IMPACT OF HEADWATER HYDROLOGICAL DEFICIT ON THE DOWNSTREAM FLOOD-BASED FARMING SYSTEM IN NORTHERN ETHIOPIA†

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ABSTRACT

Flood-based farming is a means of improving crop production in rain-deficit lowlands. Such spate irrigation systems grow in importance; though effects of headwater hydrological deficit on downstream flood-farming are lacking evidence. This study investigates the impacts of headwater hydrological deficit on the extent of spate-irrigated agriculture in Guguf spate system. Length of canals and area of spate-irrigated agriculture to the right and left of Guguf River for 1980s and 2010s were tracked using Global Positioning System and mapped in a Geographic Information System interface; while climate data collected from National Meteorological Agency. Trends for selected hydroclimatic variables were analysed using linear regression and Pettitt-test. Flash-flood shrunk by $7.36 \times 10^6$ m$^3$; as a result of which length of canals and area of spate-based farms declined by 1.37 km and 1540 ha, i.e., 35 and 57.5%, respectively, only in three decades time. This corresponds to an average withdrawal of -44.0 ha

† Impact du déficit hydrologique en amont sur le système agricole inondable en aval dans le nord de l’Éthiopie
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per year. A single million cubic-meter decline in flash-flood caused a 366.4 ha decline in spate-based farms. Moreover, farm fields located next to the river course are less affected, as compared to farms on the tail of the scheme. If the current trend continues, there is likely high risk that the remaining farms currently receiving flood may be run out of spate-systems. Therefore, we suggest that flood management technologies are needed to optimize the efficiency of soil moisture in the spate system.

KEY WORDS: agriculture; flood farming; hydrological deficit; runoff response.

RÉSUMÉ

L’agriculture fondée sur les inondations est un moyen d’améliorer la production agricole dans les plaines à déficit pluviométrique. Ces systèmes d’irrigation à crues gagnent en importance; bien que les effets du déficit hydrologique en amont sur l’agriculture par inondation en aval soient peu étudiés. Cette étude examine les impacts du déficit hydrologique en amont sur l’étendue de l’agriculture irriguée par crue dans le système de crues de Guguf. Les longueurs de canaux et les zones d’agriculture irriguée par crue à droite et à gauche de la rivière Guguf pour les années 1980 et 2010 ont été suivis à l’aide du système de positionnement global et cartographiés dans une interface de système d’information géographique; tandis que les données climatiques ont été recueillies auprès de l’Agence météorologique nationale. Les tendances pour certaines variables hydroclimatiques ont été analysées par régression linéaire et test de Pettitt. Les crues éclair ont été réduites de 7,36 x 106 m³; en conséquence de quoi la longueur des canaux et la superficie des fermes à crue ont diminué de 1,37 km et 1540 ha, soit 35 et 57,5%, respectivement, seulement en trois décennies. Cela correspond à un retrait moyen de -44,0 ha par an. Une baisse d’un million de mètres cubes des crues subites a entraîné une baisse de 366,4 ha dans les exploitations gravitaires. De plus, les champs situés à proximité du cours de la rivière sont moins touchés que ceux plus éloignés. Si la tendance actuelle se maintient, il existe un risque élevé que les autres fermes recevant actuellement des inondations soient épuisées. Par conséquent, nous suggérons que des technologies de gestion des inondations soient mises en œuvre pour optimiser l’efficacité de l’humidité du sol dans le système de crues.

MOTS CLÉS: agriculture; agriculture par inondation; déficit hydrologique; réponse au ruissellement.
INTRODUCTION

Agriculture remains the dominant source of food production and the livelihood foundation of the majority of the rural poor in sub-Saharan Africa (Cooper et al., 2008). Particularly in Ethiopia, agriculture is the leading sector contributing to about 80% of employment (Erkossa et al., 2013). Access to agricultural-water is, however, a limitation hindering crop productivity and end food insecurity for the majority of agricultural societies in the drylands (Brown et al., 2017). High reliance on rainfed cultivation is among the significant challenges hindering poverty alleviation in Ethiopia (Haile and Merga, 2002). Besides, recurrent drought, unreliable and variable nature of rainfall are among the major challenges associated with rainfed cultivation (Viste et al., 2013).

Ethiopia comprises potential cultivation land estimates between 30 million to 70 million ha, out of which approximations show that only a small proportion, i.e., about 15 million ha are currently being ploughed (Erkossa et al., 2013). In the drylands of Ethiopia, particularly in Tigray, agricultural fields are mainly under rainfed cultivation systems which are highly vulnerable to interannual and short term variability in rainfall characteristics (Awulachew et al., 2010). Late onset, recurrent dry spells, and early secession during the rainy season are common phenomenon which leads to crop failure, chronic food-shortage, and poverty (Brown et al., 2017). Severity of the pressure increases with decreasing elevation, limiting crop production and productivity due to various factors including moisture stress (Erkossa et al., 2013).

Introduction of irrigation services, therefore, holds the substantial potential to improve crop production and reduce susceptibility to climate volatility and overcome the existing and potential pressures (Gebrehiwot et al., 2015; Erkossa et al., 2013; Libsekal et al., 2015). In mountain areas of the world, studies suggest that irrigation water availability helps boost farm production by increasing the capacity to produce sufficient food in moisture deficient drylands (Van Steenbergen et al., 2011, 2010a, 2010b). The initial investment cost required for development of conventional irrigation schemes is however not feasible considering farmers capacity, and lacks lasting water sources in some areas (Ghahari et al., 2014). As way out, flood-based farming such as spate irrigation is thus considered across vast lowland areas of the drylands as a complement to rainfed agriculture (Van Steenbergen et al., 2011, 2010a, 2010b; Libsekal et al., 2015). Part of this, spate irrigation has been important strategy to improve soil moisture in the Rift graben (e.g., Castelli and Bresci, 2017; Meaza et al., 2017).

Spate irrigation is form of water resource management often uses unpredictable and occasional destructive flood water from short-lived streams (Van Steenbergen et al., 2010a).
According to Van Steenbergen et al. (2011, 2010a, 2010b) and Eyasu et al. (2015), the system has a great potential in contributing to poverty reduction, adaptation to climate volatility and ensuring food security in drought prone semiarid areas. Besides, it has been estimated that flood-based farming in the Raya graben, has the potential to cover irrigable land of about 80,000 ha, using the total runoff potential of about 170x10^6 m^3 year^{-1} coming from the surrounding highland escarpments (Haile et al., 2013). In line to this, some studies reported that the Raya escarpment contributes huge flash floods to the grabens (e.g., Asfaha, 2015; Demissie et al., 2015; Meaza et al., 2018; Meaza et al., 2019a). Although spate irrigation contributes an essential role in the region’s economy and ensuring food security (Kowsar, 2011), crop-production and productivity declined mainly due to moisture stress that has led to recurrent droughts in the region. Unpredictable rainfall pattern and its spatial and temporal variability together with increasing evapotranspiration threatened the availability of moisture for crop production, and surplus water to generate runoff (Alemayehu, 2013; Gebrehiwot et al., 2015; Van Steenbergen et al., 2010b). On the top of this, several studies in the country in general and Tigray in particular (e.g. Bewket and Sterk, 2005; Descheemaeker et al., 2008, 2006; Nyssen et al., 2010; and Negash et al., 2019; Gebremeskel et al., 2019) proved that land restoration efforts determines hydrological response, revealing an inverse relationship with runoff.

Although, flood-based farming has high relevance to the drought prone farming community in the semiarid lowlands (Mehari et al., 2011), sustainability of the system is being threatened by hydrological deficit. The system is vulnerable mainly due to the entire reliance on flash-flood generated from rainfall in the highland, which is variable in amount, distribution and pattern (Van Steenbergen et al. 2010a). Recently, an empirical study by Negash et al. (2019) in Guguf River Basin showed that the amount of flood has decreased by 0.23x10^6 m^3 year^{-1} over the last three decades. This was mainly due to changing climate and an increasing soil water retention capacity in the escarpment. This will inevitably affect mainly availability of flash-flood, which literally determine agricultural lands receiving supplementary irrigation water. However, the magnitude of the effects on the size of spate-based agriculture is not known, for which this study was initiated. To the researcher’s knowledge, studies investigating on dynamics in flood-based agriculture in response to hydrological processes are not available. Therefore, the specific objectives of the study are: i) to quantify the impact of hydrological deficit on area of flood-based farms; ii) to construct the linkage between flash-flood and flood-based agriculture. The findings of this study will contribute to the sustainable development of spate irrigation in the northern Ethiopia, and elsewhere with similar geographical setting.

MATERIAL AND METHODS
Description of the study area

The Guguf spate systems are situated between 12° 44’ 15” - 12° 46’ 14” N latitude and 39° 30’ 30” - 39° 40’ 48” E longitude. Guguf River Basin is about 600 km north of national capital Addis-Ababa, and 180 km south of the regional capital Mekelle. The study area (Figure 1) is found at the edge between the escarpment and the graben bottom that receives flood from the highland areas. Figure 1 below shows the geographical location of the flood-based farms.

![Geographical location map of the study site](image)

Figure 1. Geographical location map of the study site

The main rainy (wet) season (kiremt season) usually occurs from July to September, a small rainy season (belg) occurs mainly from March to May, and the remaining months are dry. The average rainfall at the western escarpment is 981.9 ± 238 mm, whereas it is 626 ± 199 mm at graben bottom (Meaza et al., 2019a). Similarly, the escarpment has a lower average annual temperature (16 °C) than the graben bottom (23 °C).

According to Meaza et al. (2019b), the escarpments consist of volcanic rocks with Alage and Ashangi basalt formations. The graben bottoms of all the basins consist of alluvial sediments. Leptosols dominate the Raya graben escarpment, whereas Vertisols govern the graben bottom. Furthermore, the major drainage system consists of rivers originating in the western mountains and flowing to the graben bottoms (Meaza, 2018).

Shrubland and cropland are the main land covers of the Raya (Mehoni-Alamata and Kobo...
basins) escarpment and its graben bottom, respectively (Demissie et al., 2015; Meaza et al., 2019a). The crops growing in the Raya plains are annual crops dominated by cereals. The major crops are sorghum and teff in order of land coverage. According to the information from the development agent of the village, sorghum covers nearly 75% of the total cultivated land in the area. The farmers grow these crops only during the main rainy season supplemented with spate irrigation by traditionally diverting the flood that comes from the escarpment surrounding the command area.

Data collection and analysis methods

Climate and flash-flood characterization

Historical meteorological data at daily basis, mainly temperature and rainfall for Maichew station for the period 1980 – 2015 from National Meteorological Agency (NMA) were considered after data gaps were filled using an average deviation from AgMERRA satellite observation data (Rosenzweig et al., 2013; Negash et al., 2019). Due to limited or no availability of observed evapotranspiration data, it was derived using Hargreaves-method (Allen et al., 1998; Droogers and Allen, 2002).

On the other hand, since sufficient hydrometeorological data are often lucking in the Sub Saharan Africa including in the Raya graben, a previous study by Negash et al. (2019) modelled flash-flood volume of the same river basin for the period between 1984 – 2015. The study used an event-based empirical model SCS-CN (United States Department of Agriculture (USDA), 2004a, b) as a substitute (Gebresamuel et al., 2010). An optimum initial abstraction ratio of 0.05 is considered based on least squares fitting for most experimental plots in the highlands of northern Ethiopia (Descheemaeker et al., 2008; and Teka et al., 2014). The model’s statistical algorithms are given as follows:

\[ Q_d = \frac{(P - I_a S)^2}{(P + (1 - I_a)S)} \quad \text{when } P > I_a S \quad (1) \]

\[ Q_d = 0 \quad \text{when } P < I_a S \quad (2) \]

\[ I_a = \lambda S \]

\[ S = \frac{25400}{CN} - 254 \quad (3) \]

Where \( Q_d \) is estimated discharge (mm), \( P \) is the measured daily rainfall (mm), \( I_a \) is the initial
abstraction (mm), \( \lambda \) initial abstraction ratio and \( S \) is the maximum water retention parameter (mm) determined from weighted CN value. \( S \) is related to the dimensionless runoff curve number (CN), and CN is weighted curve number calculated based on the storm-event method (Schneider and McCuen, 2005), which is a data-derived value that varies according to the rainfall (Hawkins, 1993). See equation below.

\[
CN = \frac{A_1CN_1 + A_2CN_2 + A_3CN_3 + \ldots + A_nCN_n}{A_1 + A_2 + A_3 + \ldots + A_n}
\]  \hspace{1cm} (4)

Where \( A_1, A_2, A_3 \ldots A_n \) are areas of hydrological groups that a given land cover fails into, and \( CN_1, CN_2, CN_3 \ldots CN_n \) are the corresponding curve numbers.

The estimated hydrological response at the river basin outlet literally is the amount of flood-water readily available for spate irrigation in the graben considered in this study. Thus, modelled flash-flood volume from that same study (Negash et al., 2019), was adopted for this study.

Moreover, temporal anomalies in rainfall and runoff during the last three decades were analysed using linear regression (Jaiswal et al., 2015) and Pettitt test (Pettitt, 1979) methods, and rainfall and runoff hydrographs generated. The linear regression test is used to show the long-term increment or decrement magnitude including coefficient of variability, and Pettitt’s test applied to detect change point over the dataset. Rainfall runoff relationships and their association with flood-based agriculture are further investigated as indicated in the section below.

Dynamics in spate canals and spate irrigated agriculture

Spate-based agriculture in the Raya graben, including significant parts of Raya Azebo and Raya Alamata districts rely on flash-flood coming from the highland escarpments. Spate-based agriculture in Guguf spate systems were quantified by measuring length of spate canals and area of spate-based agriculture from the field. In this study, all of the 11 primary flood diversion structures found to the right (4) and left (7) of the main river in Guguf spate-systems, whose length of canal and irrigated area measured were considered. Accordingly, length of spate canals (locally called ma’egel) and area of flood-based agriculture during the period between 1980 – 1990 (hereafter called 1980s) and during the period between 2010 – 2015 (hereafter called 2010s) were tracked using Global Positioning System (GPS) starting at the outlet of Guguf River Basin. When tracking length of canals and area of spate irrigated agriculture, key informants and local elders were involved to supplement on-ground indicators, especially for the period of 1980s. Ground tracks were further overlaid on Google Earth images to further
RESULTS AND DISCUSSION

Climate and flash-flood characteristics

Temperature, rainfall and evapotranspiration in the study area showed change and variability over the study period. In this context, there has been a significant increase in temperature and evapotranspiration at a rate of 0.11 °C, and 16.4 mm year\(^{-1}\), respectively; while rainfall during the last three decades has declined in amount at a rate of 5.1 mm year\(^{-1}\) (Figure 2). In other words, annual rainfall received in 2015 was 184 mm less than the rainfall amount received in 1980. This would directly limit available moisture for crop production and river flow draining to reach Guguf spate systems as well. In addition to declining rainfall, the amount of moisture lost in the form of evapotranspiration by 2015 also showed an increase by 591.5 mm from the amount evapotranspired in 1984, sucking up much of the limited moisture. According to Gebrehiwot et al. (2015) and Tilahun (2006), declining rainfall coupled with high evapotranspiration rate aggravates moisture stress. This in turn makes the available moisture insufficient for crop-production. Very recently, Negash et al. (2019) demonstrated that the rainfall runoff, evapotranspiration runoff and landcover runoff have strong relationships in the study area.

![Co-efficient of variability for selected climate variables, i.e., T (°C), Rf (mm) and ET (mm)](image)

Where T is average temperature in degree Celsius, Rf is rainfall in mm year\(^{-1}\) and ET is potential evapotranspiration in mm year\(^{-1}\).

As a result, spate volume reaching the spate systems has shrunk at a coefficient of
0.23x10^6 m^3 year^{-1}, i.e. totalling to 7.36 x 10^6 m^3 in 32 years’ time, with a change point detected in 2001 (Figure 3). Change point for rainfall hydrograph was also detected during the same year 2001, strengthening the direct rainfall runoff relationship. In areas where the livelihood of the farming community is reliant on flash-flood to supplement the limited rainfall, these changes would further intensify hydrological deficit from bad to worse. As also proved by Descheemaeker et al., (2006), Nyssen et al. (2010), Gebresamuel et al. (2010), Negash et al. (2019), and Gebru et al. (2019)), dynamics in climate and land-cover determines hydrological response of any given river basin, where such effect is further exaggerated in arid and semiarid lands such as in the Raya graben. Besides, a study by Negash et al. (2019) in Guguf River Basin revealed that number of rainfall events and rainfall events capable generating river flow have been declining; referring beyond average value for the period before 2000 while all year after 2001 remained below average.

Figure 3. Rainfall (mm) and direct-runoff (1 x 10^6 m^3) hydrograph

**Impacts of hydrological deficit on area of flood-based farms**

Spate-based agriculture along 9 of the 11 spate systems in Tsige’a and Genete plains received significantly lesser volume of flash-flood in 2010 – 2015 as compared to 1980 – 1990 (Figure 3). As a result, average length of functional spate canals was shortened from about 3.92 km to 2.55 km during the period between 1980 – 1990 and 2010 – 2015, respectively, and total area of spate-irrigated agriculture diminished from about 2,675 ha to 1,137 ha (Figures 4 and 5). In other words, length of spate canals declined by 1.37 km (35%) in average, with the highest retreat of about 3.2 km occurring in Kusra spate canal, while there was no reduction over Kombolicha and Gashi’a spate canals. As length of spate-carrying canal shortened, the average area of spate-irrigated agriculture per spate-structure was also reduced by about 140 ha (57.5%). The highest observed areal reduction was about 399 ha in Kusra spate, followed by 368 ha in Keshot, and no areal reduction over Kombolicha and Gashi’a spates. Length of canal and area of spate-irrigated agriculture along Komolicha and Gashi’a spate-systems remained unchanged mainly as a result of supplementary base flow in Kombolicha, and farms bordered by Mekoni.
town at 1.9 km distance from the source in Gashi’a spate system. Moreover, it is also noted that farm fields located next to the river course are less affected by declining flash-flood, while farms located towards the tail part of the spate canal are the victims of declining flash-flood.

According to Van Steenbergen et al. (2010a), flood-based farming is characterized by
high variability in size and frequency of floods which directly determines availability of supplementary irrigation water mainly for crop production. In line with this study, Haile et al. (2013) also revealed that, the average annual rainfall in the highlands of the Raya valley is around 800 mm, while the lowlands receive less than 350 mm. As the rainfall is also erratic both in time and spatial distribution, it is difficult to get a good harvest of crops growing in the area using rainfed agriculture in the lowlands. As a response, the lowlanders need to supplement their fields with floods, i.e. spate-irrigation. Otherwise, without which crop production and productivity are susceptible to drought (Castelli et al., 2018). Flood water reaching Guguf spate-systems is however limiting over time (Negash et al., 2019). Consequently, it threatens the flood-based agriculture in the plains.

Despite the fact the risks of crop failure are quite high in flood-based farms (Van Steenbergen et al., 2010a), the likelihood of receiving flood is not fairly distributed throughout the spate-based farm lands in the study area. Regarding this, a study by Van Steenbergen et al. (2010a) also proved that, the implications of variability in flood are more pronounced on farm fields located on tail parts and lesser impact as you go closer to the diversion source. There is a widely varying chance of farm lands receiving flood water in a given spate-based command or in an area supplied from the same offtake. Probabilities of receiving flood water primarily vary from very high for farms nearby the spate source, to very low for these farm fields located on tail part of the canal and at the downstream end of the schemes. Since crop production and productivity in most drylands are highly variable with moisture availability (Van Steenbergen et al., 2010a; Hagos et al., 2014; Erkossa et al., 2013; Gebrehiwot et al., 2015), implications are worse to the level that, in some occasions the land may run out of production while in other areas may only grow some animal fodder. Yield variation on spate-based fields are also basically associated with the erratic nature of flood water supply and the level of control the lowlanders can practice over the flood (Van Steenbergen et al., 2010a).

**Linkage between flash-flood and flood-based agriculture**

It is clear that runoff volume of $10.4 \times 10^6$ m$^3$ received between 1980 – 1990 was sufficient to irrigate 2,680 ha, while in 2010 – 2015 about $6.2 \times 10^6$ m$^3$ runoff volume could only support 1,140 ha (Table I). This indicates that, a $1 \times 10^6$ m$^3$ decline in flood caused spate-based agriculture to reduce by 366 ha. Thus, years with a higher runoff response are expected to have a relatively more extensive area of spate-based agriculture and vice versa. Availability and quantity of floodwater that reaches farm lands in the lowland depends on the amount, distribution and intensity of rainfall received and the land-cover conditions in the highlands (Van Steenbergen et al., 2010a; Alemayehu, 2013; Erkossa et al., 2013; Gebrehiwot et al., 2015).
Table I. Changes in direct runoff volume (average) and area of flood-based farms

<table>
<thead>
<tr>
<th>Variables</th>
<th>1980 - 1990</th>
<th>2010 - 2015</th>
<th>Change (ha)</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct runoff (1x10^6 m^3)</td>
<td>10.4</td>
<td>6.2</td>
<td>-4.2</td>
<td>-40.4</td>
</tr>
<tr>
<td>Spate-based agriculture (ha)</td>
<td>2680</td>
<td>1140</td>
<td>-1540</td>
<td>-57.5</td>
</tr>
</tbody>
</table>

On the top of the everchanging climate, improvements in water abstraction capacity of the soil in the highland mainly as a result of improved land-cover and soil and water conservation interventions also stand among the determinants of water abstraction capacity of the soil. These measures are nowadays the most prevalent means of land restoration and agricultural escalation in most highland escarpments (Berhanu et al., 2002; Nyssen et al., 2010), including in the study area. Land restoration does not only imply increased vegetation cover, rather it also promotes soil health and thus contributing to higher infiltration rates and lesser runoff return (Descheemaeker et al., 2006, 2008). As any amount of rainfall below abstraction potential of these structures will not leave the fields, soil and water conservation measures also limit hydrological response of a river basin (Berhanu et al., 2002; Descheemaeker et al., 2006; Girmay et al., 2009; Nyssen et al., 2010). Flood-based farming in the lowlands is thus being threatened with changes in climate and increased water abstraction upstream.

Implications of hydrological deficit on sustainability

In many drought prone semiarid lands, like in the study area where rainfall is the limiting resource, flood-based farming contributes to food security and is a potential climate change adaptation measure too (Van Steenbergen et al., 2010a). However, only during the study period, the size of spate-based agriculture in the study area has shrunk by the size of 1540 ha between 1980 and 2015. This is equivalent to 57.5% of the total area supplied with spate in 1980 – 1990. This is primarily because of the effect of changing climate and water abstraction capacity of the soil in the highlands, further reducing irrigation water availability in the lowlands. In addition, a certain level of competition is observed for water among the highland and lowland users. The field observation indicates that, new irrigation schemes are constructed in the highlands which abstracts a significant amount of water. Similarly, various moisture harvesting structures are built in many parts of the upstream areas. These, in turn, reduced the amount of flood water reaching downstream areas, subsequently threatening flood water, i.e., supplementary irrigation on which spate-based agriculture users in the lowlands rely.

As land-cover in the highland keeps changing due to conservation measures coupled with the changing climate, leading to reduced spate (Negash et al., 2019); the probability is high that the remaining spate irrigated fields in the study area could be abandoned. On the other hand, climate change does not only remain in the downstream, but it also has a similar effect in the
upstream part as well. As the result of this what so ever rain is available, the highland farming community would also want to retain much of this rain to fulfil their needs. This substantially reduces the amount of flood water reaching the spate-systems and subsequently diminishes the size of spate-irrigated fields downstream. In the absence of supplementary flood water, the rainfall amount received in the lowlands is not sufficient for crops to grow as the same rate as in the past. As a result, food security is threatening. Apart from that, competition for water may also arise conflict between the upstream and downstream users in the study area. However, there are no any legally binding policies and strategies to mediate such contesting interests apart from the traditional bylaws. In agreement with Mehari et al. (2011), modernization of spate irrigated agriculture could sustain the spate irrigation in the study area.

CONCLUSION

In this study, the subsequent implications hydrological deficit on spate-irrigated agriculture was analysed for the period between 1980 and 2015. The study has established that the hydroclimatic variables of temperature and evapotranspiration increased while rainfall diminished. Besides, the volume of flash-flood reaching Guguf spate systems diminished over time. Moreover, decline in spate volume exerted significant effect on the area of spate-irrigated agriculture. These implications are more pronounced on farm fields located on tail parts of spate canals, and a lesser impact as you go close to the spate diversion source. Furthermore, the study highlights that competition on scarce water resources exist in the study area. This study further emphasized that the spate irrigated agriculture has declined during the study period. In general, headwater hydrological deficit has affected the flood-based farming in northern Ethiopia. However, further study may be required to understand the impacts at a better spatial and temporal scales to fully support the system in the region and other areas with similar setup.

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