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Research-2-Practice Forum on Renewable Energy, Water and Climate Security in Africa
16 - 18.04.2018, Tlemcen, Algeria

Category: Research and Scientific Contributions

The main topics of the extended abstract should fit within the areas of water, energy, climate change, the nexus within water, energy and climate change. The abstract should also be in line with ongoing projects and priorities of the research agenda at PAUWES as a contribution to the Agenda 2063 of the African union.

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Scanning Climate Change Impacts on Water Resources of the Largest African River Basins

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Short Abstract

The objectives were to ensemble and analyze the projected signals of climate change recently published in peer reviewed outlets with respect to five African river basins, viz. Nile, Senegal & Volta, Niger, Congo, and Zambezi & Limpopo. Results of 55 papers were assessed (distributed as 30, 25, 16, 13, and 16%, respectively). Findings stated the dominant tendency for using unmitigated emission pathways (A2 for the Nile and RCP8.5 for the remaining basins), with fewer applications to hypothetical scenarios. Compared to the individual member, the majority of the papers followed the ensemble GCMs approach to obtain robust results compared mostly (40-50%) to the 1960-1990 baseline. Nevertheless, all models agreed in the increasing trend of temperature compared to the dominant uncertain trends in rainfall. The studies applied 19 hydrological models (especially SWAT, HBV and CLiRuN) coupled with limited land use considerations. In contrast to uncertain trends in future rivers' flow, all basins showed decreasing trends in runoff. This discrepancy in climate change projections delayed the adoption of adaptation plans. Technically, runoff, stream flows and evapotranspiration terms were largely misused. The north-south cooperation is direly needed in building observational datasets, a priori input for characterizing the regional uncertainty and better climate change projections.

Keywords: Climate change; predictions; Uncertainty; largest river basins; Africa

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1. Introduction

Climate change grasps much scientific attentions nowadays. However, predictions in climate change remained a controversial issue, especially water-related ones. Among facts so far are: firstly, scientific guidelines to deal with climate change have been clearly set, i.e. IPCC; secondly, prediction scenarios are not climate forecasts per se rather plausible approximations; thirdly, Africa, where most of the least developing countries exist, is the most vulnerable continent to climate change; and finally there is an urgent need for adopting mitigation and adaptation plans. The later which is mostly a decision-based activity hurdled by the large uncertainty in climate change studies, especially the regional downscaled predictions albeit with the advance progress made on regionalization and downscaling techniques. In the surfeit climate change literature, the uncertainty (the most daunting task) is being characterized and mostly related to: GCM configuration, emission scenario, temporal scale, observational datasets, and hydrological model parameterization. In this study, via reviewing the recent published papers pertinent to climate change, trends in annual rainfall in Africa showed uncertain trends as in average 53% of the reviewed papers stated simultaneously increasing and decreasing projection signals.

Most of the livelihood generations in Africa are climate-driven activities. However, the African climate and hydrology were endowed with large variability, spanning super-humid and desert climatic zones. Thus, internal variability is another paramount source of uncertainty especially into regional and shorter timescale scenarios (Elshamy et al. 2009; Giorgi et al. 2009; Aich et al. 2014; Hargreaves and Annan 2014). This explains the gap between scientific community and the adoption of adaptation plans by policy and decision makers, especially in developing countries where fund is limited. Thus, climate change scientists used several measures for increasing confidence/likelihood on climatic change predictions. Among which is the generation of ensemble of models/simulations then weighting the direction of change, i.e. producing a range of predictions. The threshold of accepting the projection signal is 66%, i.e. the projected signal is robust if at least 66 % of the models agreed in the direction of change (Haensler et al. 2013). Rather than ensemble models, this study ensembles results obtained by published peer reviewed papers, as a further step in offsetting errors across climate change models and techniques applied in five African river basins (Nile, Senegal & Volta, Niger, Congo, and Zambezi & Limpopo); By this way, the predicted changes in water resources-related parameters due to climate change would not fall outside the results presented in this study. The aims of this study were to quantify and compare the projection signals due to climate change recently presented in peer reviewed journals and database with respect to five African river basins (Nile, Senegal & Volta, Niger, Congo, and Zambezi & Limpopo); and to list the hotspot research issues in Africa, especially to the African mid-career researchers. These two objectives would have added values regarding filling the gap in climate change combating efforts, especially towards adopting the most likely adaptation plan(s).

2. Methods

The methodology was to far extend similar to that followed by Roudier et al. (2014) who reviewed the climate change impacts on West Africa. In this study, impacts of climate change on water resource of the largest African basins (Nile, Senegal & Volta, Niger, Congo, and Zambezi & Limpopo) were assessed via reviewing 55 papers, being published in the last ten years (2008-2017), distributed respectively as follows 30%, 25%, 16%, 13%, and 16%, respectively. During the reviewing process, the emphasis was given to the followings: 1. Emission scenarios, 2. Applied climate change model(s), 3. Prediction's time windows, 4. Applied hydrological model(s), 5. Historical baseline, 6. Predicted trends in temperature, rainfall, runoff, flows and reference evapotranspiration (ET_o), 7. Considerations of land use/cover in the hydrological modelling, and 8. Methods used for estimating ET_o. The results were stored, analyzed and quantified using Excel sheets. Trends in temperature, rainfall, runoff and flow were segregated into three categories: increasing, decreasing and uncertain. The increasing trend implies that a pure increasing trend (all predictions > 0) and the opposite holds true for the decreasing trend (all predictions <0). In cases where the projection indicates simultaneously increasing and decreasing trends, then this trend is assigned as uncertain. The percents of consent among trends were then estimated for each basin. For example, if three authors of three different papers projected pure increasing trends, the percents of consent for this increasing trend are 100% for the decreasing trend, 0% for decreasing trend and 0% for uncertain trend. The considerations of land use in the prediction process were assigned to two categories "Yes or No", which were translated to its corresponding percentages.

3. Results and discussion

The choice of emission scenario is a cardinal in predicting climate change impacts (Aloysius and Saiers 2017; Haensler et al., 2013; Vetter et al. 2017). The majority of the reviewed papers showed high tendency for using unmitigated future emission pathways (A2 for the Nile and RCP8.5 for the remaining basins). These high CO_2 emission scenarios lead to warmer conditions by the year 2100 (IPCC, 2013), explaining the overwhelming increasing trends found in temperature throughout the basins. This confirms the result of Aloysius and Saiers (2017) that emission scenarios dominate the temperature regime. While, fewer studies applied hypothetical scenarios in order to study the climate change impacts (3 studies in Niger and 1 study per each for Nile and Zambezi & Limpopo), the majority of the studies used the ensemble GCMs approach, mostly downscaled to regional climate models (53% of papers in Senegal & Volta, 55% for Niger, 100% for Congo, 89% for Nile and 70% for Zambezi & Limpopo). This multi-models approach might encompass all future trends and outperform any individual simulation (Erfanian et al., 2016; Nikulin et al., 2012). Thus, the most robust climate change adaptation plan could be figured. Owing to fragmented and disconnected observational datasets, the future changes in climatic parameters were being evaluated using several baselines. Thus, it was very difficult to compare results across the basins. Relatively, the period 1960-1990 is the widely used baseline in all basins, except in Senegal & Volta in which the period 1980-2000 is the dominant. Predicted rainfall associates normally with high uncertainties worldwide. In this study, rainfall showed uncertain trends in all studied basins, with the exception of the Senegal & Volta where a decreasing trend exists (Figure 1a). This high discrepancy in rainfall prediction is also confirmed by Aich et al. (2014) who compared rainfall trends of four African river basins using ensemble GCMs.

Intrinsically, GCMs are unable to directly estimate future changes in runoff and stream flows, evoking the need for using hydrological models. Selecting the most appropriate hydrological models and its parameterization however are major sources of uncertainty. The reviewed papers have applied 19 hydrological models of conceptual and semi-distributed types. Among which, the SWAT model was largely applied throughout the basins (50% for Congo, 36% for Senegal, 30% for Niger. 25% for Zambezi& Limpopo and 18% for the Nile), whilst the CLiRun model dominates the Zambezi & Limpopo studies at 50%. Vetter et al. (2017) called that the choice of the hydrological model is the least source for uncertainty compared to GCMs and emission scenarios; in line with this, relatively all basins showed decreasing trends in runoff even where rainfall had shown uncertain trends (Figure 1b). However, this large consensus is missed in detecting trends of rivers' flow (Figure 1c). Only the flows of Senegal & Volta showed a larger agreement (83%) on its decreasing trends.

The land surface– atmosphere interaction becomes an undeniable relationship nowadays (Nicholson, 2000). A comparable research showed that under short-term climate extremes, the land surface model plays a more important role in controlling the regional climate compared to cumulus parameterizations under current model configurations (Lisi et al., 2014). Wang and Eltahir (2000) simulated that a change threshold of 20% in land cover in West Africa will result in regional persistent droughts conditions. Despite this, the reviewed papers gave little considerations to change in land use/cover in predicting climate change (Table 1).

All basins experienced increasing trends in ET_o, with the exception of the Nile basin where uncertain trends existed. This increase ET_o could be easily justified by the increased trend in temperature as the Hargreaves model (a temperature-based model) is being dominantly used with the exception of Senegal& Volta basin where the Penman-Monteith is the dominant. Such increases have detrimental impacts on available water resources, decreasing runoff and rivers flows, i.e. in many cases the increase in rainfall may be diminished by the increase in ET_o. Generally speaking, the increased ET_o will increase the actual evapotranspiration/irrigation water, however how plants stomata response to high CO_2 concentrations is still a controversial topic.

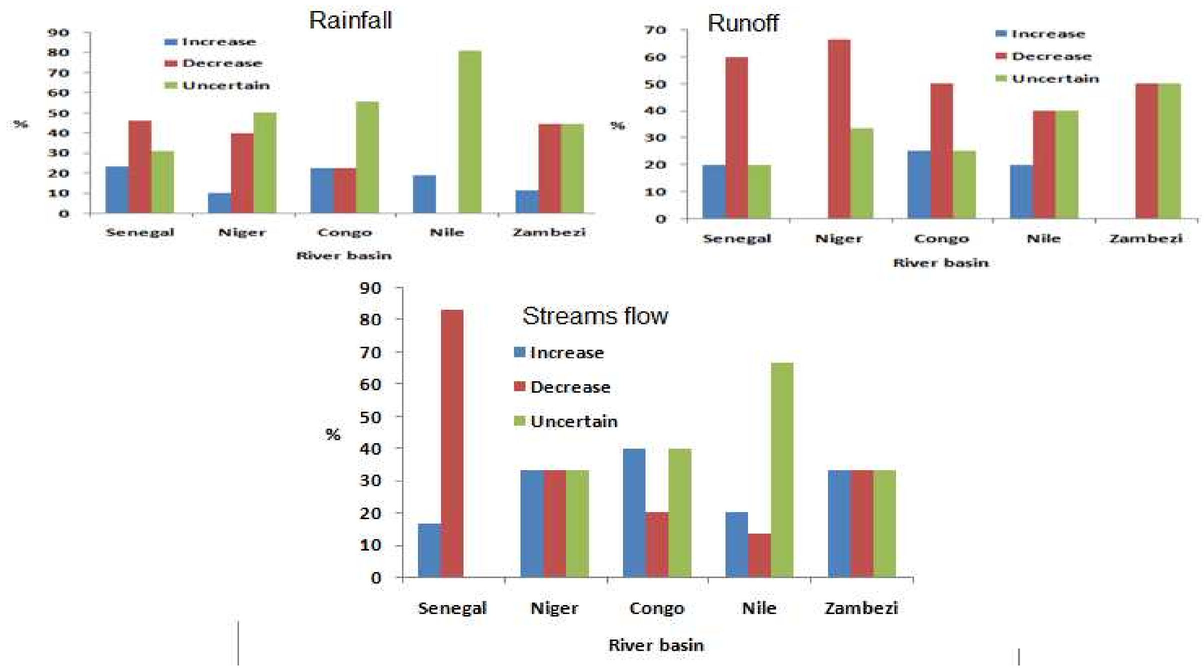

Figure 1: percents of concensus in trends of rainfall, runoff and stream flow in selected African River basins

Table 1: Percents of considering land use/cover in predicting climate change hydrological impacts

category	Senegal& Volta	Niger	Congo	Nile	Zambezi& Limpopo
Yes	50	60	71	50	30
No	50	40	29	50	70

4. Conclusions

Expenditure on climate change adaptation plan is limited by the uncertainty associates with climate change predictions, especially at smaller spatial scales. In order to increase the robustness of predictions, climate change scientists have used the ensemble model approach rather than the individual member; however still uncertainty exists despite its lesser degree. In this ensemble approach a very sensitive step shall be well considered that is the weighting average process. As a matter of fact the weighting process remains the controversial step among the multi-criteria assessment scientists. Lacking of observational datasets contributes largely to regional uncertainty in Africa. The HAPEX (1992) was one of the prominent north-south experiments aimed at deep understanding of the land-atmosphere relationship in the Sahel, by which good observational datasets were attained. Expanding such experiments and cooperation is utmost important in understanding climate change impacts. Runoff and River flow are two different hydrological terms (Beyene et al. 2013) however many studies interchangeably used them. Assessing the performance of given hydrological model(s) depends on flows' gauging stations (rating curves). However, most of the African rivers experienced human interventions (dams, irrigation schemes, etc), changing the historical head-discharge relationships. Thus, careful considerations should be given to these issues in calibrating and configuring hydrological models. In many reviewed papers, evapotranspiration (ET) has stood alone without one of its intuitive prefixes "potential, reference or actual" which change the meaning totally. Moreover, fewer papers made clear statements on how ET was being computed. Authors and reviewers should fully consider the proper use of the term evapotranspiration. Climate change is a global issue, studying its impacts entails multidisciplinary approach.

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