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Bottom-up climate risk assessment of infrastructure investment in the Niger River Basin

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Abstract The Niger River is the third largest river in the African continent. Nine riparian countries share its basin, which rank all among the world's thirty poorest. Existing challenges in West Africa, including endemic poverty, inadequate infrastructure and weak adaptive capacity to climate variability, make the region vulnerable to climate change. In this study, a risk-based methodology is introduced and demonstrated for the analysis of climate change impacts on planned infrastructure investments in water resources systems in the Upper and Middle Niger River Basin. The methodology focuses on identifying the vulnerability of the Basin's socio-economic system to climate change, and subsequently assessing the likelihood of climate risks by using climate information from a multi-run, multi-GCM ensemble of climate projections. System vulnerabilities are analyzed in terms of performance metrics of hydroelectricity production, navigation, dry and rainy season irrigated agriculture, flooding in the Inner Delta of the Niger and the sustenance of environmental flows. The study reveals low to moderate risks in terms of stakeholder-defined threshold levels for most metrics in the 21st Century. The highest risk levels were observed for environmental flow targets. The findings indicate that the range of projected changes in an ensemble of CMIP3 GCM projections imply

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only relatively low risks of unacceptable climate change impacts on the present large-scale infrastructure investment plan for the Basin.

1 Introduction

The Niger River Basin (NRB) is shared among nine riparian countries, Guinea, Mali, Ivory Coast, Burkina Faso, Niger, Benin, Nigeria, Cameroon and Chad. The Niger River, with a total length of 4,100 km, is the third longest river in Africa and has the ninth largest river basin in the world (Itiveh and Bigg 2008). The population in the NRB is estimated to be more than 100 million, of which 64 % is rural, with a current annual growth rate of 3.2 % (Ogilvie et al. 2010). Agriculture is the major source of income in the NRB and crop production comprises 25–35 % of GDP, while livestock and fisheries account for 10–15 % and 1–4 % respectively (BRLi and DHI 2007). There is a vast potential for irrigated agriculture, but currently only 15 % of the cultivated area is irrigated (Ogilvie et al. 2010). The hydropower generation potential in the NRB is estimated at 30,000 GWh per year, of which only 6,000 GWh has been developed (Andersen et al. 2005). Dry season flows at Markala, Mali, significantly affect the sustainability of the Inner Delta's ecosystem, which features the two largest bird nest colonies in Africa and more than 110 fish species. The Inner Delta provides ecosystem services crucial for the livelihood of local populations, including agriculture, livestock, fisheries and navigation (Kuper et al. 2003; Zwarts et al. 2005).

The key development challenges and constraints in the NRB are rapid deterioration of land and water resources, poor performance of and inadequate investments in water infrastructure, food insecurity, rampant poverty, and high rates of population growth and urbanization (Namara et al. 2011). The region has a history of marked climate variability with significant societal and environmental impacts (Tarhule and Woo 1998; Niasse 2005; Wilby 2008). The prolonged droughts during the 1970's and 1980's are considered to be a primary reason that the Sahel-Sudan zone of sub-Saharan Africa has fallen behind other developing countries in terms of economic growth (Barrios et al. 2006). There is concern that during the 21st Century climate change may exacerbate and accelerate the existing trends in poverty, underdevelopment and environmental degradation (Sissoko et al. 2011).

Recognition of the significant environmental and socio-economic needs of the NRB and its potential for economic development led to the adoption 9in 2008 of a 20-year Sustainable Development Action Plan (SDAP). SDAP includes the investment of about $8 billion in water infrastructure over 20 years and was adopted by the Heads of States of the nine member countries of the Niger Basin Authority (NBA) (Niger Basin Authority and World Bank 2010). The investment plan aims to develop water-based socio-economic infrastructure, while providing ecosystem protection. The plan includes a number of new dams, rehabilitation of existing dams and a huge expansion of irrigated agriculture. The investment program was designed to cope with the prevailing historical climate variability. Potential climate change impacts on the performance of the SDAP investment plan have not been previously investigated.

An impediment to assessing climate risks is the deep uncertainty of future climate, especially in a tropical region such as West Africa. Uncertainties in climate change projections for the region generally emerge from multiple sources, such as parameterization and untested assumptions of the models, inherent variability of the earth's climate system and uncertainty of future emissions (Murphy et al. 2004; Lempert et al. 2004), due to systematic errors in representing the African climate, such as misplacement of the Atlantic Inter-Tropical Convergence Zone (ITCZ), or West African monsoon (Paeth et al. 2008), and underestimation of climate feedbacks by vegetation (Hulme et al. 2001). The uncertainty of future climate for the NRB region makes clear that the typical use of climate projections as the basis of a climate risk assessment would not be effective. Recently, some researchers have proposed approaches that focus on first understanding the climate response of the system of interest, bringing in GCM projections at a later stage of analysis to inform risks (Brown et al. 2011; Brown 2011; Wilby 2008; Brown et al. 2012). The approach applied here, described in Brown et al. (2011) as "decision-scaling", follows this philosophy, beginning first with the system of concern and identifying risk thresholds through engagement with stakeholders. The climate changes that cause threshold-crossing risks are then identified through a process of parametrically varying the climate inputs, yielding the response to climate change in terms of selected performance metrics. Information from climate projections is then used to estimate the relative probability of the identified risks. The paper commences with an overview of the hydrological characteristics of the NRB and the model used to represent the many facets of water system operations in the NRB. Next, a brief description of the research methodology is presented. Results for selected performance metrics under selected infrastructure scenarios are then briefly discussed. The research described in this paper forms part of a larger World Bank funded research project focused on building resilience to climate related risks in the Niger River Basin.

2 Hydrological characteristics of the Niger River Basin

The Niger River rises in the mountains of Guinea and Sierra Leone, flows through the vast flood plains of the Inner Delta in Mali, and is joined in its lower reach in Nigeria by the Benue River, which flows from the eastern extent of the basin in Chad and Cameroon, before finally reaching the Atlantic Ocean through the Maritime Niger Delta in Nigeria. The Niger River delineates a drainage basin of 2,170,500 km^2 in area that cuts across all the major climatic zones of West Africa (Ozer et al. 2003; Abrate et al. 2010); nearly 1,400,000 km^2 actively contributes surface runoff to the River. Rainfall occurrence and magnitude is influenced by the strength and position of the West African Monsoon, which follows the ITCZ from south to north. The annual mean rainfall varies from north to south and from east to west, and fluctuates from over 2,000 mm/year in southern Nigeria/Cameroon to less than 400 mm/year in Northern Mali and Niger (Itiveh and Bigg 2008; Sissoko et al. 2011).

The climate regime of West Africa and the Sahel region is marked by strong variability in rainfall on interannual and decadal scales (Brooks 2004; Giannini et al. 2008). West Africa experienced severe climate variations in the 20th Century, with relatively rapid transitions between wetter and dryer periods. Severe drought conditions were observed during the 1910's and 1940's, followed by a fluvial period from the 1950's to the early 1960's, followed again by droughts during the 1970's and 1980's, when 30-year mean rainfalls decreased by 20 to 40 % (Tarhule and Woo 1998; Nicholson 2001; Sivakumar et al. 2005; Wilby 2008; Sissoko et al. 2011). Beginning with the 1990's, annual rainfall has recovered and approached the century-long mean, but the debate regarding the status of the region's long-term drought remains open (Ozer et al. 2003; Held et al. 2005; L'Hote et al. 2003).

There is a large degree of uncertainty accompanying expectations of climate change in the region. According to the Intergovernmental Panel on Climate Change (IPCC), the median temperature increase in West Africa is projected to be from 3 °C to 4 °C by 2100, roughly 1.5 times the predicted global averages (Christensen et al. 2007). Projections do not agree on the direction and magnitude of changes in future mean precipitation (Cook and Vizy 2006; Mohamed 2011; Jung and Kunstmann 2007; Paeth et al. 2009).

3 Methodology

3.1 Decision-scaling

An alternative to a GCM-driven analysis for climate change impact assessment is focusing on the identification of climate risks through vulnerability analysis (Fig. 1). This study advances the usual vulnerability analysis method by employing a process described as decision-scaling which identifies risk in an exploration of climate sensitivity and then uses climate information such as GCM projections to quantify the relative probabilities of risky climate conditions (Brown et al. 2012). The use of climate projections at a later stage of the analysis reduces the propagation of uncertainties, and allows the impact assessment of a wide range of climate changes, which are not necessarily restricted to GCM projections. Additionally, it provides a transparent analysis framework by first specifying the response of the performance of the system to climate changes, allowing the framing of the uncertain climate information in terms of the performance metrics and thresholds that concern stakeholders. It also facilitates the incorporation of subjective judgment of climate experts and stakeholders into the assessment of risks.

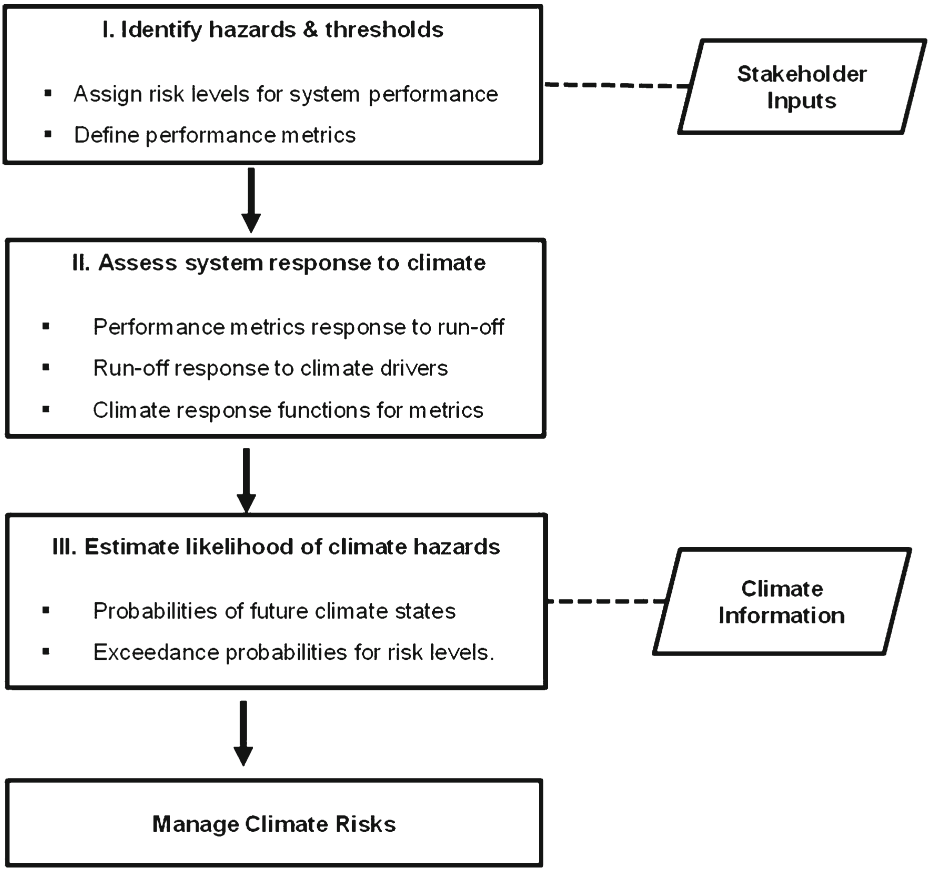

Fig. 1 Conceptual flow chart for climate risk assessment in the Niger River Basin

The decision-scaling process has three steps: Problem Definition; Hazard Discovery; and Estimation of Climate Informed Risks. These steps as applied to the Niger Basin SDAP investment program are described below.

3.2 Application of decision-scaling to the Niger River Basin

3.2.1 Problem definition: identification of thresholds and climate hazards

The first stage of the decision-scaling process is to identify the potential hazards to the system that result from potential changes in climate. Here, the term hazard is used as distinct from risk, where hazard implies the adverse impact of a climate change but not its probability. Risk is defined as the expected loss equal to the product of the consequences of a hazardous event and the probability of that event (Brown et al. 2011). The process begins with stakeholder consultations to identify the relevant performance indicators, and also, if appropriate, thresholds of acceptable changes in performance levels. Beyond these levels, the performance for a particular measure would be defined unacceptable. Examples of historical climate events are a useful mechanism for facilitating these discussions.

In the Niger Basin analysis, stakeholder discussions were held in a workshop organized by the NBA with delegations from all member countries, held in Ouagadougou, Burkino Faso in May 2010 (Niger Basin Authority and World Bank 2010). Hydroenergy, navigation, wet and dry season irrigated agriculture, flooding in the Inner Delta, and minimum environmental flows at various points along the main stem of the Niger River were chosen as the major sectors of interest, reflecting previously agreed upon objectives for the SDAP investment plan. Following an iterative discussion process, stakeholders agreed to a critical threshold of 20 % as maximum acceptable reduction due to climate change from the baseline performance of the investment plan (i.e. based on 30-year mean historical climate). Based on this key threshold, six risk levels were identified ranging from “no risk” to “extreme risk”, as a function of the projected percentage reduction in investment plan performance (Fig. 2).

3.2.2 Hazard discovery: assessing the system response to changes in climate

Following the definition of performance metrics and thresholds, the next step is to seek an understanding of how the system responds to changes in climate. This process identifies climate conditions that cause unacceptable performance levels. Through the exploration of the effects of plausible climate changes on the system, climate conditions that cause risks (i.e., probability of unacceptable performance) are exposed. Estimation of the NRB’s response to changed climate conditions was conducted through the following steps: i) Modeling the response of the sectors of interest to changes in long-term mean annual basin runoff by the application of a water resources system model, ii) Estimating the climate elasticity[1] of mean annual basin runoff by linking historical variations in annual basin runoff to the commensurate changes in annual mean precipitation and temperature, and iii) Developing climate response functions for the performance metrics.

The response of system performance to changes in long-term mean annual runoff was estimated using the Mike Basin model of the basin developed previously for the NBA (BRLi and DHI 2007). Mike Basin is a GIS-based water resources system model that simulates streamflow, reservoir releases, hydropower generation, irrigation water delivery and crop

[1] The precipitation elasticity of runoff defines the response of runoff to changes in precipitation and the temperature elasticity defines runoff response to changes in temperature (due to changes in evapotranspiration).

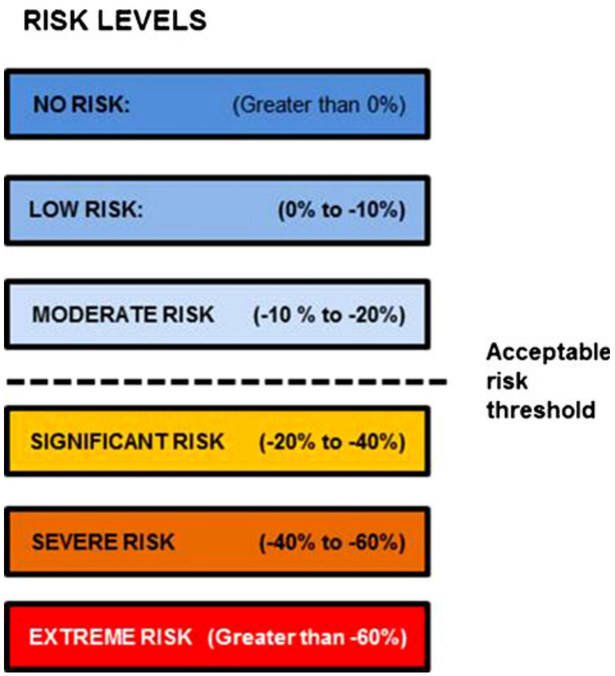

Fig. 2 Stakeholder defined risk levels based on percentage change in performance metrics

yields for irrigated agriculture. The model represents the basin as 60 sub-basins, with 420 river nodes, 21 existing and 4 planned dams, 10 hydropower plants, and 92 abstraction points for various uses (BRLi and DHI 2007) (Fig. 3). The model includes the entire Niger Basin.

The study used two infrastructure and two water demand scenarios. The infrastructure scenarios consisted of a baseline scenario with existing dams and irrigation schemes in the basin, and an investment scenario with three planned dams (Fomi, Taoussa, and Kandadji dams), along with a huge expansion of irrigated agriculture. The water demand scenarios were a baseline scenario with irrigation and domestic water demands projected for the period of 2025–2050 based on the historic climate, and a scenario with an additional irrigation water demand increase of 10 %, reflecting increased crop water requirements due to increased potential evapotranspiration.

The hazard discovery was conducted by parametrically varying the mean annual tributary runoff in the Mike Basin model, to reflect a change in mean climate conditions, and then simulating system performance with the water resources system model, to generate the resulting changes in the performance metrics. In this case the mean annual runoff was varied from +10 % to −30 %. Given the largely linear response of the performance metrics to these runoff changes, it was determined that a finer resolution of these changes was not necessary. The range of change was based on the initially estimated hydrologic response of the basin to increasing temperature and possibly increasing or decreasing precipitation. Since the climate risk is ultimately assessed based on GCM projections and/or other expert judgment regarding future likely conditions, the only requirement for this initial range is that it encompasses a plausible range. The baseline hydrologic time series used were monthly precipitation, runoff and potential evapotranspiration time series for the period 1966 to 1989, which included the severe droughts observed during the 1970's and 1980's and the wetter period at the end of the

Fig. 3 A screen display of the Mike Basin model for the Niger River Basin

1960's. A potential shortcoming of this study is that a stochastic assessment of natural variability was not conducted but this is not atypical of climate change impact assessments.

The analysis revealed that under the baseline climate, the planned infrastructure provides a huge benefit in irrigated agriculture (up to five-folds), a 15 % increase in hydro-energy production and a major improvement of minimum dry season flows throughout the Inner Delta and Middle Niger; however, SDAP also causes a loss of 10 % to 20 % for the metrics of navigation and Inner Delta Flooding. The impacts of climate change on performance metrics were evaluated both for the existing and for the new infrastructure scenarios (Fig. 4). For both infrastructure scenarios, rainy and dry season irrigated agriculture showed limited sensitivity to changes in climate, with an average run-off elasticity[2] of only 0.1. Hydro-energy, navigation and flooding in the Inner Delta were found to be more sensitive, with average run-off elasticities of about 1.0 for the future SDAP scenario and about 0.8 for the present (2005) infrastructure conditions (Fig. 4). The highest runoff elasticities were observed for the minimum flows at Markala, the Mali-Niger Border and Niamey; respectively 4, 3 and 2 (Fig. 4). The planned infrastructure investments will as such significantly improve the sustenance of dry season environmental (minimum) flows at Markala and further downstream compared to the present conditions, but are not able to mitigate the effects of significant reductions (>10 %) in runoff on minimum flows, unless some design changes (adaptations) are implemented. In general, the results indicated that the performance metrics were relatively insensitive to small changes in runoff (<10 %), but impacts become significant for major reductions in runoff (>20 %) for all selected sectors other than irrigated agriculture.

The next step in the hazard discovery linked mean annual basin runoff to mean climate conditions, as a precursor to defining system vulnerabilities in climate terms. The mean

[2] The runoff elasticity of a performance indicator defines the response of the indicator to changes in runoff; for example, a runoff elasticity of 1.5 indicates that a 10 % decrease in runoff causes a 15 % decrease in performance.

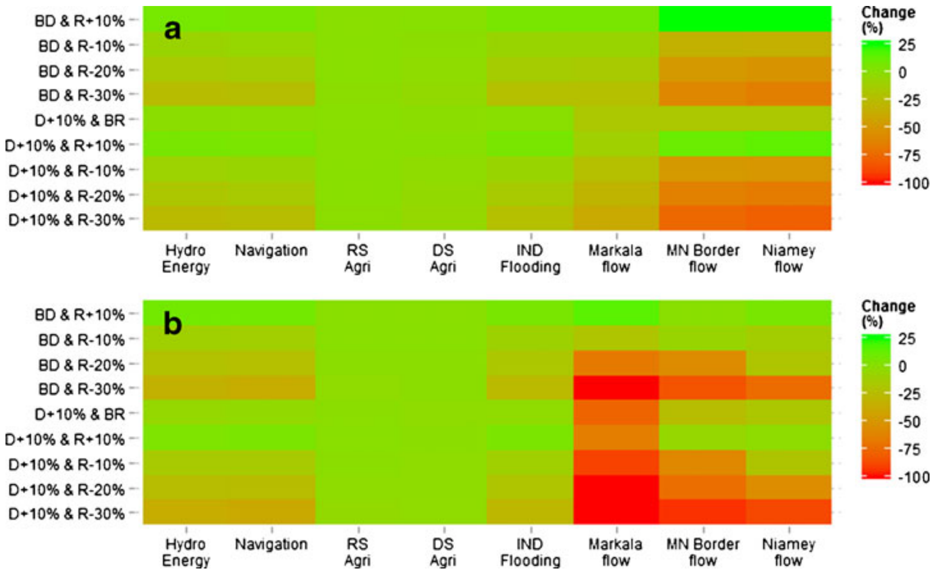

Fig. 4 Sensitivity of performance metrics to changes in long term mean runoff and water demand for **a** Current infrastructure scenario, **b** Planned Infrastructure scenario. The changes are eepressed in terms of percentage change over the baseline demand and baseline runoff conditions. Abbreviations are B: Baseline demand, D: demand, R: run-off

hydrologic response of the basin to changes in long-term mean temperature and precipitation was estimated empirically and through physically-based hydrologic modeling. The empirical analysis was based on observed streamflows at 14 monitoring stations distributed across the Basin for the period of 1966–1989. Based on this analysis, a best fit empirical model was defined as (Grijsen et al. 2012):

$$Q/_{Q_0} = \left(P/_{P_0}\right)^{2.5} * \left(T/_{T_0}\right)^{-0.75} \quad (1)$$

where, Q, T and P denote the estimated mean annual basin-runoff (m^3/s), annual precipitation (mm/year) and annual mean temperature (°C); and Q_0, T_0 and P_0 denote the reference values of 220 mm/year, 26.6 (°C), and 1,244 mm/year respectively.

The model evaluation in terms of goodness of fit to the historical records revealed that the mean annual runoff in the NRB is well approximated (adjusted R^2=0.85) and the F-test showed that the model is significant at 95 % confidence. A physical-based hydrologic model, the Variable Infiltration Capacity (VIC) model (Liang and Lettenmaier 1994), was also used for estimating hydrological sensitivity to climate changes and produced similar responses (results forthcoming). Hence, the precipitation elasticity of runoff in the NRB was assessed at 2.5 and the temperature sensitivity of runoff at −0.75/26.6 or about −3 % per °C.

Based on the empirical model of basin-runoff and climate variables, a temperature increase of 2 °C alone would result in a decrease in annual mean runoff in the order of 6 %. Similarly, a 10 % decrease in precipitation alone would cause a decrease in mean runoff of 25 %. These findings are consistent with the hydrological sensitivity estimates in previous studies (Gleick 1987; Sankarasubramanian et al. 2001; Agoumi 2003).

The quantification of the runoff response to climate change allowed the translation of the changes in performance metrics as a function of changes in runoff to changes in metrics as a function of changes in precipitation and temperature. These "climate response functions," shown in Fig. 5, provide the link between impacts due to climate change and projections of climate change. This provides at least two important advantages over the use of climate projections to drive the analysis. First, it provides a basic understanding of what climate conditions are problematic, independent of the possible uncertainties associated with projections of climate change. Second, the climate response function can be used in conjunction with projections from multiple sources, including CMIP3 and CMIP5, and provide new estimates of climate risk without performing the entire analysis with each new set of climate projections. This step is described next.

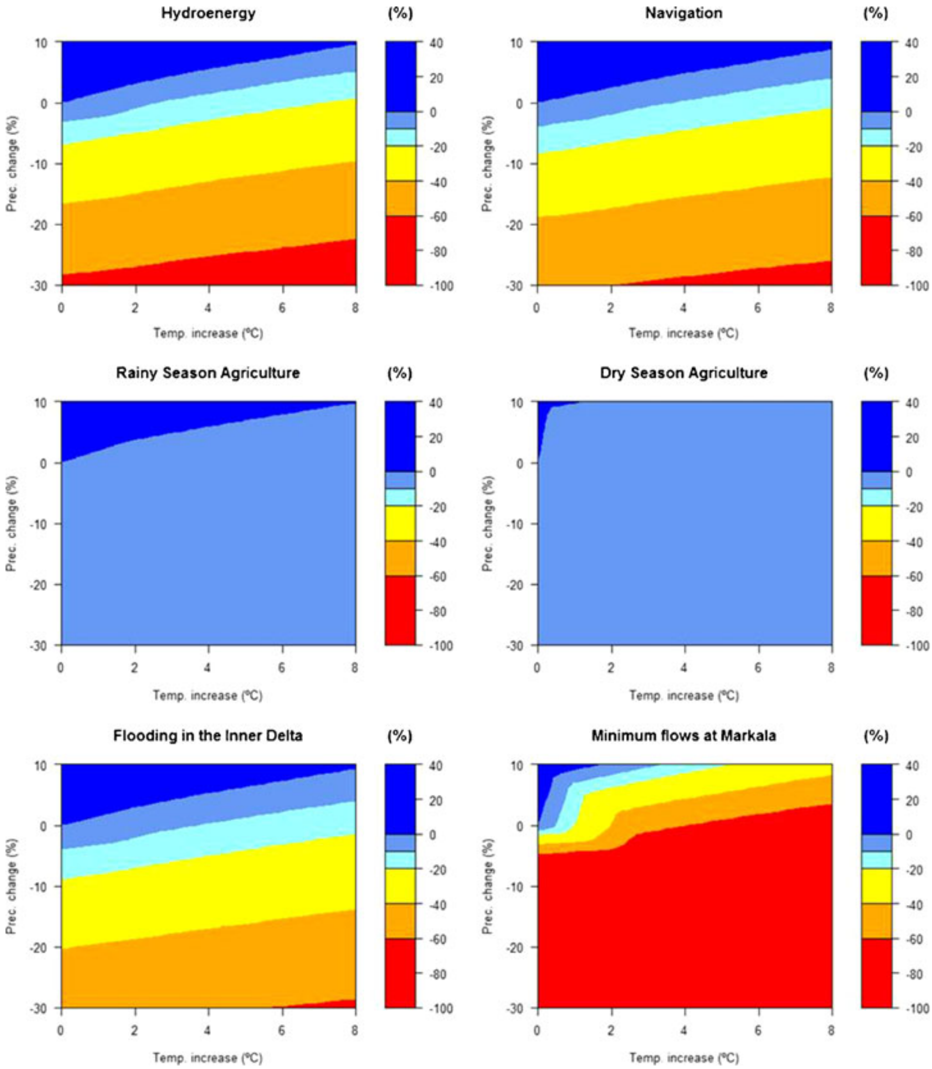

Fig. 5 Climate response surfaces for performance metrics. Contour lines represent changes in the magnitude of response variables: hydroenergy generation (GWh), navigation (navigable days), rainy and dry season irrigated agriculture (ha), Flooding in the Niger Inner Delta (m^3/s), minimum stream flows at Markala (m^3/s). Values at x and y-axis's indicate increase in temperature and percent change in precipitation over the mean historic climate conditions

3.2.3 Climate informed risks: estimating the likelihood of climate conditions and hazards

The final stage in the decision-scaling process is the use of the best available climate information to make judgments regarding the relative likelihoods of the climate conditions identified as critical in previous steps. In this case, the risks of violating the thresholds for the system performance were assessed using a total of 38 climate change projections from 15 GCMs for theA1B emission scenario, obtained from the Data Library of the International Research Institute for Climate and Society (The International Research Institute for Climate and Society 2013). In this case the A1B emissions scenario was chosen as an indication of central tendency, although differences in emissions will have little effect on projections prior to mid-century. Each projection was treated as equally plausible; alternative approaches to weighting have been found to provide little benefit (Mote et al. 2011). Biases from each projection were removed using quantile mapping, a widely used downscaling technique in hydrological applications (Wood et al. 2004). The quantile mapping transfer functions between GCM and observed values were estimated for the simulation period of 1901–1999. The transfer functions were then applied to the future projections for the entire GCM monthly time-series (2001–2099).

The analysis of climate projections revealed no consensus trend in future precipitation, while all the projections indicated increases in temperature. The ensemble mean values were 30-year mean annual temperature increases of 1.5, 2.1 and 2.7 °C, and 30-year mean annual rainfall increases of 1 %, 1.4 % and 3.1 % for the near (2030), mid (2050) and distant future (2070) respectively, over the mean baseline conditions from 1901 to 1999. Overall the projections translated on average to a basin runoff change of only −1.7 %, −1.9 % and + 0.7 % by 2030, 2050 and 2070 respectively. However, the wide range of future precipitation projections, e.g. from 1170 to 1415 mm/year by 2050, prevents the ruling out of conditions that may be wetter or drier in the future. Note that the IPCC AR5 which is likely to be more reliable than AR4 is released as this paper is still under review. The use of these recent GCMs might change the results as they incorporate more processes and feedbacks than earlier models.

The bias corrected GCM projections were used as inputs to the climate response function to estimate climate risks in terms of performance metrics. A normal distribution, based on the estimated mean and variance of the 38-member ensemble, was fitted to the ensemble of projections (Fig. 6). The normal distribution was judged to fit the data reasonably well, as would be expected for a set of means according to the central limit theorem.

The result is a probabilistic estimate of risk based on available climate projections and the system's response to climate changes. The results indicated a significant risk probability for environmental flows, especially at Markala, and relatively lower risk probabilities for flooding of the Inner Delta, hydro-energy and navigation metrics (Fig. 6). Climate risks to irrigated agriculture are minimal due to its allotted high priority for water allocation in the NRB.

Of particular interest to stakeholders is the resulting ability to summarize the projections in terms of the probability of exceedance of the above defined threshold of acceptable changes. The probability of falling below the threshold of acceptable performance (i.e., 20 % below the baseline level) of various performance metrics is shown in Fig. 7. Here the relative risk to different performance metrics is clear. Projections for the year 2030 indicate high probabilities of unacceptable minimum flows for Markala (95 %), the Mali-Niger border (55 %) and Niamey (20 %). The other performance metrics show relatively low risks with only hydro-electricity production approaching a probability of 10 % of crossing the threshold by the year 2050. Rainy and dry season agriculture showed no risk relative to the 20 % threshold for the projection years 2030, 2050 and 2070.

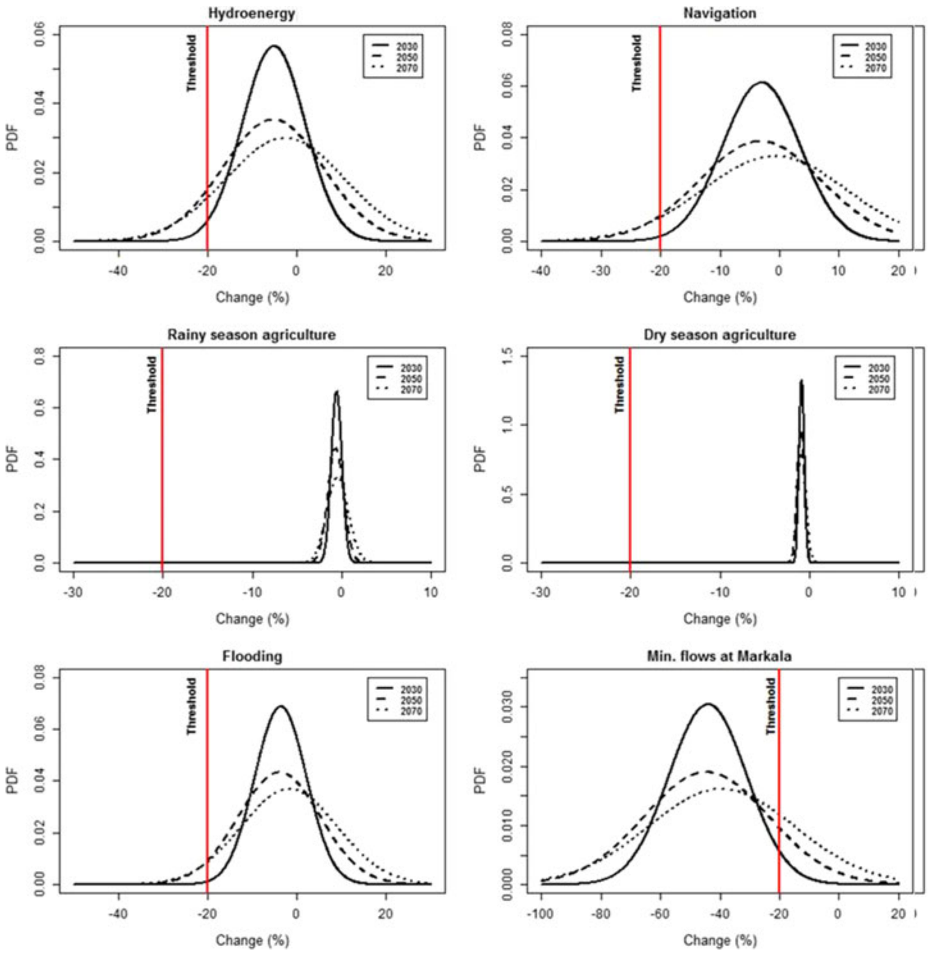

Fig. 6 Probability distributions of climate risks for selected performance metrics for the new infrastructure scenario. X-axis in each plot show percent changes in the performance metrics over the mean historic climate conditions. Y-axis in each plot show corresponding probabilities of change in the performance metrics, for hydroelectricity, navigation, flooding in the Inner Delta, Rainy season and Dry season irrigated agriculture. The vertical threshold line indicates the 20 % threshold level

4 Discussion

The climate risk assessment of a complex large-scale water resources system such as the NRB requires a framework that can clearly communicate relevant information to the decision makers within a context of uncertainty. Decisions related to investments in long-lived water infrastructure may be jeopardized by the uncertainty of future climate and the risks associated with anthropogenic climate change. This study utilized a risk-based approach that allowed the framing of the climate uncertainty in terms of the stakeholder-defined risk levels of performance metrics. The approach does not attempt to use projections to reduce climate uncertainty but rather uses them to inform the risks that are relevant to planning decisions.

In the analysis presented here the performance of the SDAP under climate change was assessed relative to its expected performance under stationary climate, for which it was

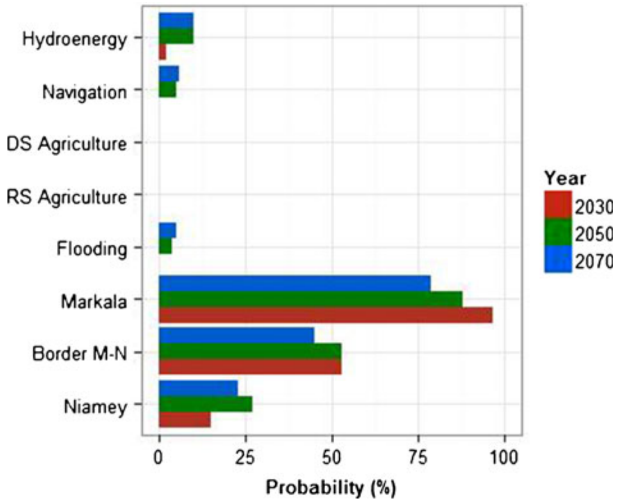

Fig. 7 Estimated probabilities of risks for the performance metrics in the new infrastructure scenario. X-axis shows exceedance probabilities of the threshold risk level (i.e., 20 % reduction in performance) for each performance metric

planned. We have not attempted to assess in detail the performance of SDAP relative to no investments or alternative investments in this study. However, the benefits of SDAP were estimated as part of this project and reveal that compared to the baseline of no investments, the benefits for all sectors, including the maintenance of environmental flows, are very large and much larger than the potential negative impacts of climate change.

There are several significant uncertainties in addition to the use of mean changes in climate that remain. The hydrologic response to changes in climate is primary among them. Also, future changes in the annual and seasonal variability of the Niger Basin's climate may pose additional risks to the water resources system. However, at this point there is little guidance on how variability might change. There is also uncertainty in the progression of the investment plan itself. The ability and political will to make the investments necessary to expand irrigation and rehabilitate old and construct new infrastructure may be a more important determinant in the success of the basin investment program.

Given the limitations in our ability to fully anticipate the risks that may be associated with climate change, a strategy to manage climate risks, including those identified here and those that remain plausible (e.g., a return of substantial drying related to decadal scale variability), is a prudent response. In general, there is wide potential for coordinated management of the available water resources through the guidance of the NBA to mitigate much of the potential impact of climate variability and change in the near future.

5 Conclusions

Uncertainty and risk associated with climate change raise concerns for infrastructure planning in water resources. A methodology was applied in this study for conducting a risk-based assessment of climate change impacts for a major investment plan in the NRB. Climate risk was defined based on the probability of selected percentage changes in performance metrics under climate change scenarios relative to baseline conditions. Although the GCM projections disagree on the direction and magnitude of changes in future precipitation, the analysis indicates that the available projections do agree that the projected future changes present a low risk to the planned SDAP investments.

The conclusion from this study is that impacts of climate change may potentially be a threat in the mid-term and distant future for the Niger River Basin for environmental flows, but adequate adaptation is possible by slightly reducing the future dry season irrigated acreage and/or improving irrigation efficiencies. However, in the immediate and near future—before the full scale implementation of SDAP—the risks associated with the present climate variability should receive more attention as most actions to manage climate variability would also help to reduce the risks associated with climate change. The proposed risk assessment method, with a focus on the assessment of the system's climate vulnerability, allows a clear understanding of the sensitivity of the investments to changes in climate. It also provides a context for interpreting the uncertainty of climate change relatively to the thresholds of investment performance that the stakeholders are concerned with.

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