



## Projected water resource dynamics in the sub-humid Upper Nile Water Management Zone of Uganda, East Africa

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### ABSTRACT

Projected scenarios in land, population, resource use, land use/cover, climate and urbanization over the Nile Basin reveal an acceleration and dynamical transitions in near-to-medium term. These changes have a bearing on water resource dynamics including the acceleration of the long-held yet hitherto managed conflicts over the Nile waters. This paper presents a projection of water resource dynamics in the River Nile using the Upper Nile Water Management Zone (UNWMZ) of Uganda as a reference site. Results showed variability in sub-catchment discharge into the Upper Water Management Zone. By 2040, the catchment's water resources base will decrease by 12.6% whilst gross and net demand will increase. The projected decrease in the water discharge in the catchment can be attributed to the anticipated increase in temperatures, a decrease in rainfall and expected increase in human population in the sub-region. It is recommended that routine monitoring of catchment discharge is enhanced and intensified. Further, exploration into the technical and scientific mechanisms that will facilitate effective adaptation to increased water demand in the catchment should be undertaken in response to the projected increase in gross and net water demand in the catchment.

Key words: Upper Nile Basin, Water resource dynamics, Uganda

### RÉSUMÉ

Les scénarios projetés concernant les terres, la population, l'utilisation des ressources, l'utilisation / la couverture des terres, le climat et l'urbanisation sur le bassin du Nil révèlent une accélération et des transitions dynamiques à court et à moyen terme. Ces changements ont une incidence sur la dynamique des ressources en eau, y compris l'accélération des conflits sur les eaux du Nil, qui ont longtemps été jusqu'alors maîtrisés. Ce document présente une projection de la dynamique des ressources en eau dans le Nil en utilisant la zone de gestion des eaux du haut Nil en Ouganda comme site de référence. Les résultats ont montré une variabilité dans les rejets de sous-bassins versants dans la zone supérieure de gestion des eaux. D'ici 2040, la base de ressources en eau du bassin versant diminuera de 12,6%, tandis que la demande brute et la demande nette augmenteront. La diminution prévue du débit d'eau dans le bassin versant peut être attribuée à l'augmentation anticipée

des températures, à la diminution des précipitations et à l'augmentation attendue de la population humaine dans la sous-région. Il est recommandé de renforcer et d'intensifier la surveillance de routine du débit des bassins versants. De plus, une exploration des mécanismes techniques et scientifiques faciliteront une adaptation efficace à une demande en eau accrue dans le bassin versant en réponse à l'augmentation prévue de la demande en eau brute et nette dans le bassin.

Mots clés: Bassin du haut Nil, dynamique des ressources en eau, Ouganda

## **BACKGROUND**

The River Nile basin is a dynamical region of many interactions in space and time. Dynamical relationships exist in the region to the extent that the former Egyptian President Anwar Sadat in 1979 indicated that “the only matter that could take Egypt to war again is water”. Similarly, in 1988, Boutros Boutros-Ghali, the then Egyptian Foreign Minister who later became the United Nations Secretary General, provided a futuristic perspective to the effect that the next war in the Middle East would be fought over the waters of the Nile and not politics (Kameri-Mbote, 2007). Such power relations and dynamics underlie the water resources management of the River Nile and the Nile basin. In the recent past, tension has been mounting over water resources access and use; Ethiopia, Egypt and Sudan are locked in the conflict (Khalil, 2018; Raphelson, 2018). While 86% of the water to Egypt and Sudan is from the Ethiopia, the other balance is from the catchments with origins in the Nile basin countries such as Uganda (Carlson, 2013; Allington, 2018).

Historical accounts (100-800 C.E.) have shown that Egypt and Ethiopia have over years conflicted over the rights to use and access to the Nile waters (Carlson, 2018). However, regardless of these relational dynamics between these two countries; four development needs now typify the Nile basin; i) water for irrigation and hydroelectric power production, ii) prevention of floods, ii) watershed management, minimization of erosion and siltation of reservoirs, and iv) prevention of water pollution (Mason, 2004). These development needs are being mediated by the spatial-temporal dynamics over the Nile basin

including: accelerated population growth (Nile Basin Initiative, 2016); climate change (Beyene *et al.*, 2010), land degradation (Williams, 2009), land use and land cover transitions (Bewket and Sterk, 2005), and urbanization (AbouKorin, 2017; Enserink and Onencan, 2017). These dynamics and emergent relations within the Nile basin have raised a considerable concern relating to the future of water resources within the Nile basin. This is typical of the difficult choices that several countries and regions in the world are faced with particularly growing demand for fresh and clean water on one side and limited supplies on the other side (Simonoiv, 2002). Within Uganda, the River Nile plays an important role in the economy as well as ecosystems health and wealth of the people. The dependence on the Nile waters over the next coming years will be greater justifying an interest to examine the future water resource dynamics. Accordingly, this paper presents a projection of water resource dynamics in the River Nile with reference to the Upper Nile Water Management Zone (UNWMZ) of Uganda.

## **MATERIALS AND METHODS**

**Description of the Upper Nile Water Management Zone.** River Nile is a vital river system in Uganda and Africa at large. In order to facilitate ease of management and coordination, Uganda stratified the various catchments into water management zones. Accordingly, there are four water management zones; Kyoga Water Management Zone, Upper Nile Water Management Zone, Victoria Water Management Zone, and the Albert Water Management Zone. The Upper Nile Water Management Zone (Fig. 1) broadly covers the entire part of northern Uganda.

It has a spatial coverage of about 50,000 km<sup>2</sup> and comprises of the three major river catchments; the Albert Nile, Aswa and Kidepo and 20 sub-catchments (Fig. 2). The Albert Nile emerges from Lake Albert. Within the catchments, River Aswa, is one of the major river systems in northern Uganda whose extensions are wide spread including rivers such as Agago. The Kidepo River is a tributary of the Pibor River that flows in South Sudan along the border with Ethiopia. The UNWMZ straddles across areas with varied rainfall patterns and gradients. Rainfall in the catchment is variable with the northern eastern section of the catchment being generally drier owing to the semi-arid conditions (Egeru *et al.*, 2014). Meanwhile, rainfall is projected to decline by a range of -150 to -50 mm across the northern part of Uganda (Funk *et al.*, 2012). The water management zone ranges from 600m above sea level to 1200 m in the intermediate to over 3000m above sea level in the north eastern part of the country.

**Data and data analysis.** This study acquired research data through a secondary source from the Ministry of Water and Environment. Data were obtained from the comprehensive situation assessment and preparation of a Water Management Zone strategy and action plan for the Upper Nile Water Management Zone report. The water resources assessment considered the mean hydrological year that is associated with the current surface network and ground water system considering the pristine scenario situation. Further, a drought year and the impact of climate change in 2030 and 2040 period were evaluated against their influence on the hydrological dynamics of the UNWMZ. Water uses were applied to estimate the water demand from the different economic sectors and the projected demand. Accordingly, taking these conditions into hand, four scenarios for the water balance were examined; i) scenario 1: mean hydrological year and water use 2015; ii)

scenario 2: drought hydrological year and water use 2015; iii) scenario 3: mean hydrological year with climate change at 2030 and water use 2030; and iv) scenario 4: mean hydrological year with climate change at 2040 and water use 2040. These scenarios were run to produce mean and drought hydrological year and the effect of climate change on mean hydrological year in 2030 and 2040 (Ministry of Water and Environment, 2017).

## RESULTS

Results showed that the mean monthly flow of rivers in the Upper Nile Water Management Zone is varied. Results from the selected gauging stations along Albert Nile and its tributaries (Fig. 3) indicate that River Ora has the highest mean monthly flow. Additionally, all rivers experience high flow during the months of August, September, October and November (Fig. 3). On the other hand, mean monthly flow along the Aswa catchment is more pronounced in only two rivers; River Aswa and River Aswa and Nyimur taken together (Fig. 4). In these rivers, the flow intensity is nearly assuming a bell-shaped curve with the months of July, August, September and October having a higher discharge (Fig. 4).

There was observable difference between the drought hydrological year and the mean hydrological year discharge in 2015 in the Albert Nile and River Aswa. In the same period, gross water demand and net water demand in the three catchments constituting the Upper Nile Water Management zone were minimal (Fig. 5). A projection into 2030 for mean hydrological year revealed an overall computable decrease in discharge of about 12.6 percent. On the other hand, gross demand and net demand for water resources in the UNMZ revealed an increase. This increase will particularly be more pronounced in the Albert Nile and River Aswa catchments (Fig. 6).

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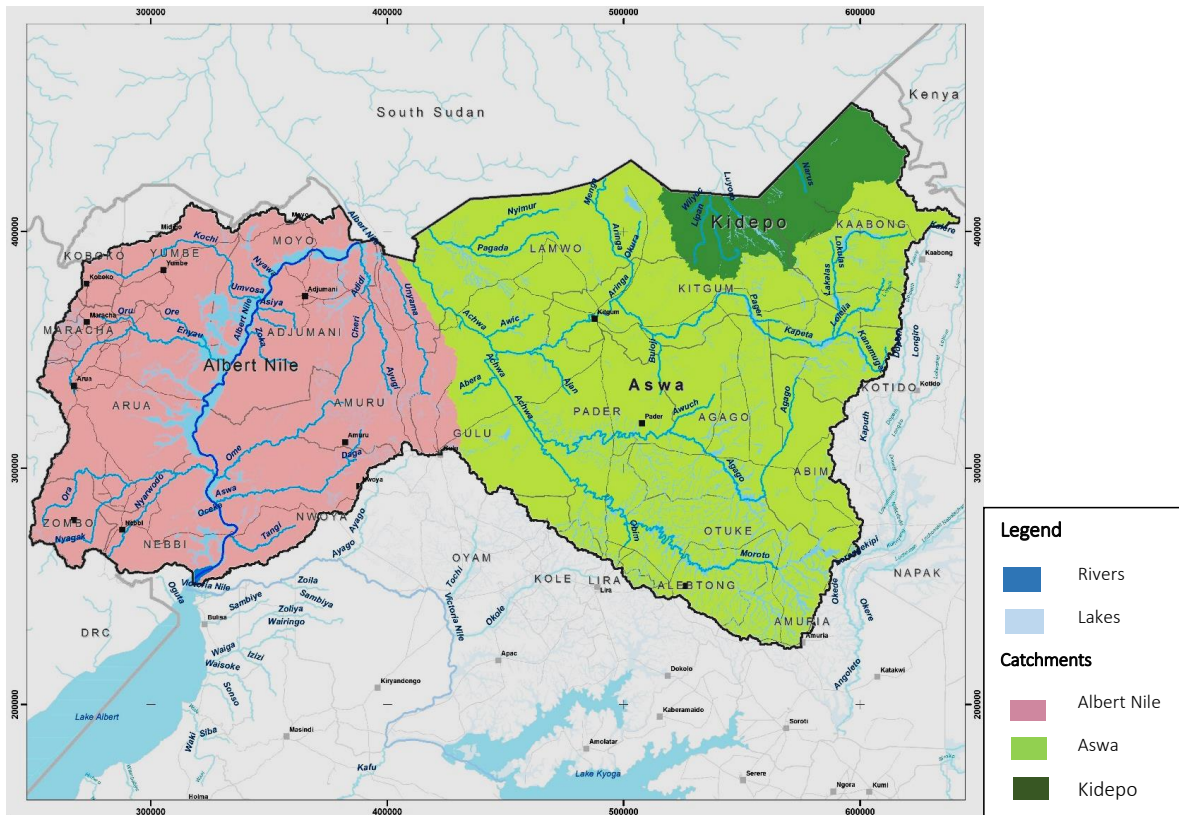


Figure 1. Upper Nile Water Management Zone and three catchments, Uganda (Source: Ministry of Water and Environment)

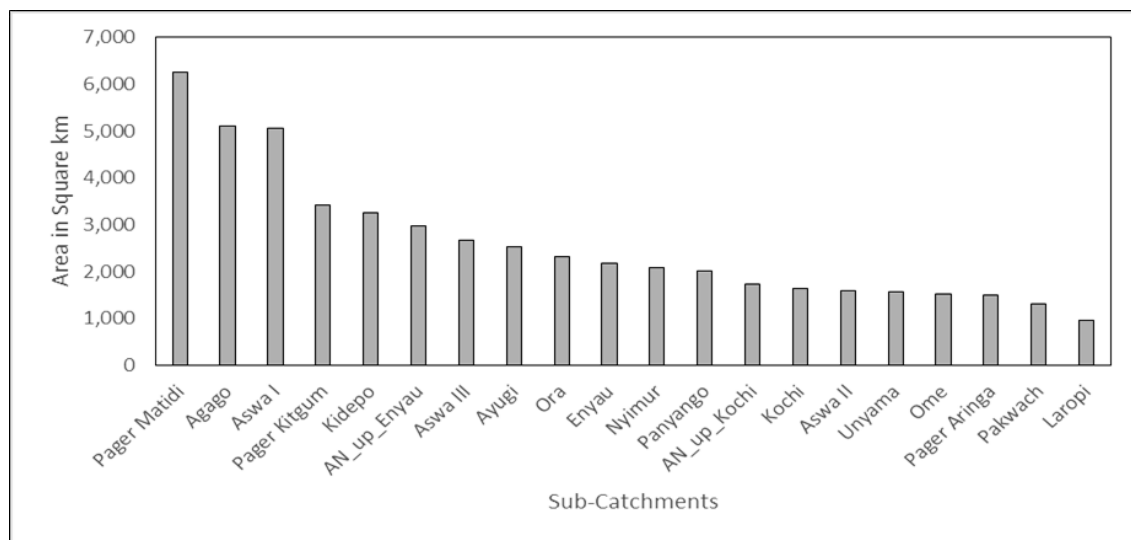


Figure 2. Sub-catchments in the Upper Nile Water Management Zone

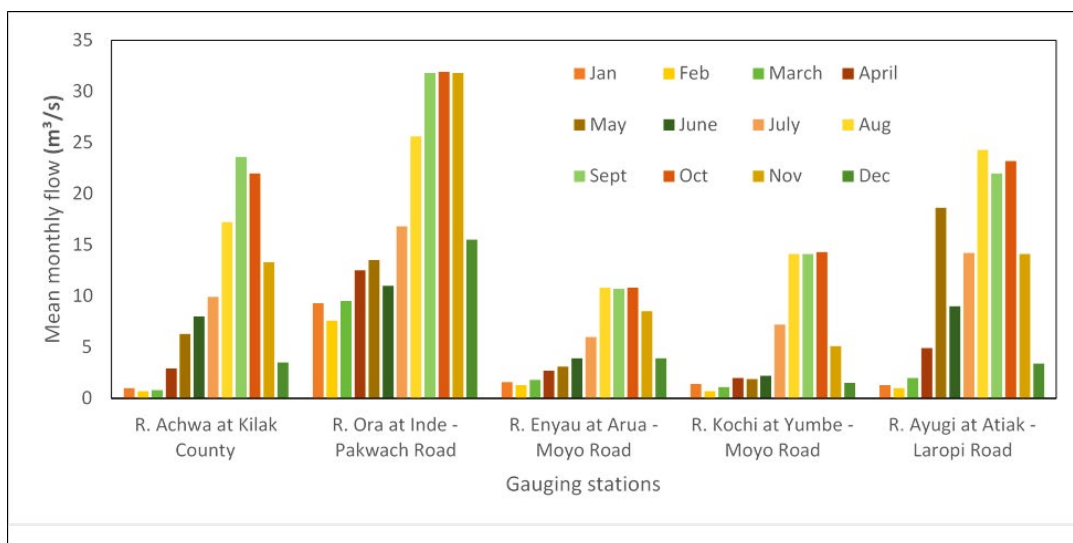


Figure 3. Mean monthly flow at selected gauging stations along Albert Nile and its tributaries

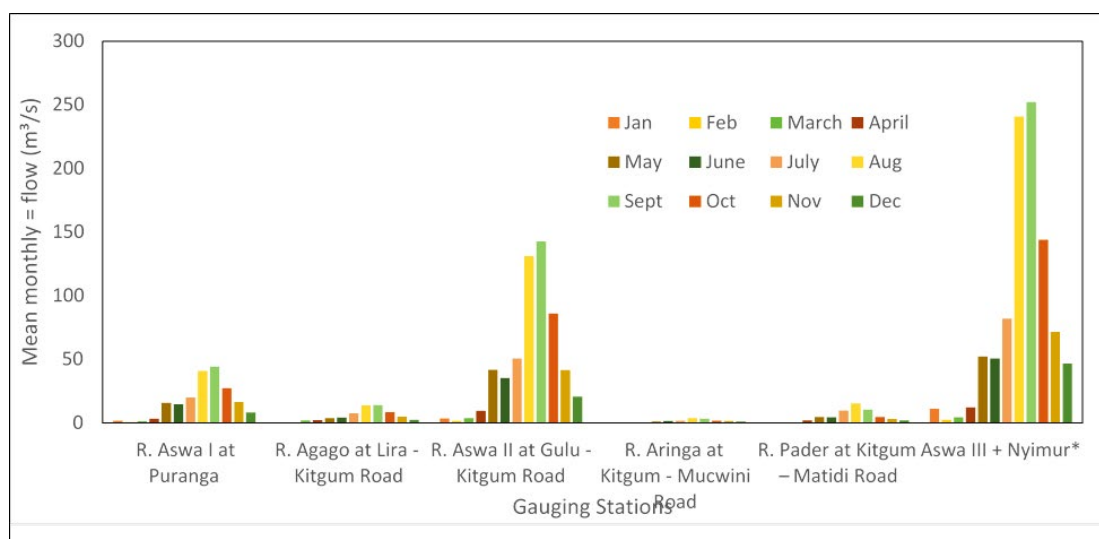


Figure 4. Mean monthly flow at selected gauging stations along the Aswa and its tributaries

**DISCUSSION**

The distinct variation between the three major catchments that constitute the Upper Nile Water Management Zone arises from the aggregative supply sources for the water into the catchment. The Kidepo valley has limited discharge and contribution because it emerges from the highland areas within the semi-arid region of Karamoja sub-region. The sub-region is

dominated by seasonal rivers with intermittent stream flow (Mugerwa *et al.*, 2014), a situation that from time to time is worsened by the intermittent drought episodes in the region (Akwango *et al.*, 2017). This study has also shown that both gross and net water demand in the Upper Nile Water Management Zone (UNWMZ) will increase yet at the same time the overall discharge in the catchment belt will

be decreasing. These trends could be attributed to projected climatic change in the sub-region that will lead to a decrease in rainfall total and an increase in temperatures with thereby the system becoming water limited rather than energy limited consequently reduce soil water availability for agricultural production in the catchment. Funk *et al.* (2012) in an early century projection (2010-2039) have indicated that rainfall over northern

Uganda will decrease from a range of -150 to -50 mm during this period. Such a decrease is sufficient to alter catchment hydrological balance. Further, projected population growth as well as changes in land use particularly with the intensification of agriculture and other farming practices will contribute to an increase in water demand in the catchment. With the projected increase in gross and net demand for the water

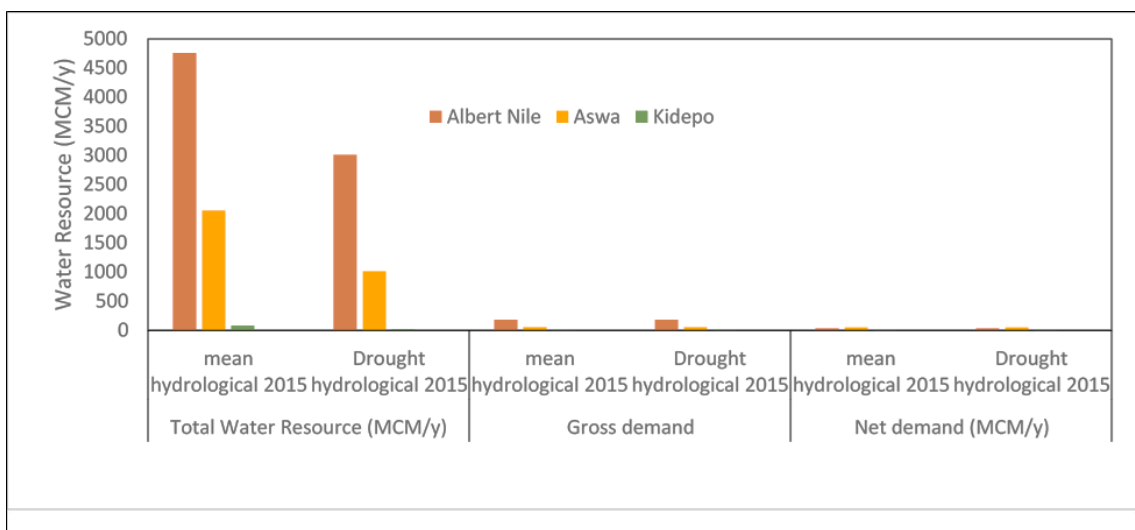


Figure 5. Mean and drought hydrological water resources and water demand in 2015

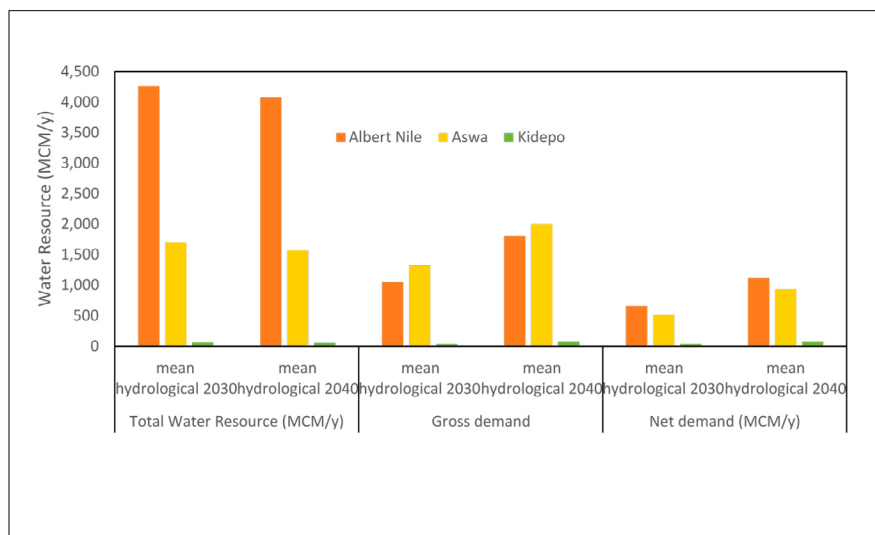


Figure 5. Mean and drought hydrological water resources and water demand in 2015

resources amidst constricting supply, a potential for conflict in the catchment may arise.

#### CONCLUSION AND RECOMMENDATION

Over the next 22 years, the Upper Nile Water Management Zone catchment will continue to experience variability in sub-catchment discharge. The catchment will also experience a decrease in water resources whilst experiencing an increased gross and net water demand. It is recommended that continuous monitoring of catchment discharge is intensified and an exploration into the technical and scientific mechanisms that will facilitate effective adaptation to increased water demand in the catchment be undertaken in response to the projected increase in gross and net water demand in the catchment.

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#### STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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