Integrated Impact Assessment for Sustainable Hydropower Planning in the Niger and Volta Catchments (West Africa)

Évaluation intégrée des impacts pour une planification durable de l'hydroélectricité dans les bassins versants du Niger et de la Volta (Afrique de l'Ouest)

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RÉSUMÉ

La lutte contre le changement climatique, dans un contexte de croissance mondiale, nécessite un passage massif aux énergies renouvelables (ER). De ces ER, l'hydroélectricité est actuellement la technologie la plus rentable. Cependant, en raison du manque d'évaluations d'impacts à l'échelle du bassin versant lors du processus de planification, la construction de centrales hydroélectriques (CH) fonctionnant avec des réservoirs peut avoir des ramifications écologiques, socio-économiques et politiques (inattendues) à court et à long terme. Dans les bassins versants du Niger et de la Volta, le faible accès à l'énergie ainsi que la forte croissance démographique exigent une production accrue d'électricité. Les projets de CH prévues exercent une pression croissante sur les deux systèmes fluviaux. Le potentiel concret des alternatives éoliennes et solaires reste peu étudié malgré la baisse continue des prix. En prenant les bassins versants du Niger et de la Volta comme exemples, l'objectif de cette étude était de développer et de tester une évaluation d'impact transposable. Nous avons donc intégré des indicateurs écologiques, socio-économiques et politiques établis pour toutes les CH prévues, tout en tenant compte de leur capacité, et nous avons élaboré une méthode de classement basée sur des catégories d'impact. Cette étude permet aux décideurs de comparer à la fois les impacts catégorisés et l'énergie générée par les CH prévus à l'échelle du bassin versant.

ABSTRACT

Mitigating climate change, while human population and economy are growing globally, requires a bold shift to renewable energy (RE) sources. Among renewables, hydropower is currently the most economic and efficient technique. However, due to a lack of impact assessments at the catchment scale in the planning process, the construction of hydropower plants (HPP) operating with reservoir-storage and dam may have (unexpected) ecological, socioeconomic, and political ramifications in the short and in the long term. In the Niger and Volta Catchments, lack of energy access and population growth call for more electricity generation. Planned HPP and other dam related infrastructure increasingly put pressure on both river systems, which harbor a globally important biological diversity. Concurrently, the potential for wind and solar alternatives remains poorly studied despite continuously falling prices. Taking the Niger and Volta catchments as example cases, the aim of this study was to develop and test a transferable impact assessment. Therefore, we integrated established ecological, socioeconomic, and political indicators for all HPP planned, while considering their capacity, and developed a ranking method based on impact categories. This study empowers decision-makers to compare both the ranked impacts and the generated energy of planned HPP at the catchment scale.

KEYWORDS

biodiversity; dams; river management; renewable energies; sustainable development

1 INTRODUCTION

During the past decades, the dominance of fossil fuels in meeting increasing energy demands has generated stress onto Earth's natural systems. Hence, mitigating global warming is part of the Agenda 2030 within the Sustainable Development Goals 7 "Affordable Energy" and 13 "Climate Action". According to the International Energy Agency (IEA), the renewable sectors hydropower, solar energy, and wind power need to expand in order to meet long-term climate goals as well as increasing energy demands. In Africa, 591.7 million people had no access to electricity in 2020. Africa's population is expected to double by 2050; in 2070 one third of the continent's population will depend on energy provided by the West African power pool. The most established renewable energy source in Africa is hydropower, accounting for over 70% of the renewable and about 16% of the total electricity share. In order to achieve universal electricity access and forward a low carbon energy transition, Africa is part of a global boom in hydropower dam construction; at least 247 dams [≥1 megawatt (MW) in capacity] are either planned or under construction. Hydropower is a renewable electricity source, but not per se climate-neutral; furthermore, it has multiple ecological, social, economic, and political ramifications (Grill et al. (2020)). However, planning tools with specific guidance and standardized methods on assessing these specific impacts of HPP on catchment scale are scarce.

The present study develops and tests an integrated impact assessment approach that supports decision makers in HPP construction on a catchment scale applying ecological, social, and political indicators (Peters et al. (2021)). Taking the Niger and Volta catchments as case study, (1) impacts are assessed and integrated for potential dam locations and, based on the outcome, a ranking of all planned HPP is derived, (2) the effects of the selection of indicators on the total ranking are tested, and (3) normalized effects of several small HPP (SHP, ≤ 50 MW) are compared to the predicted effects of few large HPP (LHP).

2 METHODS

The largest river catchments in West Africa are Niger and Volta, providing sources of livelihood for the quickly growing population of people who inhabit the 12 riparian countries.

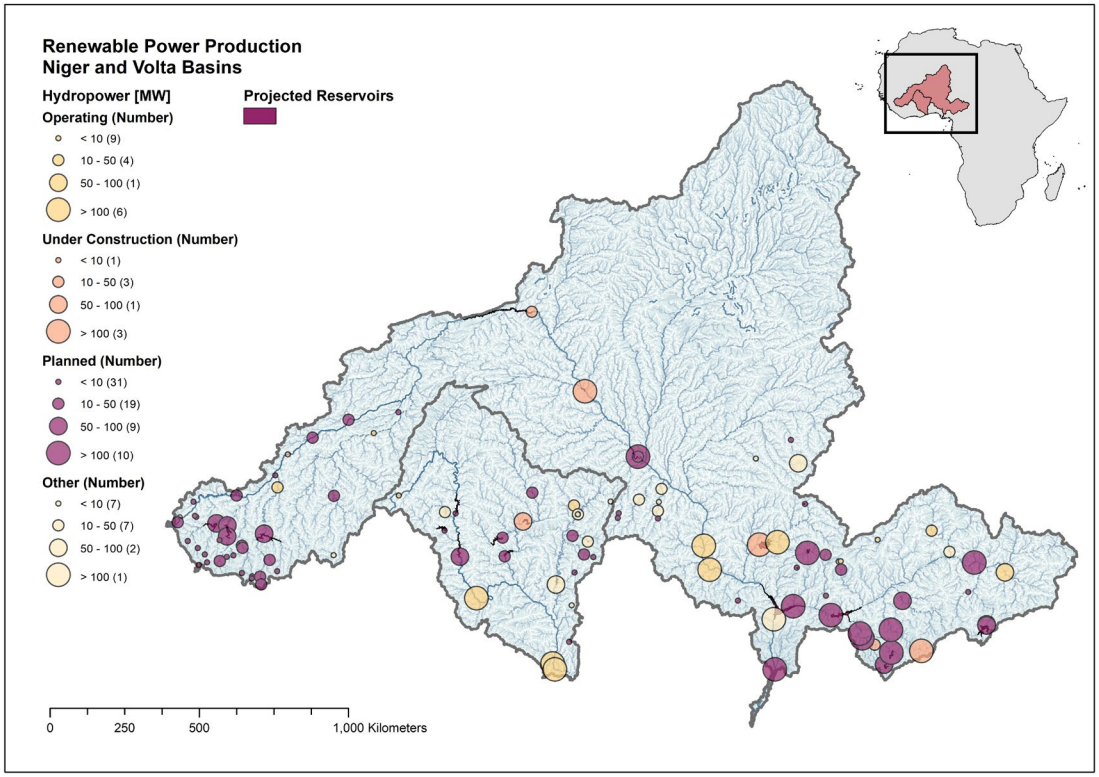

Figure 1. Niger and Volta catchments in West Africa and location of hydropower plants (HPP; existing, under construction, planned, other (halted, no evidence of progress, rehabilitation). Size of the circles represents the HPP capacity in megawatt (MW). Number of HPP per size category in brackets along Niger and Volta main stems and their major tributaries.

Both catchments also harbour a very high biodiversity. Data of HPP and projected reservoirs were obtained by merging data from the Global Reservoir and Dams Database (GRanD) and the Future Hydropower Reservoirs and Dams Database (FHReD). Information was updated considering available online resources, research articles, and newspaper articles. Missing geometry of projected reservoirs for HPP which operate with reservoir and dam were calculated based on capacity information, topology and discharge. To permit comparisons among different projects and between catchments, impact assessments were realized on the catchment scale including all planned HPP except those planned as run-of-river or pumped storage. Impact assessments were conducted for both catchments separately. The set of selected indicators represents measurable ecological, social, and economic impacts to underpin the idea of assessing dam locations in the frame of sustainability. To ensure reproducibility, the comprehensive and high-resolution spatial data used were available via open access platforms.

In a first step, planned HPP were ranked for one indicator at a time according to their calculated impact (Peters et al. (2021). Second, for each single indicator, every HPP was given the value of the respective quartile they belonged to, from 1 representing the lowest impact to 4 representing the highest impact. For each HPP, these quartile values were summed up for all indicators (overall impact). Finally, every planned HPP was ranked according to this overall impact. In order to test the sensitivity of the impact calculation to the composition of the indicators, analyses were re-run in a “leave-one-out” fashion (one indicator was excluded at a time, local sensitivity approach), and then again through excluding several indicators by creating different scenarios. Results of the impact assessment considering single indicators, all indicators and scenario-based indicator compositions were compared.

3 RESULTS AND DISCUSSION

Currently a total of 20 HPP operate and provide electricity in the Niger and Volta Catchment, 67 are planned or under construction (Figure 1). By integrating ecological, socioeconomic, and political indicators for all planned HPP in the Niger and Volta catchments, our results allow comparisons between individual projects considering their specific impacts as well as the capacity they will provide. A general correlation between capacity and impact can be observed; however, large impacts can result from SHP, which again highlights the importance of a site-specific context. The sensitivity analysis of the impact assessment considering different indicator compositions highlighted that an overall ranking is dependent upon the selection and composition of indicators. The present case study contributes important information to the discussion on sustainable hydropower development not only for West Africa.

4 CONCLUSION

Following recommendations for decision-makers can be derived: Impact assessments, applying a comparable set of criteria, should be carried out for both SHP and LHP. It is crucial to consider the additive/synergistic impacts of HPP, especially of SHP within (sub-)catchments (1); Impact assessments should include a sensitivity analysis because ranking of planned HPP might change with impact indicators selected. Policymakers should be aware of the role indicator selection has on impact ranking (2); When deciding for SHP or LHP, future capacity potential should be considered (3). Currently, hydropower is considered the most economical and efficient technique to provide renewable energy. The present study offers a transferable integrated approach to enable sustainable hydropower planning considering site and size characteristics. Still, it is of pivotal importance to carefully evaluate if hydropower remains the most suitable and sustainable option. Integration of practical potential analyses for solar and wind power could identify alternative renewable energy options at HPP sites classified as harmful and reveal pathways for renewable energy development (Sterl et al. (2020)). In addition, HPP operating as run-of-river or pumped-storage are alternatives that should be part of discussion and decision-making processes.

LIST OF REFERENCES (3 maximum)

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