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Cross-Comparison of Climate Change Adaptation Strategies Across Large River Basins in Europe, Africa and Asia

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Abstract A cross-comparison of climate change adaptation strategies across regions was performed, considering six large river basins as case study areas. Three of the

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basins, namely the Elbe, Guadiana, and Rhine, are located in Europe, the Nile Equatorial Lakes region and the Orange basin are in Africa, and the Amudarya basin is in Central Asia. The evaluation was based mainly on the opinions of policy makers and water management experts in the river basins. The adaptation strategies were evaluated considering the following issues: expected climate change, expected climate change impacts, drivers for development of adaptation strategy, barriers for adaptation, state of the implementation of a range of water management measures, and status of adaptation strategy implementation. The analysis of responses and cross-comparison were performed with rating the responses where possible. According to the expert opinions, there is an understanding in all six regions that climate change is happening. Different climate change impacts are expected in the basins, whereas decreasing annual water availability, and increasing frequency and intensity of droughts (and to a lesser extent floods) are expected in all of them. According to the responses, the two most important drivers for development of adaptation strategy are: climate-related disasters, and national and international policies. The following most important barriers for adaptation to climate change were identified by responders: spatial and temporal uncertainties in climate projections, lack of adequate financial resources, and lack of horizontal cooperation. The evaluated water resources management measures are on a relatively high level in the Elbe and Rhine basins, followed by the Orange and Guadiana. It is lower in the Amudarya basin, and the lowest in the NEL region, where many measures are only at the planning stage. Regarding the level of adaptation strategy implementation, it can be concluded that the adaptation to climate change has started in all basins, but progresses rather slowly.

Keywords Climate change · Water management · Adaptation to climate change · River basin · Questionnaire · Driver · Barrier · Amudarya · Elbe, Guadiana · Nile Equatorial Lakes region · Orange · Rhine

1 Introduction

Historically, water resources management was based on the assumption of stationary conditions. The hydrological design rules for flood management were derived using the assumption of stability and stationarity, though the relatively short time series of historical data in comparison to the return period to be estimated still led to uncertainty of results. However, in view of climate change this is not valid anymore (Milly et al. 2008). The water management rules, procedures for designing infrastructure, and the approaches to water management have to be changed, taking into account higher uncertainty (Pahl-Wostl 2007). In general, climate change issues have to be taken seriously in water management planning (Bates et al. 2008).

The dynamics of the global emissions of greenhouse gases significantly affect the magnitude of future climate change, revealed by changes in temperature, precipitation and other climate characteristics. The reduction of greenhouse gas emissions should therefore be the primary global political goal in order to mitigate climate change and to prevent disastrous impacts (Pachauri and Reisinger 2007). So, the declared goal of the European Union is to limit the temperature rise to 2°C above the pre-industrial level. This aim has to be translated into implementing policy measures and emission reduction targets. However, serious efforts are absolutely necessary to cope with the impacts of climate change, which are already happening or will be unavoidable even if the 2°C target is reached. Therefore adaptation to climate change impacts is gaining increasing relevance on the global and European political agenda. Adaptation to climate change is defined as initiatives and measures to reduce the vulnerability of natural and human systems against actual or expected climate change effects (Pachauri and Reisinger 2007). In other words, adaptation primarily aims at moderating the adverse effects of unavoidable climate change effects through a wide range of actions and measures that are targeted at the vulnerable system (Fuessel and Klein 2006).

What is the meaning of an adaptation strategy and adaptation measures in view of climate change? Should the adaptation strategy include any new measures for flood protection, management of water demand and coping with droughts, or should it be a comprehensive combination of already known measures, and another, more adaptive and integrated, approach to water management?

Adaptation to changing conditions, increasing water demand and climate variability was always assumed in water management. Water managers learned from their experience how to deal with water shortages, meet the increasing demand for water, and build infrastructure for flood protection. They also learned from their mistakes in managing water resources (e.g. extensive amelioration and drying of wetlands). In that sense the need for adaptation in water management is not something totally new. However, now it should be taken much more seriously in view of dynamical and unprecedentedly rapid changes in climate and increasing uncertainty. The measures need to be developed that enhance the capacity to cope with uncertain and often unexpected changes. This means that the adaptive capacity, defined as the whole of capabilities, resources and institutions of a country or region to implement effective adaptation measures and better cope with changes in external conditions (Smit and Wandel 2006; Fuessel and Klein 2006; Pachauri and Reisinger 2007), needs to be enhanced towards threats that cannot be well defined. Next to the fact that changes in climate can come more rapidly, their effects and impacts might also be more severe than what was known before.

The adaptation strategy should be based on an integrated approach to water resources management and consider the river basin as a functional unit (Timmerman et al. 2010). Measures will mostly focus on flood and drought protection and managing water demand. Though it is clear that current procedures for designing infrastructure and rules for managing water demand must be revised in view of climate change, not many absolutely new adaptation measures to be considered for water management at the river basin scale exist. However, some measures could be new for a specific river basin. It is necessary to create a comprehensive combination of already known measures and to put more emphasis on the less traditional non-structural approaches (UNECE 2009). Hence the involvement of stakeholders and learning from experience and success stories in other river basins are principal, and the importance of stakeholder participation in water management should be emphasized further.

A cross-comparison of climate change adaptation strategies across regions was performed in the EU FP6 NeWater project (Contract No. 511179), considering six large river basins as case study areas. A cross-case comparison can provide insights into major drivers and barriers for the development of adaptation strategies and their relationships with the perceived need for adaptation in each respective case. As such it can help to identify conditions under which the development of climate adaptation strategies is more likely. Three of the basins, namely the Elbe, Guadiana, and Rhine, are located in Europe, the upper Nile (the Nile Equatorial Lakes, or NEL region) and the Orange are in Africa, and the Amudarya is in Central Asia (Fig. 1). The objectives of the study were:

– to evaluate the state of adaptation strategies to climate change in six large river basins;
– to assess, what are the most important drivers for the development of adaptation strategy, and barriers preventing such development, and
– to analyse the **S**trengths, **W**eaknesses, **O**pportunities and **T**hreats (SWOT analysis) related to climate change in the same six basins.

This is necessary in order to understand where we are in terms of climate change adaptation in different regions, and how to enhance adaptive capacity.

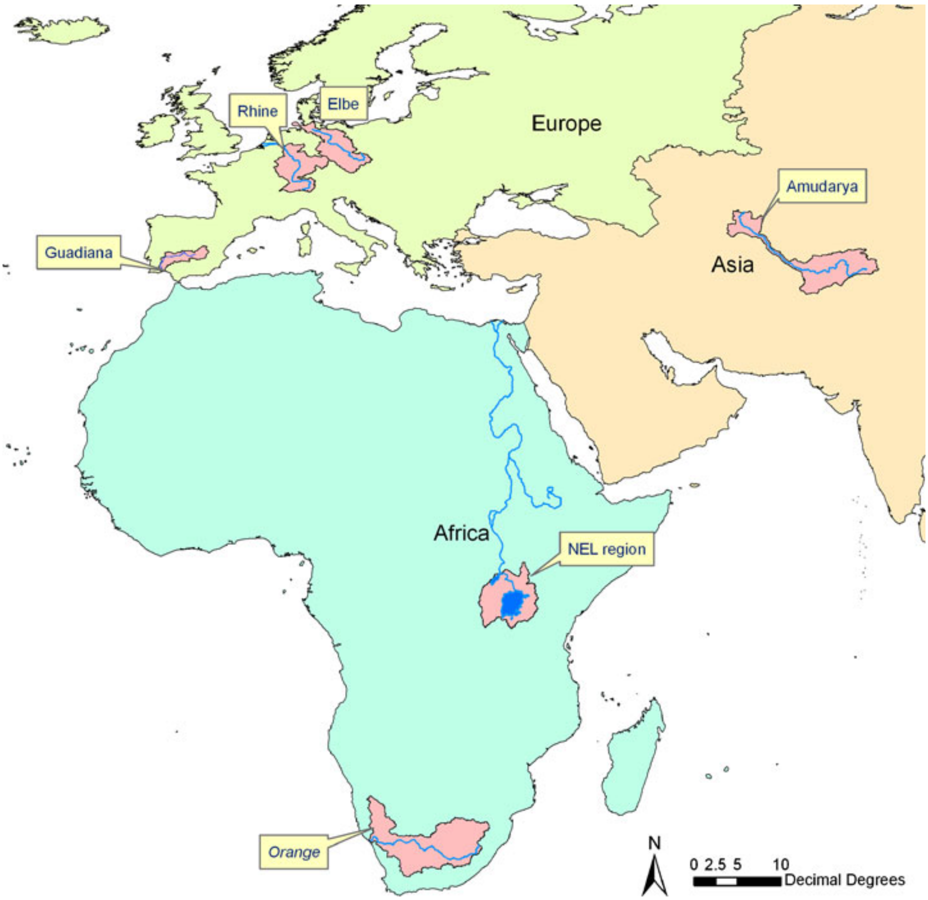


Fig. 1 Six river basins (including the NEL region) used as case study areas for the cross-comparison of adaptation strategies

The knowledge of most important drivers and barriers for the implementation of adaptation strategy could help to utilize the drivers and weaken the barriers in future development.

The evaluation and analysis were based on the opinions of policy makers and water management experts in the case study river basins expressed as questionnaire responses and elicited during the interviews. Expert opinion is considered as a legitimate source of information where required data are unavailable from other sources (Leal et al. 2007). So, in the following all described results and conclusions are based on the *perceptions of experts*. Sometimes they are compared with the modelling studies and/or policy analysis for the case study river basins reported in literature.

A preliminary study on existing practices and strategies for coping with floods and droughts was performed in the NeWater project for the same river basins (Krysanova et al. 2008). It showed that structural measures for flood protection exist in all studied river basins, whereas non-structural measures are generally not very extensive and/or advanced. The study outlined success stories and lessons learned in coping with extreme events.

2 Case Study Regions

This section provides a short overview of six case study river basins focusing on their water management issues. The formal reason for the choice of these case study basins was that they were investigated in the framework of the EU funded NeWater project on adaptive water management (Pahl-Wostl et al. 2005), and the policy maker and stakeholder communication was an important component of the study. They are large transboundary river basins with different physico-geographical characteristics and socio-economic settings located in three continents. This all makes the cross-comparison of adaptation strategies especially interesting and valuable.

The geographical and climate characteristics and status of water management in the basins are described in Krysanova et al. (2008). The basin locations are shown in Fig. 1, and some of their major characteristics, major water-related problems, and expected climate impacts are listed in Tables 1 and 2.

2.1 The Amudarya Basin

The Amudarya River flows 2,540 km from the Pjandj headstream in the Pamir mountains through the Turan lowlands to the Aral Sea. Runoff is generated almost exclusively from glacier and snowmelt in the high mountainous areas of Tajikistan, Afghanistan and Kyrgyzstan while water consumption is highest in the downstream countries of Uzbekistan and Turkmenistan. The region is characterized by a semi-arid strongly continental climate. Climate change impacts are expected to reduce river flow volume (Agaltseva 2005), change the relative runoff contributions from snow, glacier melt and rain (Ososkova et al. 2000) and thus lead to a shift in timing of peak flows (Savitsky et al. 2007) and an increase in occurrence of extreme events.

Water is a strategic and vital resource for the region's economies with agriculture, particularly cotton production, accounting for approximately 20–35% of national GDPs (World Bank 2009). Hence, water management policies are largely governed

Table 1 Characteristics of six case study regions

River basin (continent)	Countries sharing drainage basin area	Drainage area, km^2	Average annual precipitation
Amudarya (Asia)	Uzbekistan, Tajikistan, Turkmenistan, Afghanistan, Kyrgyz Republic	309,000	200 mm a^{-1} on average (from 50 to 800 mm a^{-1})
Elbe (Europe)	Germany, Czech Republic, Austria, Poland	148,268	659 mm a^{-1} on average (from 450 to 1,600 mm a^{-1})
Guadiana (Europe)	Spain, Portugal	66,800	550 mm a^{-1} on average (from 400 to 600 mm a^{-1})
Nile Equatorial Lakes region (Africa)	Burundi, Kenya, Rwanda, Tanzania, Uganda	396,000	Above 1,000 mm a^{-1}
Orange (Africa)	Lesotho, South Africa, Namibia, Botswana	896,368	From 25 to 2,000 mm a^{-1}
Rhine (Europe)	Germany, Switzerland, France, Netherlands, Austria, Belgium, Italy, Liechtenstein, Luxembourg	185,000	From 700 to 1,200 mm a^{-1}

by the priorities of agriculture sector, which uses more than 90% of the available water resources (Abdullaev et al. 2009). This increasingly leads to conflicts with other users such as hydropower generation or fisheries in the floodplain lakes of the river delta (Schlüter et al. 2009). Alterations to the river flow regime by the massive expansion of irrigated agriculture (mainly for cotton production) have caused severe ecological degradation such as the desiccation of the Aral Sea, loss of deltaic wetlands and massive soil salinization.

Major water-related problems (Table 2) are substantially aggravated by massive water overuse, high water losses due to deteriorating infrastructure and uncoordinated water allocation, as well as water mismanagement and problems of enforcement of water allocation quotas (Schlüter and Herrfahrdt-Pähle 2007). So far a technocratic top-down approach to water management has been predominant. However, in recent years responsibility for local water management has been devolved to local water user associations.

2.2 The Elbe Basin

The Elbe is a 1092 km long international river. Its basin is located mainly in Germany (≈2/3 of the drainage area), and the Czech Republic (≈1/3). About 25 million inhabitants live in the basin. The largest cities are Berlin, Hamburg and Prague. The Elbe river basin is classified as the driest among the five largest river basins located partly or fully in Germany (Rhine, Danube, Elbe, Weser, and Ems). During recent years, extreme hydrological situations were observed on the Elbe—a destructive flood in August 2002, and a severe drought only one year afterwards.

Table 2 Main water-related problems in the case study regions

River basin	Major problems related to water management	Expected climate change impacts according to literature sources	Literature sources
Amudarya	Water shortage in low water years, which severely affects agricultural production and drinking water provision; widespread soil salinization; and massive degradation of wetlands in the delta affecting the provision of wetland ecosystem services	The impacts on river runoff volume are highly uncertain, though a projected decrease by 10–15% by 2050 seems likely as well as an increase in the frequency and severity of extreme events	The first national communication of Tajikistan (2002), Savitsky et al. (2007), Chub (2007)
Elbe	Floods and their consequences for infrastructure and arable land; vulnerability against water stress in dry periods and related problems for agriculture and water supply; and pollution of surface water and groundwater	Higher average temperatures and lower precipitation in summer are projected, indicating that the water scarcity problem will grow, with adverse consequences to agriculture, forestry, water supply, navigation and recreation. The intensity of rainfall and the frequency of floods are expected to increase as well	Hattermann et al. (2008), Becker and Grunewald (2003)
Guadiana	The key water-related problems differ in three sub-regions: depletion of aquifers and loss of wetlands in the upper part, technical and policy challenges for irrigation development based on surface water in the middle part, and problems of high water demand and saltwater intrusion in the lower part of the basin	Temperatures are expected to increase by 1°C and rainfall is expected to decrease by 5% by 2030, which can be translated into 11% of potential decrease in water availability	CHG (2007b), CHG (2008), MARM (2008)
Nile Equatorial Lakes region	The most critical issue is deterioration of water quality, raising with increasing population and level of industrial activities. The main impacts on water resources include: sedimentation of water bodies, pollution of surface water and groundwater, and fecal contamination of water for domestic use, making water resources inappropriate for human consumption	The frequency of climate extremes is increasing with disastrous effects on the social-economic development. Floods cause damage to infrastructure, and create health hazards and crop destruction leading to food insecurity, malnutrition, and displacement of people. Droughts accelerate desertification, affect hydro-power generation and industrial production	CIA (2007)

Table 2 (continued)

River basin	Major problems related to water management	Expected climate change impacts according to literature sources	Literature sources
Orange	Main issues of concern are rainfall variability, water scarcity and problem of water sharing. Scarcity of water is considered to be one of the most significant factors limiting social, economic, industrial and agricultural development in the Southern Africa	A decrease in mean annual precipitation by approximately 15–25% in the western portion of the basin, and increase by up to 10% in the upper regions by 2100 are expected. An increase in the number of rainless days is projected, and number of days with heavy precipitation will also increase, exacerbating flood events	Schulze et al. (2005)
Rhine	The whole river faces the problem of pollution, mainly from non-point sources. Going downstream, the problem of flood protection becomes more severe, and increased urbanisation at the river banks has increased the potential damages in case of flooding. Also extreme droughts are increasingly drawing attention of water managers	General Circulation Models project an increase in winter precipitation of about 20% by the end of twenty-first century, causing an increase in flood frequency. However, higher summer temperatures will increase evapotranspiration, and less water will be available in summer with consequent higher risk of droughts and heat waves	KNMI (2006), Raadgever (2005)

The Elbe and its tributaries are intensively used for freshwater supply for domestic, industrial and agricultural purposes. Even though emissions from point sources have notably decreased in the basin since the 1990s due to reduction of industrial sources and introduction of new and better sewage treatment facilities, the diffuse sources of pollution represented mainly by agriculture are still not controlled sufficiently. Water management in the basin is well developed and has a good potential to introduce IWRM and adaptive management. The transboundary cooperation exists on several levels. The highest is the International Commission for the Protection of the Elbe created in 1990.

The results of climate change impact assessment studies for the Elbe basin (Krysanova et al. 2005, 2007; Hattermann et al. 2008) show that water discharge and groundwater recharge in the basin will most likely decrease under warmer climate. However the uncertainty in hydrological response to changing climate is generally higher than the uncertainty in climate input. Nevertheless, some of the impact assessment results are quite robust. For example, the low flow in late summer and autumn in the Elbe river will be most probably drastically reduced by the mid of twenty-first century (Hattermann et al. 2008; Huang et al. 2010).

2.3 The Guadiana Basin

The Guadiana River basin is located between the southern central Plateau of Spain and the Portuguese south-eastern region, covering an area of 67,000 km^2. This study focuses on the Spanish part of the basin (83% of the total area). The region is characterized by a semi-arid Mediterranean climate, and is one of the driest territories of Spain. The average annual precipitation in the basin is about 550 mm/year. A high inter-annual and spatial variability in rainfall increases vulnerability to droughts, especially during the summer season. About 1.34 million inhabitants live in the basin. The economic development in the basin is largely dependent on the agricultural sector.

The basin is very heterogeneous. In the upper Guadiana, the expansion of irrigation has been based on the exploitation of groundwater sources. It has had positive socio-economic effects for the former stagnated rural areas. But it has provoked some negative environmental impacts (Table 2) and significant social conflicts among water users, in particular those related to illegal water pumping (CHG 2007a). In the middle part of the Guadiana basin, a network of canals, reservoirs and large dams provide a massive storage capacity of nearly 8,000 million m^3 of water (84% of the total storage capacity in the basin). The lower Guadiana is characterized by pressures due to domestic water use and insufficient fulfillment of demands, and problems with saltwater intrusion. This justifies the need for designing sub-regional strategies targeted to specific areas.

According to climate change projections for the Spanish regions (Brunet et al. 2009), annual precipitation is expected to decrease by 10% to 15%, and available water resources would be reduced by about 17% for the 2060 horizon. In this context, the Guadiana basin will be one of the Spanish basins suffering the most severe reductions in water availability (CHG 2007b, 2008; Iglesias et al. 2005; MARM 2008). It is expected that climate change will have strong negative effects on agriculture due to the decline in water availability and increase in crop evapotranspiration (Iglesias et al. 2005).

2.4 The Nile Equatorial Lakes Region

The Nile Equatorial Lakes region comprises parts of five countries (Table 1). The region is a plateau in the southern part of the Nile basin with an elevation between 1,000 and 2,000 m with peaks of 5,100 and 4,300 m. This plateau contains several lakes including Lake Victoria, George, Edward and Albert (Sutcliffe and Parks 1999). The region is characterized by a tropical climate and is populated by almost 50 million inhabitants.

Land use in the NEL region is characterized by subsistence rain-fed agriculture extending to marginal lands due to continuing population growth. The conversion of natural forest, wetlands and savannah grasslands into cropland reduces the water buffering capacity of watersheds, and water availability during dry seasons is reduced. The land degradation reduces soil quality as well as agricultural productivity. The most critical issue is pollution of rivers, lakes and groundwater. In particular, water pollution of the Lake Victoria is heavily impacting freshwater fish export and, as a consequence, the income of the governments. Population and poverty can not be unlinked from water resources use in the NEL region. The pressures of population growth and economic development within the poverty-stricken communities cause water stresses and scarcities in areas, which otherwise would be endowed with sufficient water.

The increasing climate variability is making affected communities even more vulnerable to disasters (Boko et al. 2007). These countries rely heavily on rain-fed agriculture. The frequency of climate extremes is increasing with disastrous effects on the social-economic development (Conway et al. 2005). Floods cause damage to infrastructure, and create health hazards and crop destruction leading to food insecurity, malnutrition, displacement of people and communities. Droughts accelerate desertification, affect hydropower generation and industrial production. The increasing climate variability caused by climate change is making affected communities even more vulnerable to disasters.

The potential climate change impacts on hydrological processes were assessed for the whole Nile basin by Beyene et al. (2007) using downscaled climate from 11 General Circulation Models. The results show that the basin will experience increases in precipitation early in the century (2010–2039), followed by decreases later (2040–2100) with the exception of the eastern-most Ethiopian highlands with increases in summer precipitation by 2080–2100. These changes would result in higher (by 11–14%) streamflow in period 2010–2039, and lower (by 7–16%) streamflow in 2040–2100 at High Aswan Dam compared to the historical period (Beyene et al. 2007). For the Lake Victoria subbasin (a part of the NEL) an increase in precipitation by 17–23% in 2010–2039, and a decrease by 4–10% in 2070–2099 (Beyene et al. 2007) would be accompanied by the corresponding changes in runoff. Implications of climate change on the water resources were analyzed by quantifying the annual hydropower production and irrigation water releases at High Aswan Dam, which generally would follow changes in streamflow.

2.5 The Orange

Rising 3,300 m above sea level in the steep Maloti Mountains of eastern Lesotho, and flowing for some 2,300 km through an increasingly arid landscape in South

Africa, Botswana and Namibia until it reaches the Atlantic Ocean, the Orange River has one of the largest basins in the world. The basin is characterized by a variable hydrological regime fed by rainfall ranging from 50 to 2000 mm per year from west to east. Several major tributaries support the livelihoods of 19 million people.

Due to the wide variability in climate in the region, there is little certainty about whether there are already measurable changes to the water resources as a result of climate change in the basin. For many years, water resource managers have had to contend with naturally alternating floods and droughts, and in some respects are well equipped to adapt to climate induced changes.

Rainfall variability has been addressed in the basin through the development of a highly complex system of transfers and storage, to the extent that water resources are considered to be close to maximally utilised. In spite of this development, infrastructure to deliver water to local populations is lacking in many rural areas, and many households cannot afford to pay for water. The Orange basin carries one of the most regulated rivers in the Sub-Saharan Africa, encompassing the huge Lesotho Highlands Water Project, under which arrangement South Africa pays Lesotho for water storage. There are increasing tensions about the allocation of water to those living in this basin. Future water demands are likely to be met through transfers into the Orange from other river basins (Department of Water Affairs and Forestry 2004).

According to the climate impact assessment for the Orange basin (Schulze et al. 2005; Knoesen et al. 2009), rainfall is projected to generally increase, with consequential amplified increases in streamflow and the occurrence of flooding, especially for shorter return periods. The upper reaches of the basin in the east could be particularly affected. Yet, despite of the widespread projected increases in rainfall, some areas within the basin are likely to experience decreases in annual streamflow (Knoesen et al. 2009). Areas experiencing meteorological and hydrological droughts could generally decrease, especially those of shorter duration. Rainfall and streamflow are projected to become more variable in future.

2.6 The Rhine Basin

The Rhine River is one of the longest rivers in Europe (Van der Keur et al. 2008) with a length of 1300 km, of which 800 km are navigable. It spreads over an area of 185,000 km^2 and is shared by nine countries. Germany (55% of basin area), Switzerland (18%), France (13%) and the Netherlands (6%) share most of the basin area (Wolf et al. 1999), and the parts of the basin in Austria, Belgium, Italy, Liechtenstein and Luxembourg are very small. The Rhine has a combined rainfall-snowmelt driven flow regime with peak discharges occurring in winter (Silva et al. 2004). The river has favourable hydrologic characteristics and a favourable flow distribution over the year that explain why it became an important traffic chain (Huisman et al. 2000). Besides for navigation the river water is used for domestic and agricultural water supply, industry, power plants (incl. hydropower generation), fisheries and recreation. About 60 million people live in the Rhine basin (Huisman et al. 2000).

Transboundary water management has a long tradition in the basin. The International Commission for the Protection of the Rhine was established in 1950 after pollution-related problems became noticeable. Recent flood events drew political and general attention to flood management and to transboundary cooperation in flood management. Climate change can lead to important changes in the boundary conditions of the water systems in the basin. According to recent research, severe floods and droughts are expected to occur more often in the Rhine basin (Middelkoop et al. 2001; Raadgever 2005). Increasing attention is paid to upstream and downstream effects of measures, which activates transboundary cooperation (Raadgever et al. 2008b).

3 Methods

Two methods used (a) for the cross-comparison of adaptation strategies and (b) the SWOT analysis in the basins are described below.

3.1 Cross-Comparison of Adaptation Strategies

The method chosen for the evaluation of the state of climate change adaptation strategies was a questionnaire survey. The elicitation of expert opinions was considered as a legitimate source of data because the required information is unavailable from other sources (Leal et al. 2007). The questionnaire was distributed among the water management experts in the basins, and results analysed and evaluated looking for dominant answers by a majority of experts, and priority lists of chosen options. This method seems to be appropriate for the objectives, because the results for every basin come as a common opinion of a group of knowledgeable people (experts on the main subject), which would allow to compare results between the regions.

A questionnaire for evaluating climate change adaptation strategies in the six river basins was developed at a workshop by a group of authors of this paper and experts in water management. Altogether, three workshops were conducted, at which the questionnaire was developed, methods of evaluation were determined and discussed, and the results evaluated. The questionnaire included the following seven questions:

1. Is climate change happening? Which changes of climate are expected in your region?
2. What are expected climate change impacts in your region?
3. What are the drivers for developing an adaptation strategy?
4. What are the barriers for developing an adaptation strategy?
5. Which adaptation measures are needed, existing, and planned in your region?
6. Please specify climate change adaptation strategy in your region:
   - is there a shared recognition of climate change related problems?
   - is there a shared vision for an adaptation strategy and action plan?
   - is there a program/plan of activities and measures related to climate change adaptation?
   - are there any institutional adaptations taking place or planned (changes in laws/rules/policies/decision-making procedures)?
7. What is the status of the adaptation strategy implementation in your region?

Every question had suggested options for answers, and an open option. The lists of options were created at the abovementioned workshop. The scope of the study with seven questions is shown in Fig. 2.

The analysis of responses and cross-comparison were performed with rating of responses where possible. Evaluating the responses, the *dominant answers* (expressed by a majority of experts) were looked for, and *priority lists* (e.g. lists of the most important impacts, drivers or barriers confirmed by a majority of responders) were established. We looked for *overall conclusions* resulting from the majority expert opinions in all or almost all regions, as well as *conclusions for every region*. The latter were cross-compared where possible.

Question 1 was about understanding the perceptions of the respondents on climate change in the regions, and had two parts. The first sub-question "Is climate change happening in your region?" suggested three options: "yes", "no", and "unclear". The second sub-question included seven options, such as "warmer and less precipitation", "changed seasonality", etc. to express expected changes in climate characteristics in the region. Doing evaluation of responses on this question, the *dominant answers* and *priority lists* of expected changes in climate for the basins and overall were looked for.

Question 2 was aimed in evaluation of expected climate change impacts on water and water-related sectors, and included 16 options (listed in Section 4.2). For every option it was possible to distinguish between "strong impact expected", "some impact expected", and "not expected". Here the *priority lists* of impacts for the basins and overall impacts in all or in a majority of the basins were established.

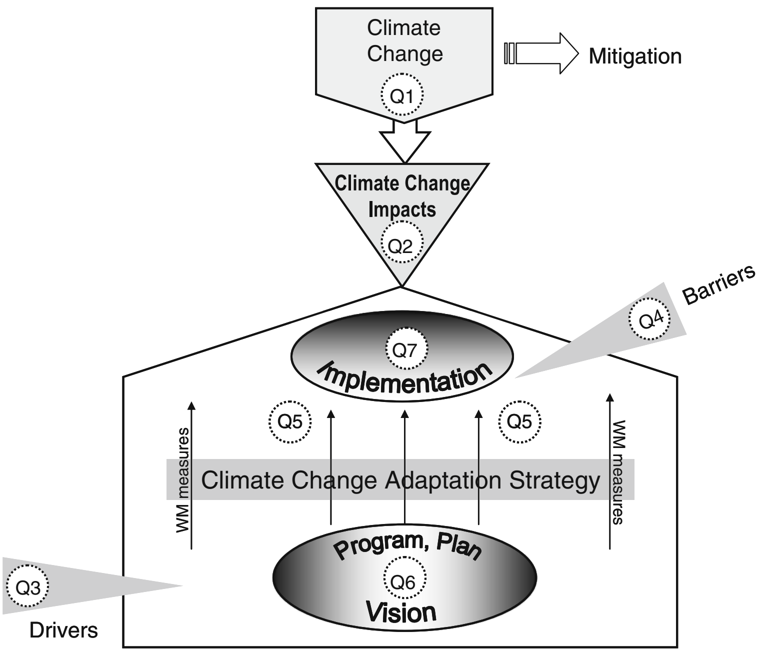


Fig. 2 Scope of the study indicating Questions 1-7 (Q1…Q7) included in the survey

Question 3 about actual or potential drivers for the development of climate change adaptation strategy suggested 9 options (see the list in Section 4.3). Doing evaluation of results, the *priority lists* of drivers for the basins and overall were created.

Question 4 was about main barriers for adaptation to climate change. There were 17 options (see Table 8), which were suggested and confirmed at the abovementioned workshop. The responders had to distinguish between "strong barrier", "not a strong barrier", and "not a barrier" for these options. Evaluating this part, the *priority lists* of barriers confirmed by a majority of respondents in the specific basins and *overall barriers* confirmed by a majority of respondents in all the basins, were established.

Question 5 intended to evaluate the status of adaptation measures in the regions, under which 36 water management measures divided into eight categories (Table 3) were understood. The following eight categories of measures were considered:

- use of climate information,
- infrastructure,
- measures in agriculture,
- spatial planning measures,
- hard measures in water resources management,
- soft measures in water resources management,
- social measures, and
- measures related to distribution of information, communication and education.

There was also a possibility to add other measures. Many of the listed measures are already used in water management for centuries. They were included, as in our understanding the adaptation strategy to climate change assumes a comprehensive combination of already known measures, which are applied in an integrative manner for the whole drainage basin (see more explanations in Section 1, par. 5).

Every measure had to be evaluated by the experts, firstly for its necessity in the basin (needed or not needed), and secondly for its level of implementation, distinguishing the following options:

- existent and fully implemented,
- existent and planned,
- existent, but not planned,
- not existent, but planned,
- not existent and not planned.

Here, *weighted average indices* were calculated for every measure regarding its "level of implementation" using the scores from 5 (existent and fully implemented) to 1 (not existent and not planned) and taking into account number of responded experts. Then, *average indices* per category were calculated for every basin, considering only those measures, which were confirmed as "needed" by the majority of experts (>66%). The threshold of 66% was accepted to comply with the qualitative analysis method used for evaluation of other responses as well. Using

Table 3 List of water management measures divided into eight categories, which were included in the evaluation (Question 5)

Category	Measures
5.1 use of climate information	Regional climate change scenarios
	Improved monitoring, forecasting, application and evaluation of water supply and water management models
	Flood mitigation systems of forecasting, early warning, evacuation, and post-flood recovery
	Early warning system for droughts
5.2 infrastructure	Maintenance and enhancement of infrastructure (dams, levees, dykes, river embarkments)
	Maintenance and enhancement of water storage reservoirs
	Increasing water storage capacity in surface and groundwater reservoirs
	Conjunctive use of surface water and groundwater
	Water transfer from external sources (inter-basin)
5.3 agriculture	Improved land use in agriculture: crop substitution and diversification, modified vegetation cover to reduce evapotranspiration
	Agriculture practices reducing runoff (catch crops, no black fallow)
	Adjustment of planting dates and crop varieties
5.4 spatial planning	Land use planning accounting on higher frequency of extreme events
	Zoning (delineation of floodplain zone with low-value infrastructure)
	Ensuring appropriate construction methods in flood-prone areas
5.5 WRM hard measures	Increase of natural water retention and water storage in watersheds (extending floodplains, creation of wetlands and polders)
	Enhancement of infiltration and retardation of water (reducing impermeable areas, building groundwater cisterns etc.)
	Water reuse and water recycling
	Expanded use of rainwater harvesting
	Sea water desalination
5.6 WRM soft measures	Improved water use efficiency in different sectors
	Development of water allocation strategies among competing demands, exchange of water rights
	Drought contingency planning: restrictions on water use, rationing schemes, special water tariffs, reduction of low-value uses
	System of water pricing, quotas and subsidies, legal measures
	Improved industrial practices with water saving schemes
5.7 social measures	Emergency and disaster recovery committees (also transboundary)
	Development of non-farm livelihoods in drought affected areas
	Household mitigation and preparedness actions
	Risk spreading method: climate-related hazards insurance

Table 3 (continued)

Category	Measures
5.8 information, communication and education	Capacity building (improving climate change awareness, understanding and preparedness) Awareness raising among population on climate change issues Information and education on scarce water resources usage Information and education on flood protection issues Information and education of better management practices in agriculture Improvement of transboundary cooperation (monitoring, early warning) Application of new technologies: efficient cooling systems, improved seeds, desalination technologies, etc.

the indices, spider diagrams were built to cross-compare basins for every category of measures.

Question 6 about climate change adaptation strategy in the region had four sub-questions (see above). The descriptive answers of the respondents were evaluated for these four sub-questions, putting them into categories "yes", "some, in progress", or "no", and then shares of experts responded were calculated, and *dominant answers* by a majority of respondents were determined.

Question 7 on the status of adaptation measures implementation in the region suggested a choice between three options:

- only traditional water management, no signs of moving to climate change adaptation,
- adaptation to climate change starts, but slowly, and
- a progress is visible: existing adaptation strategy, some measures are implemented, other planned.

The network of experts used for the survey was taken from the NeWater project which included these six river basins as case studies. Through the project contacts, the questionnaire was sent to (or interviews were conducted with) the water managers, water-policy makers, NGOs and researchers dealing with water management in their basins. The people were selected for the survey on the basis of their knowledge of the water management situation in their basins. The authors had long-term communication with most of them in the framework of the NeWater project. Altogether, 71 experts responded the Questionnaire or were interviewed in six basins (see Table 4). Most of the respondents are not experts on climate change issues but encounter climate impacts on water-related sectors and adaptation in their work. Some of them are recognized expects in climate change.

For example, the experts in the Amudarya river basin were from the main Hydrometereological Service in Uzbekistan (which is the main authority for assessing the state of water resources in the basin); from the main research and planning Institute of the Ministry of Agriculture and Water Resources; policy makers from the same Ministry; and researchers that have conducted research on water resources in

Table 4 Experts involved in the study on adaptation strategies

	Policy makers	Water managers	NGOs	Scientists doing research on WRM	Total
Amudarya	4	1		8	13
Elbe	9		3	9	21
Guadiana		1	3	6	10
Nile		3	3	5	11
Orange	4			2	6
Rhine	3	4		3	10
Total	21	9	9	32	71

the Amudarya for many years. Thus the official perception of the Uzbek government and its institutions and the scientific understanding were represented. What was missing was the perception of the civil society, e.g. representatives of NGOs. Some of the people interviewed in the Amudarya are experts in climate change, the others are all experts in water management, and some are involved in developing adaptation measures. Thus the survey allowed to assess, to what extent the water management community, which has to carry out adaptation measures in the basin, perceives climate change impact and adaptation.

Another example is the Guadiana case study. An expert representing the group ‘water managers’ is responsible for the Water planning office of the Guadiana River Basin Authority. Two of the NGO representatives work for the Water Department of national and local environmental conservation group, and the third one works for an independent foundation on issues related to water management and public participation in the Guadiana basin. Two of the interviewed scientists are involved in climate change EU projects applied in Spain. The remaining researchers are high-qualified scientists in the field of water resources management.

Doing evaluation of results, the dominant answers were identified using a robust qualitative analysis. For that, the shares of experts in percent were calculated for every option related to the number of all experts responded to this particular question, and expressed: as **XX** (two capital letters) if the share was more than 66%, as **X** (one capital letter) if it was between 34% and 66%, and as **x** (one small letter) if it was less or equal 33%. The first letter of the basin name was used to express the shares instead of **X**. This allowed to identify the dominant answers by a majority of respondents, to establish the priority lists of options, and cross-compare responses between basins.

In total, similar but slightly different methods were used to evaluate the results: dominant answers and priority lists for question 1, priority lists for questions 2–4, indices based on weighted average estimates and spider grams for question 5, and dominant answers based on descriptive answers for questions 6 and 7.

3.2 SWOT Analysis

SWOT is a common application in business circles where it is used to evaluate the situation that an organization finds itself in. There is no “original” publication of this method which was developed by Albert Humphrey, Stanford Research Institute between 1960–1970. It was first presented at the “Seminar on Long Range Planning” at the Dolder Grand, Zurich in 1964. SWOT analysis may be used in any decision-making situation when a desired objective has been defined. It may also be used in pre-crisis planning and preventive crisis management.

In our study, the approach was applied using data and information collected by the six case study teams. The aim was to compare and evaluate the situation in the case study basins in view of adaptation to climate change in addition to the questionnaire survey as described in Section 3.1.

The method clusters the information and enables managers to identify useful trends with a view to making management decisions. The SWOT analysis looks at how each case study is prepared for climate change under the following headings:

Strengths: what are the strengths of the basin in its preparedness for climate change? Strengths are attributes that can be worked on to enhance them.

Weaknesses: what are the weaknesses of the basin in its preparedness for climate change? Weaknesses are flaws that can be worked on to fix them.

Opportunities: what opportunities can people in the basin respond to in order to be better prepared for climate change? Opportunities are things beyond our direct control, but we can respond to and even benefit from them.

Threats: what are the threats that people in the basin need to be aware of if they are to be ready to respond to climate change? Threats are beyond our direct control but we can respond to them to minimize their impacts.

In this study each case study team compiled their own information gained during the research for this paper into the format required for presentation as a SWOT analysis. Given the way that the study was carried out in limited time, with several of the interviews done telephonically, it was not possible to have a SWOT process that gained direct stakeholder inputs. From the collected data it became clear that while the different basins have their own unique situations, there are some common issues which have been highlighted by the SWOT process.

4 Results of the Cross-Comparison of Adaptation Strategies

The results presented in this section are based on the responses to the Questionnaire and represent the perceptions of experts, which were evaluated as explained above. Where appropriate, they were compared with other evidence, such as modelling studies (see e.g. Section 4.2) or policy analysis. The evaluation of results was performed at the third workshop in October 2008.

The sub-sections are ordered according to questions, whereas results for questions 6 and 7 are included in one sub-section. The overall conclusions resulting from the majority of expert opinions are formulated as numbered conclusions from 1.1 to 6.1, and for question 5 they are collected in Table 9. The basin-specific options selected by the majority of experts in the regions are summarized in Tables 5, 6, 7 and 8. The results are supported by specific examples from the case study basins.

Table 5 Changes in climate expected in the case study basins according to the expert responses (only responses given by more than 66% of respondents included)

Region	Expected climate change
Amudarya	Glaciers retreat
Elbe	More precipitation in winter, less in summer
	Changed seasonality
	Higher frequency/intensity of floods and droughts
Guadiana	Warmer and less precipitation
	Changed seasonality
	Higher frequency/intensity of droughts
NEL region	Warmer and less precipitation
	Changed seasonality
	Higher frequency/intensity of floods and droughts
	Glaciers retreat
Orange	Warmer and less precipitation in the west but wetter in the east
	Greater intensity of floods and droughts
Rhine	More precipitation in winter, less in summer
	Higher frequency/intensity of floods and droughts

Table 6 Climate change impacts expected in the case study regions (based on the expert responses)

Region	Strong impacts on	Some impacts on
Amudarya	Droughts, irrigation	Water availability, water quality, drinking water, desertification, biodiversity
Elbe		Water availability, droughts, floods, water quality, crops, irrigation
Guadiana	Water availability, crops, irrigation, biodiversity	Droughts, erosion, wildfires, desertification
NEL region	Water availability, droughts, erosion, crops, hydropower	Floods, drinking water, irrigation, food security, desertification, diseases, biodiversity
Orange	Water availability, drinking water	Droughts, floods, crops, food security, wildfires
Rhine		Water availability, droughts, floods, water for cooling

Table 7 Drivers for development of a climate change adaptation strategy confirmed by the experts in six basins

Region	Most important drivers for adaptation
Amudarya	Disasters, funding opportunities
Elbe	Disasters, national and international policies, land use change, institutional changes
Guadiana	National and international policies, disasters, institutional changes
NEL	Disasters, national and international policies, land use change, funding opportunities
Orange	Disasters
Rhine	Disasters, national and international policies

Table 8 Barriers for climate change adaptation identified in the six regions (X means "a strong barrier" and o means "a moderate barrier"):

	Amudarya	Elbe	Guadiana	NEL	Orange	Rhine
Low level of awareness		o	o	**X**		
Spatial and temporal uncertainties	**X**	**X**	**X**	**X**	o	o
Lack of adequate financial resources	**X**	o	o	**X**	**X**	
Lack of needed technologies	o			**X**		
Lack of regulatory framework	**X**		o			o
Lack of legal provisions				o		
Problems in organisational setup	o		o	o		
Lack of vertical cooperation	**X**			**X**		
Lack of horizontal cooperation	**X**	o	**X**	o		o
Lack of transboundary cooperation	**X**					o
Local/subregional interests		o	o	o		
Lack of knowledge production		o	o	o		
Lack of stakeholder participation	**X**			o		
Lack of human capital	o			**X**	o	
Different risk perception		o	o	o	o	
Different preferences		o	o			
Gender, poverty and minority issues				**X**	o	

4.1 Expected Climate Change

It is important to note that also the evaluation on climate change in the regions was not based on the results of GCM scenarios for the corresponding regions, but mainly on the opinions of respondents (perception of the experts) in the case study basins. Nevertheless, the numerous publications on climate change issues and IPCC assessments known to the experts could, of course, influence their responses. It is also possible that some policymakers are unfamiliar with the recent IPCC reports for their regions. In this part, climate change in terms of changing temperature, changing precipitation, changing seasonality, higher frequency/intensity of extreme events as floods and droughts and glacier retreat was evaluated.

Two main conclusions were drawn in this part:

Conclusion 1.1 According to the expert opinions, there is an understanding in all six basins that climate change is happening. The number of climate change skeptics varied between 0% and 25% in the regions.

and

Conclusion 1.2 In all six basins the following changes in climate are expected:

- warmer and less precipitation, but wetter in some parts of basins,
- changed seasonality, and
- higher frequency and intensity of droughts.

Apparently, a majority of the basins face the issues listed in Conclusion 1.2. However, in some of the basins (e.g. Amudarya, Rhine) these three issues were not confirmed by the majority of experts.

In some basins there was a disagreement on the expected climate changes, as expressed by numbers of votes. Table 5 includes only the issues confirmed by responses from more than 66% of experts in the corresponding basins. It allows to cross-compare the basins, and to compare the expert responses with the published climate change scenarios for the regions.

In most of the regions the majority of experts had similar view on expected change in average climate characteristics (e.g. precipitation), and change in extreme events. However, this was not the case for the *Amudarya*, where only the glacier retreat was confirmed by the majority of experts. Maybe it is caused by a high uncertainty of the current GCM projections for this region: some of them project increased precipitation, while others simulate decreased precipitation (Krysanova et al. 2008). Moreover, climate change issues in the Amudarya are closely interwoven in the issues of water scarcity and energy security that already today are severely affecting the livelihoods in the region (Perelet 2007). This may explain why the climate change topic might not be prominent enough and attract less attention of policy makers and population in this region.

The results of our survey on expected climate change in the *Elbe* basin based on the experts perception fully correspond to the published climate change scenarios for the region (Krysanova et al. 2005; Orlowsky et al. 2008; Hattermann et al. 2008), which confirms the high level of experts awareness.

In the case of the *Guadiana* basin, the expected impacts of climate change refer mainly to those projected for the Mediterranean region, like increased temperature and reduced precipitation (IPCC 2007a). However, there is a common perception that the Guadiana basin is likely to be one of the most affected regions in Spain. It is worth pointing out that in Spain warming has been greater than the European average (between 1.2°C and 1.5°C) during the twentieth century, and the Guadiana is considered one of the driest regions in Spain (Castro et al. 2004; Abanades et al. 2007). For the last third of the twenty-first century an increase of 3–6°C in the average temperatures is expected (compared with 2–6°C on average in Europe), and a precipitation decrease ranging from 20–30% (also in the upper range of the expected rainfall reduction in Europe; Brunet et al. 2009; Iglesias et al. 2005).

The expert opinion "warmer and less precipitation" in the *NEL region* (Table 5) is not supported by modelling studies. Two of seven global models applied to the region indicate less rainfall in the NEL region, and five others indicate higher annual rainfall in the region (Kwadijk 2007).

The options chosen for the *Orange* River have been recently validated by an intensive climate change modelling exercise that has sought to quantify not only the climate but the changes in river flow that will be experienced in the future (Knoesen et al. 2009).

For the *Rhine* basin, glacier retreat and snowmelt are important drivers for more precipitation in winter, and less in summer. The direct effects of glacier retreat and snowmelt are mostly felt in the upper part of the basin, from which no experts were involved in this survey. The respondents for the Rhine therefore reported on the secondary effects.

4.2 Expected Climate Change Impacts

In this part of the survey the following options of climate change impacts were evaluated by the experts: impacts on water availability, water supply, water quality, erosion, floods, droughts, water for irrigation, crops, food security, hydropower, cooling of power plants, inland navigation, wildfires, diseases due to extreme events, desertification and biodiversity. The list differs essentially from question 1 (Section 4.1), where mainly the direct climate characteristics were evaluated. The main conclusion on the climate change impacts can be formulated as follows:

Conclusion 2.1 The following climate change impacts are expected in most of the regions (priority list):

– decreasing annual water availability,
– increasing frequency/intensity of droughts, and to a lesser extent floods,
– reduced crop production,
– reduced water availability for irrigation,
– loss of natural habitats and biodiversity.

The underlying conclusion from the first two options in the list (decreasing water availability and increasing frequency and intensity of droughts) could be that although several case study basins are located in a temperate climate, *drought is an issue in all regions*, and is therefore possibly underestimated in general climate adaptation.

The expectation of *higher risk of droughts than floods* may well be due to the impression that climate change may exacerbate flooding, but that this is not expected to be extremely important, but merely something that is already addressed and needs some additional attention because of climate change.

Table 6 includes the strong and moderate impacts expected in the six regions, and allows performing a cross-comparison of climate change impacts expressed as the perceptions of experts. As one can see, very severe impacts, like shortages in drinking water supply and reduced food security, are expected in the NEL region and in the Orange basin. On the other hand, no strong, only moderate impacts are anticipated in the Elbe and Rhine basins.

The perceptions of the experts on climate change impacts in the *Amudarya* river basin are more or less congruent with the expected impacts published in the literature, e.g. the decrease in water availability for irrigation and increase in occurrence of droughts. According to other sources (e.g. Perelet 2007), a decrease in water availability and increase in tensions about water use are expected in the Amudarya basin. However, the magnitude of the decrease and its timing are highly uncertain. No significant changes in river flow are projected in nearest future, but water deficit might become stronger (SIC-IWCW 2002).

The impacts described by the respondents for the *Rhine* and *Elbe* seems to be based on the impact studies for the regions (a.o. Hurkmans et al. 2007; Middelkoop et al. 2001; Krysanova et al. 2005; Hattermann et al. 2008) known to the experts, so there are no differences between our study and other sources.

In the *Guadiana*, the strongest perceived impacts are mainly related to droughts, crop production, and to the loss of natural habitats and biodiversity. This corresponds, in broad terms, to the expected climate change impacts reported in literature, such as reduction in water flows, water shortages, summer droughts, increased irrigation requirements, lower crop yields and desertification (CHG 2008; Iglesias et al. 2005; MARM 2008). However, these effects and the capacity to deal with them vary along the sub-regions of Guadiana. According to several studies on adaptation to droughts (Iglesias et al. 2007; Varela-Ortega 2008), Upper Guadiana experience shows that wherever reliable groundwater supplies exist, these may act as a buffer to mitigate the potential effects of climate hazards over long period of time. Though the water storage capacity in the medium and lower Guadiana is large due to the high number of dams and reservoirs, surface water irrigation systems could be strongly affected by prolonged droughts. Thus, the high diversity in agro-climatic conditions and socio-economic settings in the Guadiana basin makes it necessary to develop specific adaptation measures at the sub-regional level.

The economies of the countries in the *NEL region* depend largely on subsistence agriculture. With little artificial water supply (irrigation) in agriculture, statistics show a high correlation of the national income with precipitation records. The very limited extent of other economic sectors in these countries also limits the marketing of agricultural products, the possibility to invest in (supplemental) irrigation, and almost automatically results in food security issues. The vulnerability of these countries to climate change is high. The perceived climate change impacts with strong effects on water availability, droughts, crops and hydropower, and moderate effects on floods and irrigation (Table 6) are more or less compatible with the expected impacts published in the literature (Beyene et al. 2007; Kwadijk 2007).

In the *Orange* basin, the strongest perceived impacts are related to water availability and drinking water supply, and moderate impacts on droughts, floods and crop productivity are reported. In general, it is well comparable with the projected climate impacts expressed in literature (Schulze et al. 2005; Knoesen et al. 2009), though the potential impacts on floods seem to be underestimated by the experts.

4.3 Drivers for Development of Adaptation Strategy

Among the possible drivers for the development of adaptation strategy the following options were included in the survey: climate-related disasters, national and international policies, political changes, institutional changes, population dynamics, consumption patterns, land use change, globalization and market change, and funding opportunities. An example of international policy is the UN Framework Convention on Climate Change (UNFCCC) to facilitate comprehensive national adaptation strategies, and an example of national policy is an action plan for climate change adaptation for a country. The national and international policies were not distinguished in our survey but considered together as one option.

The better knowledge of drivers for developing the adaptation strategy is very important, as it may help to modify human-related drivers, and better understand other drivers (e.g. climate-related disasters), which are independent or less dependent on people. Insight into the most significant reasons or drivers for countries to design and develop an adaptation strategy is essential, as this provides an insight into the aspects that determine why action is taken. This in turn may support countries to determine where to focus attention in order to put adaptation on the agenda.

The analysis of responses about the potential drivers allowed establishing the overall priority list, and the lists of drivers chosen by the experts in every region. The overall priority list looks as follows:

Conclusion 3.1 The most important drivers for development of climate change adaptation strategy are:

– climate-related disasters, and
– national and international policies.

The next most important drivers are:

– institutional changes,
– land use change, and
– funding opportunities.

The remaining four options: political changes, population dynamics, consumption patterns and globalization were not confirmed as important drivers for adaptation.

The most important drivers for the development of adaptation strategy identified by experts in the basins are listed in Table 7. As one can see, the *climate-related disasters* and *national and international policies* were chosen as major drivers in practically all cases. It seems like an "instructive" disaster is needed to set things in motion. The climate related extreme events like disastrous floods, hurricanes and prolonged droughts trigger changes in national policies and institutional changes.

On the other hand, it is not surprising that climate-related disasters were identified as a major driver of adaptation strategy. There are numerous examples confirming this fact, from flood management (reduced damages caused by the following flood, especially if it occurs within a short period of time) in particular, to the understanding of climate change, in general. It is a confirmation of the saying that there is no bad without good.

It is worth mentioning that *the national and international policies* for climate change adaptation are underway (see e.g. EU White Paper 2009 on Adapting to climate change (EC 2009a) and National Adaptation Strategies). As confirmed by the experts in our study, they form an important driver for taking adaptation into account when developing water management programmes and plans. One example is the implementation of the Water Framework Directive, which contributes to an improved water resources management at the river basin scale, and can be considered as a driver for development of climate change adaptation strategy.

Several examples from the case studies illustrate the chosen drivers for development of adaptation strategy.

All *Amudarya* countries are developing National Communications under the framework of the UNFCCC (United Nations Framework Convention on Climate Change), where some issues related to climate change adaptation are included, e.g. improvement of monitoring and forecasting, increase in water use efficiency, etc. Other positive examples from the Amudarya are that an availability of donor money provides support for development of adaptation strategies, and that an opportunity for change in cropping patterns and land use arises through land reforms. However the latter is practically unrealized in Uzbekistan so far due to strong government control on agricultural production.

The study shows the relevance and the major role that policies play in adaptation to climate change. Spain in general and the *Guadiana* basin in particular have been facing water scarcity problems for a long time. Therefore plenty of legal provisions and programs have been developed regarding the adaptation to water scarcity, and they are contributing to climate change adaptation as well. In accordance to this, the synergies between existing policies and climate change measures must be highlighted, though the former ones were not climate change driven. Many of these policies are being revised and redesigned taking into account new climate change policies, but a further coordination is still needed.

For the *NEL region* the UNFCC effort to mobilize national experts to draft the National Adaptation Programmes of Action (NAPA) has been an important driver for the development of adaptation policies. The UNFCC supports Least Developed Countries to develop NAPAs, and to identify the first priority activities that respond to their urgent and immediate needs to adapt to changing climate—those for which further delay would increase vulnerability and/or costs at a later stage. With the exception of Kenya, all NEL counties have prepared such NAPA reports. Adaptation options identified are for instance land use changes in Burundi, Rwanda and Tanzania; water and land management options in Burundi, Rwanda, Tanzania and Uganda; and improvement of hydrological forecasting in Burundi, Rwanda and Uganda.

4.4 Barriers for Adaptation

Among the possible barriers for the development of adaptation strategy the following options were included in the survey: low level of awareness among decision makers on climate change issues, spatial and temporal uncertainties in climate scenarios, lack of adequate financial resources, lack of needed technologies, lack of regulatory framework, lack of legal provisions, problems in organisational setup related to horizontal and vertical integration, lack of cooperation between hierarchical levels (vertical cooperation), lack of cooperation between different sectors (horizontal cooperation), lack of cooperation across administrative boundaries, local/subregional interests, lack of consensual knowledge production, lack of stakeholder participation, lack of human capital (people skilled and educated for certain tasks), different risk perception, different preferences, and gender, poverty and minority issues (see Table 8).

The knowledge of barriers for developing an adaptation strategy is also very important. It could influence the international and national policies aimed in climate adaptation, and reduce the effects of certain barriers.

Based on expert responses, the overall priority list and the main barriers chosen in every region were established. The overall priority list consists of two parts:

Conclusion 4.1 The most important barriers for adaptation to climate change are:

- Spatial and temporal uncertainties in climate scenarios,
- Lack of adequate financial resources,
- Lack of horizontal cooperation.

The next important barriers are:

- Different risk perception
- Lack of human capital,
- Lack of transboundary cooperation,
- Lack of vertical cooperation,
- Lack of regulatory framework,
- Problems in organisational setup related to horizontal and vertical integration,

– Low level of awareness,
– Lack of needed technologies.

The spatial and temporal uncertainties in climate scenarios were identified as a most important barrier for adaptation. However, the uncertainties in climate projections are very difficult to reduce. Despite many efforts and research funding since the IPCC First Assessment Report in 1990, the uncertainties in projections of precipitation change and, consequently, projections of changes in river flow at the basin scale, remain high (IPCC 2007b).

The horizontal cooperation was identified as a stronger barrier compared to the vertical cooperation. Most probably, this is due to the fact that traditional top-down governance assumed some vertical interactions.

It is worth pointing out that *different preferences* were confirmed as a barrier in the Guadiana and Elbe basins (though as not strong). Stakeholders' perception of climate change and adaptation varies across different stakeholder groups. Namely, policy makers and water managers have a more technical policy-driven vision than other stakeholders. Scientists dealing with water management issues have a more profound knowledge on climate scenarios, impacts and related uncertainties. Scientist consciousness about climate change is high and they perceive it as a global phenomenon that must necessarily affect social and political views. Independent experts indicate the importance of public participation and stakeholder involvement to produce adequate strategies. Environmental NGO groups' perception focuses mainly on the impacts of climate change on ecosystems, and they are highly concerned about that.

The most important barriers for the development of adaptation strategy identified in the basins are listed in Table 8. As one can see, mainly moderate barriers were identified by the experts in the Rhine, Orange, Elbe, and Guadiana basins. On the other hand, many strong and moderate barriers were indicated by the experts in the Amudarya basin and in the NEL region. Among them are the following strong barriers, which were not identified as "strong" in other basins:

– lack of required technologies in the Nile,
– lack of regulatory framework in the Amudarya,
– lack of vertical cooperation in the Amudarya and Nile,
– lack of transboundary cooperation in the Amudarya,
– lack of stakeholder participation in the Amudarya,
– gender, poverty and minority issues in the Nile.

Several examples from the case studies illustrate the chosen barriers for adaptation.

In the *Nile basin* countries poverty is the main issue drawing attention of the national governments. Adaptation to climate change is generally seen as important, but as a problem for the future and therefore less urgent than the immediate poverty problem. Adaptation plans are further hampered by the limited (water management) governance structure and insufficient horizontal coordination between Ministries. Another important barrier obviously is the limited scientific capacity. For example, Burundi has only a few hydrologists trained at academic level.

Countries in the *Amudarya* basin are undergoing socio-economic transition and have to cope with large deteriorating water infrastructures. Some of them (e.g. Tajikistan) are very poor and impacted by a recent civil war. There is a lack of will for reforms among the leading elites, and corruption is wide-spread. All this strongly affects the availability of financial resources for the development of climate change adaptation strategies. Besides, the legal and regulatory framework is only under development. Regarding the vertical cooperation on the transboundary level, since independence there is little trust in it as the countries push their own interests to the forefront. As regards the horizontal cooperation, water management in Uzbekistan is currently subordinated to the needs of agriculture, and thus cannot develop and implement water management strategies in the needed way. Other water users such as households and ecosystems are little considered in water allocation planning.

Considering the situation in the *Orange* basin, in South Africa at least, where has been a great deal of very effective research carried out on climate change, thus suggesting that financial resources for research are not limited. Unfortunately it is in the translation of this research into active policy, where financial resources and a severe skills shortage amongst governments lessens effective uptake of these ideas and results.

In the case of the *Guadiana* basin, only two aspects were highlighted as strong barriers: spatial and temporal uncertainties and lack of horizontal cooperation. The upper, middle and lower sub-basins of Guadiana have their own regional governments with competences in environmental affairs and are obliged to elaborate their own mitigation and adaptation plans. The challenge for the River Basin Authority is to perform climate change adaptation measures in coordination with these regional governments that will address the regional differences.

In general, there is a relatively high level of consensus on the situation with regard to climate change in the *Rhine* and *Elbe* basins. Consequently, the barriers against adaptation are not considered to be strong. Rather, the issues mentioned slow down the adaptation.

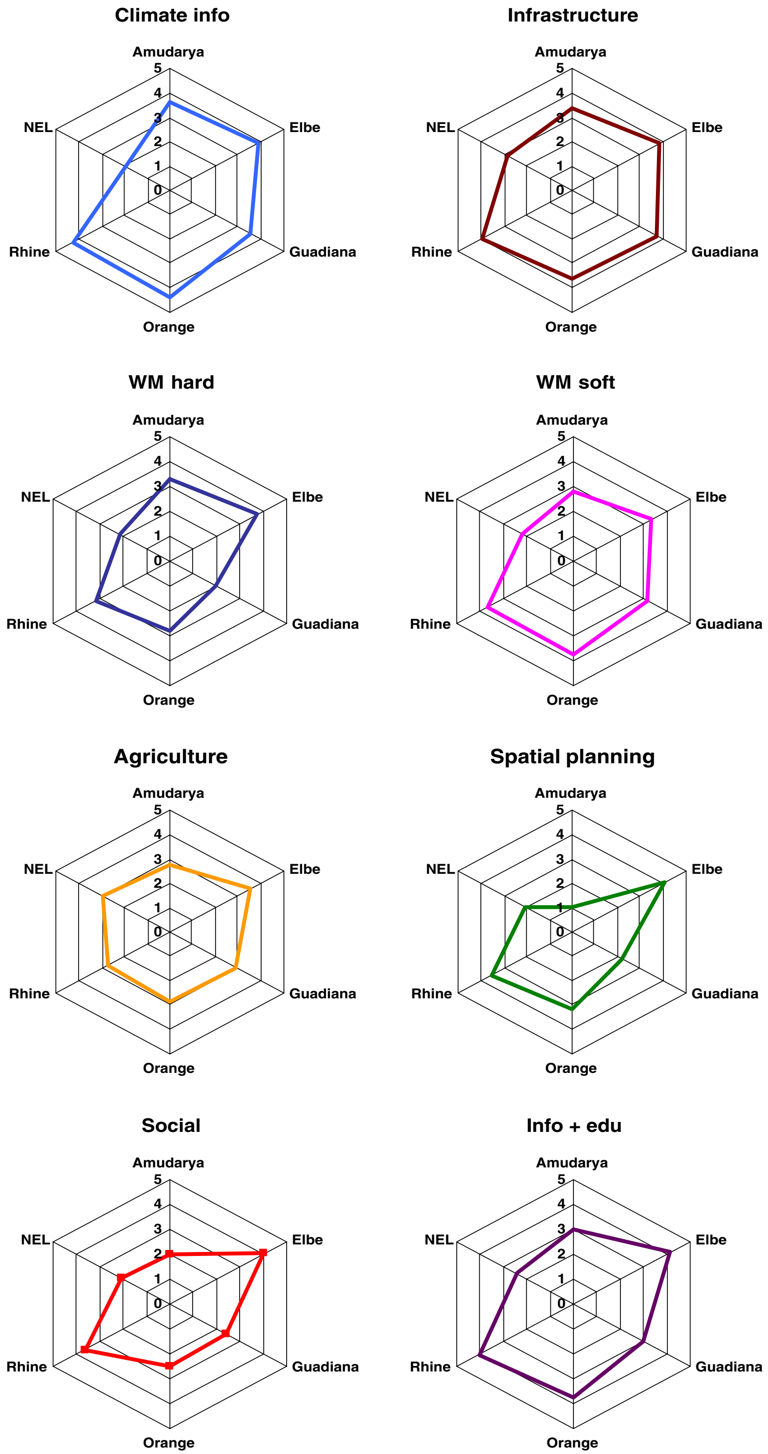
4.5 Adaptation Measures

A wide spectrum of water resource management (WRM) measures was evaluated in this study, most of which are well known. Altogether, 36 measures divided into eight categories, were evaluated by indices related to the level of implementation. The results are presented as spider diagrams (Figs. 3 and 4). Figure 3 shows the indices for all six basins separately for each of eight categories, and Fig. 4 allows comparing water management measures implementation for all six regions. The conclusions for this part of the survey that can be drawn from spider diagrams are collected in Table 9.

In total, the range of WRM measures is on a relatively high level in the Elbe and Rhine basins (most of measures exist and are planned), followed by the Orange and Guadiana. It is lower in the Amudarya basin, and the lowest in the NEL region, where many measures are only at the planning stage. It is worth mentioning that the highest score 5.0 (full implementation of measures in a category) was not obtained for any category and basin.

The *Amudarya* shows a very low score for spatial planning measures, meaning that such measures are non-existent and not planned, and this is the only case with the lowest score 1.0.

The low score of the *NEL region* in implementation of adaptation measures could possibly be explained firstly by the prevailing poverty in the region, and secondly


Climate info
Infrastructure
WM hard
WM soft
Agriculture
Spatial planning
Social
Info + edu
Amudarya
Elbe
Guadiana
Orange
Rhine
NEL
0
1
2
3
4
5

◀ **Fig. 3** Evaluation of adaptation measures implementation in six river basins (explanations in the text)

by the political instability that has plagued the region in recent decades. One could say that adaptation to climate change in the NEL region does not receive the high priority as it does in the more affluent countries in Europe due to other more urgent problems with higher priority.

It is also worth pointing out that the expected climate change impacts (according to climate projections and expert opinions) are also stronger in the basins with lower level of WRM measures implementation and more numerous and stronger barriers to adaptation.

4.6 Adaptation Strategy and Status of its Implementation

As follows from the responses, a shared recognition of climate change related problems exists in the Elbe, Guadiana, Orange and Rhine, and at a lower level in the Amudarya basin and NEL region. There is a shared vision for an adaptation strategy in the Rhine basin, and some vision in all other basins except Amudarya. A program or plan of activities and measures related to climate change are already included in national Programs in the Rhine, Elbe, Guadiana and Amudarya basins and in the NEL region, but not yet in the Orange. However, such plans should not be overestimated, but rather considered as a first step to adaptation at the policy level. According to expert responses, some institutional adaptations are taking place or planned in the Elbe, Guadiana and Rhine basins and in the NEL region, but little or none in the Amudarya and Orange.

Regarding the level of adaptation strategy implementation, it can be concluded from the expert opinions that

Conclusion 6.1 Adaptation to climate change has started in all basins, but progresses rather slowly. Some progress is visible in the NEL region and Rhine basin.

It seems that sometimes the insights of the experts on the adaptation strategy and status of the implementation in the study could be influenced by the existing implementation of the Water Framework Directive (WFD). Though WFD is not

Fig. 4 Cross-comparison of water management measures implementation in six basins

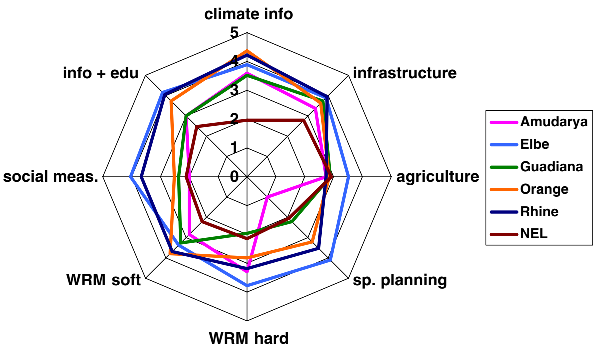


Table 9 Conclusions 5.1–5.8 on the water management measures

Category of measures	Conclusions
Climate information	Climate information exists in all basins, except the NEL region, where it is considered insufficient and is planned to be collected
Infrastructure	According to the expert responses, the infrastructure is well developed in the Rhine, Elbe, Guadiana and Orange (existing and planned). The level of infrastructure development is lower in the Amudarya basin. In the NEL region infrastructure also exists, but not much is planned
Agriculture	Agriculture measures related to WRM and climate adaptation are virtually nonexistent in all basins, only in the Elbe the level is approaching the "existing and planned" category
Spatial planning	Spatial planning is quite far developed in the Elbe, followed by the Rhine. Some exists in the Orange. In the three other basins spatial planning is needed and virtually non-existent
WRM hard measures	The WRM hard measures are best developed in the Elbe (existing and planned), followed by the Amudarya and Rhine. In other three basins they are mainly at the level of planning
WRM soft measures	The WRM soft measures exist and are planned in the Orange and Rhine, followed by the Elbe and Guadiana. According to the expert responses, in the NEL and Amudarya they seldomly reach the planning level
Social measures	Social measures are well developed in the Elbe, followed by the Rhine. In four other basins they are only planned
Information + education	Information and education measures are well developed (existing and planned) in the Elbe and Rhine, followed by the Orange. They exist in the Guadiana and Amudarya. In the NEL region they are at the planning level

directly related to climate change adaptation, a number of measures considered in this survey are also considered there.

Also, some projects dealing with the present climate variability at the river basin scale can be considered as a first step towards adaptation to climate change and future increased climate variability. For example, the present climate variability in the *NEL region* is already very high. Due to population pressure new and marginal (sloping) lands have been brought under cultivation. In order to deal with the resulting land degradation, soil and water conservation receives serious attention from governments and NGOs, and there are projects dealing with climate variability there.

Another example from the *Guadiana* shows that the key challenge in Spain and, specifically, in the Guadiana basin is to move from global principles to local actions. At a national level adaptation strategies are starting to be developed, but there is a need for a proper downscaling from the national program to the regions, capturing and reflecting regional and local specificities. Regional strategies, protocols and guidelines must be elaborated on a basis of public participation. In this context, the institutional setting plays a major role in promoting an efficient coordination across administrative units.

Currently, awareness on climate change issues is rising enormously across regions, and many policies are being revised and redesigned taking into account climate change. Most current policies and climate change strategies focus mainly on mitigation, both at national and regional levels. However, adaptation is starting to play a major role. So, the European Union that has recently launched a common framework for action under the White Paper on Climate Change Adaptation (WPCCA; EC 2009a), which highlights the prominent role of member states, regional and local authorities for an efficient adaptation strategy, and stresses the need for integrating adaptation strategies into sectoral policies.

5 Summary of the SWOT Analysis

In this study a SWOT analysis was applied using data and information collected by the case study teams. The value of this approach is in the presentation of the same or similar information but categorised in different ways that may be more appropriate for a management response. The SWOT analyses for each of the case studies are described in the Synthesis Product 6 of NeWater (see on: http://www.newater.info/index.php?pid=1049).

Below (see also Fig. 5) is an extraction of the common features for all or most of all investigated regions, not in any quantifiable or defensible way, but rather to highlight the main issues.

Strengths Those people consulted in the basins in most cases did not feel that they were being restrained by a lack of data. There is a perception that climate change is a reality and that they know enough about the issues to be able to manage the situation. They also acknowledged that there is a considerable awareness about climate change in all levels of society and that there are moves within governments to address the threats. These moves are now being reflected in the drafting of policy in many of the basins.

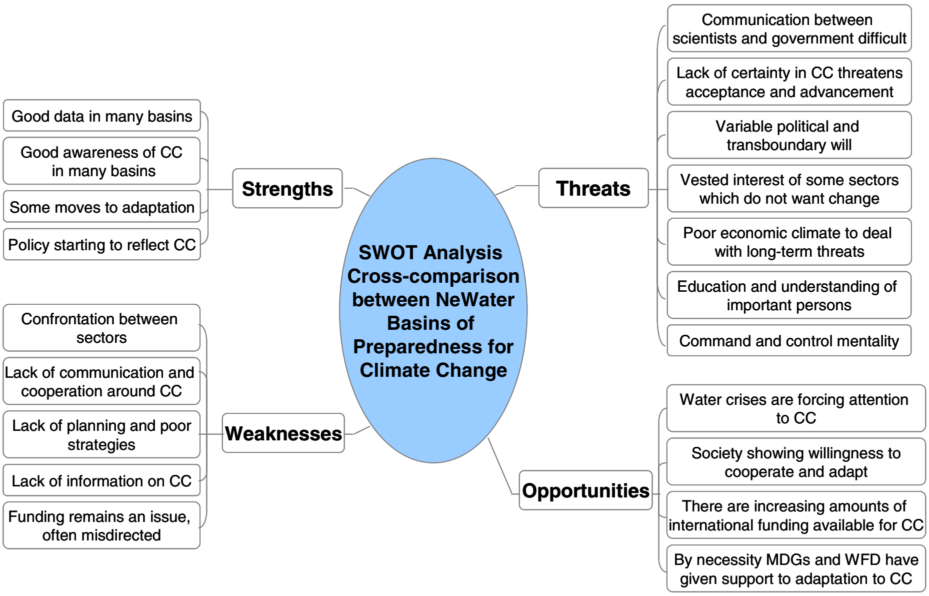


Fig. 5 Common features of the SWOT characteristics of the six case study basins

Weaknesses Conflicting with the above, some views expressed that there is a lack of information on climate change which is hampering the move ahead. In addition, in some basins there is a lack of cooperation between the various agencies and states which is hindering a united approach. Besides, the available funding that could be used for further adaptation to climate change often does not reach the most useful sectors and thus has little impact.

Opportunities The growing number of crises related to water experienced in most basins creates the positive impact of raising the importance of climate change and thus pushing this into the forefront of governance activities. When linked to an obvious readiness in all sectors of society to respond to climate change, this creates a rare opportunity for a science to respond to a real need. These attempts are being supported by the inclusion of climate change issues in major policy (e.g. the Water Framework Directive and Millennium Development Goals) which in turn has directed the attention of funding agencies who have responded with finance.

Threats Possibly the greatest threat to adaptation is the lack of certainty in the information describing climate change (scenarios), which weakens the support given by policy makers and governments and reduces the enthusiasm for the subject among managers. Part of the problem here revolves around communication between scientists and the rest of society, where the message may create confusion. Having said this, it has to be acknowledged that primarily the efforts of the IPCC in communicating a complex problem to society have been unprecedented. Implementation of climate change response strategies also remains a problem due to, at times, poor cooperation between riparian states and also to the protection of vested interests not only by states but also by important individuals in government and even in the science fraternity. A command and control mentality on the part of many government officials also prevents the type of adaptive management that is necessary for dealing with this problem. Poor education and also poor economic conditions also make it more difficult to move towards a sound implementation of these strategies.

SWOT analysis revealed also some distinct differences betweens the basins. For example, an advanced water resources and flood management belongs to the strengths for the Elbe and the Rhine, while for the Amudarya only the highly developed but inflexible and deteriorating irrigation management, and for the NEL an experience of local communities on dealing with climate variability were highlighted in this respect. On the other hand, the weaknesses revealed for the NEL and Amudarya (dependence on subsistence agriculture, lack of national funds for adaptation and dependence on donors, misuse of financial resources) are much stronger and hardly comparable with the weaknesses confirmed for the Elbe and Rhine (too much trust on dikes safety, insufficiently developed non-structural flood protection measures, reduced retention capacity in some areas).

6 Summary and Conclusions

Adaptation to climate change is recognized worldwide as a topic of considerable policy relevance and social concern (Kelly and Adger 2000), which, compared to mitigation, still requires a better understanding (Burton et al. 2006) and a further development of strategies. This study has analyzed different aspects of adaptation to climate change based on a cross-comparison among six different river basins.

6.1 Approach

One of the strengths of this research is the ample stakeholder's consultation carried out in all the basins. All described results and conclusions are based on the perceptions of experts, which are sometimes compared with the modelling studies for the case study river basins reported in literature. Our study has shown that it is important to consult with different stakeholder groups, as the perception of climate change issues and adaptation strategies varies across groups.

The applied approach and the resulting comparison of the perceptions of the experts on the levels of implementation of climate change adaptation measures across the selected river basins have their limitations. The six basins have very different biophysical and socio-political settings, which affect both the need and opportunities for the development of adaptation measures. As mentioned before some of the basins in developing countries such as the Amudarya, the Nile and the Orange are struggling with other issues such as poverty or socio-economic transition that dominate the political agenda giving climate change adaptation a lesser priority. Climate change is only one of the multiple pressures those river basins have to cope with already today (Mysiak et al. 2009).

Moreover governance setting and policy making processes are different in each basin affecting e.g. the degree to which public participation is or could be implemented. On the more methodological side this can also affect the way respondents evaluate different adaptation measures and their state of implementation. As explained above, all the experts are experienced and knowledgeable on water management issues, and even some of them on climate-related issues, so all of them are qualified for answering the questionnaire, and all the answers are valid insights to illustrate the barriers and drivers for designing and applying adaptation strategies. However, their interests and contexts are different. Therefore, a comparison across this range of cultural and environmental settings should be interpreted with care keeping those differences in mind.

For example, in the Amudarya the need to cope with current problems of water scarcity and conflicts of water use between hydropower and irrigation has priority and leads to many ad-hoc strategies and measures but not to any long-term adaptation to climate change. Besides, there is a strong emphasis on improving current water and land management by the government and international donors. As a result, climate change issues remain in the background (see Amudarya case in Section 4.1). This context is very different from other countries where the primary concern are floods, occurrence and intensity of which could increase under warmer climate conditions.

The differences in the expert interests and contexts could be illustrated on the example of Guadiana, where water users (as in the Amudarya) are more concerned about short-term issues, e.g. current water availability or potential water constraints for the next irrigation campaign. Climate change is seen as a long-term issue, and more as a policy concern. Water managers and policy makers are conscious of the potential climate change impacts in the mid and long terms, because its consideration is a policy requirement. In this sense, climate change consciousness is going along a top-down process. The consciousness of scientists and environmental NGOs about climate change is also high, but they perceive it as a global phenomenon that may have important ecological and socio-economic consequences, which should affect socio-political views. A common feature in all stakeholder groups is the perception of stakeholders' involvement as a key issue in climate change adaptation strategies.

Another shortcoming is the relatively small numbers of experts interviewed in each case study, which does not represent the variety of stakeholder perceptions in the basins, and does not allow comparison between different stakeholder groups in the basins. However, the results of each case study are based on an assessment of at least the practitioner and the water management research communities, which represent two major groups. Generally, the results of this study provide a valuable picture on the current status and development of adaptation measures and strategies, and allow comparing them across regions.

6.2 General Conclusions

In general, from this cross-comparison it becomes clear that there is a broad awareness that climate change is happening and that adaptation is needed. Important barriers for implementing adaptation can be found in insufficient communication between actors and reluctance of actors to change. Lack of sufficient knowledge is mentioned as a barrier, but note should be taken that this is often used as a hide-out to prevent action (Timmerman and Langaas 2004). Nevertheless, the willingness to cooperate and adapt is increasing, also because many extreme weather events occurring more frequently than before focus the public attention on climate change. Accordingly, the occurrence of natural disasters has been reported as one of the main drivers for climate change adaptation (Section 4.3).

It is indeed an unfortunate reflection on our society which relies on the impact of disasters before taking real action to prevent or solve a problem. That this is a wide-spread phenomenon is evidenced by the generally slow response by governments to the warnings contained within the IPCC reports and other sources (see e.g. Auf der Heide 1989). Unfortunately, in this situation the disasters due to changing climate may be too large and too permanent for society to effectively mitigate them.

A comparison of the level of adaptation between the basins is possible when looking at the implementation of adaptation measures (Section 4.6). Here we see that the Elbe, Rhine and Orange seem to be most advanced, followed by Guadiana and Amudarya. The NEL region has the lowest scores (also see Raadgever et al. 2008a).

While the scores do not show very large differences, the SWOT analysis (Section 5) suggests higher differences among regions, especially when looking at the weaknesses. Another study by Raadgever et al. (2008b) making a close comparison between the Orange and the Rhine suggests that the differences between the Orange and Rhine are larger than the scores for the adaptation measures in our study suggest. Further research is needed to determine the differences, and the ways to promote adaptation strategies, especially in the Least Developed Countries.

On the other hand, it is not surprising that in general the more affluent, developed countries have higher levels of implementation of adaptation measures (higher opportunities), which stands in contrast to the fact that other countries with more numerous and stronger barriers to adaptation will be most likely more severely impacted by climate change (higher urgency).

The most important conclusions from the cross-comparison of adaptation strategies are:

- There is understanding in all six basins that climate change is happening.
- Decreasing annual water availability and increasing frequency and intensity of droughts are expected impacts in all six basins, though in some basins only moderate impacts are anticipated.
- Regarding the increasing intensity and frequency of floods, only moderate impacts are expected.
- The most important perceived drivers for development of climate change adaptation strategy are climate-related disasters, and national and international policies.
- The following most important barriers for adaptation were confirmed by the experts: spatial and temporal uncertainties, lack of adequate financial resources, and lack of horizontal cooperation.
- The adaptation to climate change has started in all basins, but progresses rather slowly.

The relation of natural disasters with adaptation actions (e.g. policy changes) has been widely discussed in the literature (Adger et al. 2007; Smit and Skinner 2002; Oppenheimer and Todorov 2006; Christoplos 2006). Adger et al. (2007) argue that disasters may raise awareness, move up to reach consensus and enhance political will in the short term. But, in turn, once the disaster is over, there is a tendency to return to the original situation instead of developing long-term policies (Christoplos 2006). In fact, the short term actions are proven to increase, in many times, the long-term vulnerability (Adger et al. 2007; Smit and Skinner 2002).

6.3 Outlook

Common efforts are needed to strengthen adaptation to climate change worldwide. There are examples when the current water management based on the concept of Integrated Water Resources Management (IWRM) fails to satisfactorily solve the problems it is facing (Falkenmark 2000; IWA 2002; Kabat and van Schaik 2003). Moreover, IWRM seems to fall short in dealing with uncertainty and adaptive capacity of water management. The challenge is to create robust water management that would be able to deal with the uncertainty of future climatic conditions. Adaptation calls for more flexible solutions not only in infrastructure and river basin management, but also in water management institutions and in the water-related sectors themselves. In line with this, the Impact Assessment of the EU White Paper on climate change adaptation (EC 2009b) emphasizes that policy and institutional issues may become a more difficult challenge for adaptation than finding technical solutions (Swart et al. 2009). If protection against floods can no longer be guaranteed due to uncertainty in future climatic conditions, the infrastructure in flooding areas and the infrastructure that provides protection should become less vulnerable to the flooding itself. If water supply during more frequent and prolonged periods of droughts can no longer be guaranteed, the water use sectors should be made less vulnerable to drought (i.e. less dependent on water supply).

Adaptation to climate change definitely requires much more than merely re-designing infrastructure, extending the set of water management measures, and refining established procedures and actions. It requires a transition of the whole management regime, involving changes in policy development, type of leadership, cooperation structures, governance, information management and risk management. An integrated approach to water management needs to be applied to decrease vulnerability and increase adaptive capacity of a river basin as a whole. Besides, the adaptation strategy should also include the time aspect into the planning—the evolution of changes. This is new in water management, and not easy to implement.

Climate change is a trigger for new approaches such as Adaptive Water Management, which is defined as a systematic process of improving management policies and practices by learning from the outcomes of already implemented management strategies (e.g. Medema et al. 2008; Pahl-Wostl et al. 2007). Adaptive management is both a goal as new management paradigm and a means for building adaptive capacity required to meet the challenges posed by climate change. An adaptive approach advocates strongly that a collaborative learning process is a more robust strategy in conditions of uncertainty than any belief in prediction and control. There is no generic blue-print for the kind of adaptation strategies to be implemented in river basin. They have to be developed and implemented in collaborative learning processes taking into account the specific characteristics of a river basin. Adopting a systematic adaptive management approach will increase effectiveness and efficiency of such processes and will allow sharing lessons on success and failures and building empirical evidence on different approaches and the circumstances under which they perform best.

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