additional sustainability component, following recommendations are considered as appropriate to support a balanced growth:

- Definition of critical thresholds for freshwater, e.g. carrying capacity or ecological stability (Grunwald & Kopfmüller, 2006);
- Monitoring of environmental pressures caused by direct effects, e.g. indicators for biodiversity loss and wetland degradation (Spilanis et al., 2012);
- Inclusion of the local population and resource users (tourism industry) in the management of resources (Lawson et al., 2010)
- Establishment of waste disposal and evaluation criteria (Gaulke et al., 2010);

- Establishment of modern and appropriate water infrastructures and management (Alonso-Almeida, 2012; Gössling et al. 2012);
- Strong reduction of open water channels for irrigation;
- Establishment of wastewater treatment and reuse for irrigated tourism areas (golf courses and garden areas) by a fixed share of freshwater and recycled water (Tekken et al., 2013);
- Establishment of technologies for water generation, e.g. rainwater collection and storage systems in tourism facilities (as part of building planning and design)
- Monitoring system for tourism water by indicators: water use in m^3, seasonal annual abstraction in m^3, and the share of recycled/re-used water compared to freshwater;
- Monitoring/Measurement of groundwater salinity as indicator for overabstraction;
- Establishment of a pro-active water management, e.g. measurement of tourists' water footprint (Gössling et al. 2012);
- Laws on the planning of human settlements at local and regional level to avoid uncontrolled littoralization and landscape change into (Leontidou et al., 1998);
- Legally binding regulations for public administration and private businesses and control mechanisms to ensure compliance (Cabanillas et al., 2013);
- Integrated Coastal Zone Management (ICM) involving local communities in the management of coastal resources (Caffyn and Jobbins, 2003);
- Inclusion of anthropogenic drivers in the region for the reform of the water sector (Doukkali, 2005).

6. Conclusion

This article sketches out the necessity of a balanced sustainability for luxury tourism development in north-eastern Morocco. Despite a unique, sensitive and worth to be protected environment in the coastal zone between the cities Nador and Saidia (RAMSAR site Moulouya river basin), the landscape will be altered significantly by a large-scale tourism development. Consciousness regarding the serious interference with nature is expressed in the “sustainability” labelling of regional tourism development plans. As environmental protection measures are often seen as obstacles for economic interests, despite the existence of environmental legislation, ecological rhetoric frequently replaces effective implementation. However, many countries must take action to improve the living conditions of their populations. In Morocco, the economic diversification is an important step in the country’s development from a mainly agrarian to a more service-oriented economy. Morocco has great potential for successful coastal tourism, however, to make tourism prospective and sustainable in the long-term, the estimation of the environmental carrying capacity should be an integral part of management strategies to avoid the depletion of ecosystem quality and the sectoral failure (Castellani et al., 2007; Spilanis, 2009).

In this article we exemplarily analysed the anchoring of sustainability in the respective development plans for north-eastern Morocco, and detected the neglect of the current critical resource (water) situation, which is a crucial aspect for a successful establishment of tourism. We consider “*balanced sustainability*” as intermediate way between strengths and weaknesses of sustainability concepts (Steurer 2001). In fact, it depends very much on the particular case, but for north-eastern Morocco tourism development must be supported by appropriate public policies and management. The current absence or inadequacy of institutional, legal, and other policy instruments enables economic growth at the expense of the environment. High ecological risks, such as critical water shortage, must be prevented. Compliance with high environmental standards ensures the long-term availability of resources, which is not the main emphasis of the interest of tourism businesses. A balance is needed between the interests of facilitators of socio-economic development and environmental protection under the responsibility of public authorities. The transformation process of the regional economy currently is resource pragmatic, as neither resource threshold values are defined, nor measures for an effective and appropriate water management. The resource reality is already critical: there is scientific evidence for severely limited water availability. New practices and standards regarding the management of nature are needed, that go beyond mere rhetoric. Thus, the success or failure of socio-economic development in north-eastern Morocco, facilitated by luxury tourism, remains first and foremost a matter of governance structures (UNEP/MAP, 2012).

Acknowledgements

This work was supported by the project "ACCMA—Adaptation to Climate Change in Morocco" as part of the program "Adaptation aux Changements Climatiques en Afrique (ACCA)" of the International Development Research Centre Canada (IDRC) and the UK Department for International Development (DFID).

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Acknowledgements

This dissertation is the outcome of research carried out at the Dept. Climate Impacts and Vulnerabilities, Research Area Climate Change & Development (head: Prof. Dr. Jürgen P. Kropp), Potsdam Institute for Climate Impact Research, Germany. The evaluation of increasing water scarcity under climate change and development pressures was a key topic of the ACCMA project ("Adaptation to Climate Change in Morocco", 2007-2010), research funded by the UK Department for International Development (DFID), as part of the program "Adaptation aux Changements Climatiques en Afrique (ACCA)" of the International Development Research Centre Canada (IDRC).