FEED THE FUTURE INNOVATION LAB FOR LIVESTOCK SYSTEMS
in collaboration with the
FEED THE FUTURE INNOVATION LAB FOR SMALL SCALE IRRIGATION

ESTIMATING WATER RESOURCE AVAILABILITY TO PRODUCE LIVESTOCK FODDER IN THE RAINFED AGRICULTURAL LAND IN ETHIOPIA USING SMALL SCALE IRRIGATION

Background

Livestock is an integral part of the agricultural system in Ethiopia, accounting for nearly 40% of the agricultural gross domestic product (Amsalu and Addisu, 2014; Stapleton, 2016), and it provides employment to over 30% of the agricultural labor force (Asresie and Zemedu 2015). The livestock sector in Ethiopia serves as a source of food, power for farming, and transportation. The majority of the poor in Ethiopia depend on livestock for their livelihoods. The country has the largest livestock population in Africa; however, a shortage of feed, seasonality, feed quality and quantity, and lack of access to basic veterinary services are major constraints to a productive livestock system (Ahmed et al. 2016, Tonamo 2016).

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To stimulate the economic development of the country, the Ethiopian government has been prioritizing the agriculture sector through its Growth and Transformation Plans I and II (GTP-I, 2010; GTP-II, 2016). Along with these policies, the livestock sector is seen as having a critical role to reduce poverty; improve food security; grow national income, exports, and foreign exchange earnings; and increase climate mitigation and adaptation. In support of these objectives, a comprehensive livestock masterplan was developed (Shapiro et al. 2015), which lays out interventions to improve productivity and total production in the key livestock value chains for poultry, red meat, milk, and crossbred dairy cows that help meet the development agenda of GTP-II (GTP-II, 2016). Mayberry et al. (2017) showed that livestock productivity could be improved by developing feed production technologies that enhance feed quantity and quality.

Project

This research was conducted as part of a project that focused on analyzing the integrated impacts of livestock systems in terms of agricultural productivity, environmental sustainability, household income, and nutrition from field to national scale in Ethiopia. It is as a collaborative effort between the Feed the Future Innovation Lab for Small Scale Irrigation at Texas A&M University and the Feed the Future Innovation Lab for Livestock Systems at the University of Florida.

This brief presents the potentially available water resources to produce fodder in rainfed agricultural lands in Ethiopia. It centers on rainfed agricultural lands, since the aim was to estimate available water resources that could be used to produce fodder using small scale irrigation during the dry season. Grasslands are communal lands in Ethiopia and irrigation could not be practiced on such land use types. Hence, there was no need to present the potentially available water resources that could be used for irrigation in those land use types. However, the tool developed for this study estimates available water resources in all the landscapes in the study area.

Approach

The study applied the Soil and Water Assessment Tool (SWAT), which is part of the Integrated Decision Support System (IDSS, Clarke et al. 2017), to estimate the available water resources across Ethiopia. SWAT is a physically based model that was developed to predict impacts of management and climate on water, sediment, and agricultural chemical yields in watersheds due to changes in land use, land management, and climate (Arnold et al., 2012). The other components of the IDSS are the Agricultural Policy Environmental eXtender (APEX, Wang et al. 2007) and Farm Income Simulator (FARMSIM, Bizimana & Richardson, 2019). The APEX model was used to parameterize crop parameters for the major rainfed crops in Ethiopia, while the land management information was obtained from household surveys, which are key inputs to the FARMSIM model. The study also leveraged crop management data from ILSSI ex-ante and ex-post analysis.

The SWAT model uses spatial (e.g., land use and soil) and temporal data to set up, calibrate and validate the different biophysical processes. The study used 30-m resolution land use data, which was obtained from China's Global Land Cover Mapping (Chen et al. 2015). The soil data was obtained from the Africa Soil Information System (AFSIS) and has a spatial resolution of 250 m. The AFSIS data includes grids of soil properties such as sand, silt and clay fractions, coarse fragments, and organic carbon, for a depth of up to six soil layers (Vågen et al. 2010). Climate data was obtained from the Ethiopian National Meteorological Services Agency (ENMSA 2016). Observed climate data included rainfall and maximum/minimum temperatures for 246 meteorological stations located across Ethiopia. Climate data from the synoptic meteorological stations, including rainfall, maximum/minimum temperature, relative humidity, wind speed, and solar radiation was used to prepare a weather generator. The weather generator was used to complete missing data. The model was calibrated and validated using observed streamflow in 10 meso-scale watersheds, where there is a better quality observed streamflow data.

The calibrated and validated SWAT model was used to estimate the available blue and green water resources at a 10 km grid. Refer to Box 1 for the definition of blue and green water resources. Estimating the blue and green water resources is vital to know the amount of water available to produce a fodder crop. The study also assessed whether the available blue and green water storage were sufficient to meet water requirements to produce livestock feed during the dry season using small scale irrigation. Blue water and green water storage are the potentially available water resources that could be tapped using small scale irrigation technologies. Green water flow is the consumptive water, which often evaporates, mainly during the rainy season.

Available blue and green water resources in rainfed agricultural land for small scale irrigation

The available blue and green water resources were estimated in the rainfed agricultural land since small scale irrigation systems are intended to improve the productivity of existing agricultural lands. The blue water generated in the rainfed agricultural lands ranges between ~3 mm and 1525 mm (Figure 1a). Accounting the green water storage into the water resources for small scale irrigation increased the available blue and green water storage in the rainfed agricultural lands between ~3 mm to ~1720 mm (Figure 1a). A blue water focus estimate indicated that in about 40% of the rainfed agricultural

Blue water is the liquid water in rivers and aquifers while the **green water** is naturally infiltrated rain which is attached to the soil particles and accessible to roots (Falkenmark and Rockstrom, 2004; Rockstrom et al., 2010). There are two forms of green water: green water flow and green water storage. The green water flow is the invisible water that evaporates from the soil and plant canopy, and that transpires through plants stomata (Rockstrom and Falkenmark, 2004). Green water storage is the amount of water that is stored in the soil moisture. In terms of SWAT estimates, blue water is the sum of the water yield and deep groundwater recharge (cf. J Schuol et al., 2008). Water yield is the total amount of water leaving the area and entering the main channels, while deep groundwater recharge is the amount of water from the root zone that recharges the deep aquifer. The green water flow and green water storage are similar to actual evapotranspiration and soil moisture in the SWAT model conceptualization, respectively (Schuol et al., 2008).

land, the blue water resource amount was more than 500 mm. However, when the green water storage was added in the blue water, about 51% of the agricultural land has a blue water and green water storage amount of more than 500 mm (Figure 1b). More than 30% of the rainfed agricultural land has a blue and green water storage of more than 750 mm. This shows that there is a substantial amount of agricultural land and water resources to cultivate biomass feed for livestock in Ethiopia using small scale irrigation during the dry season.

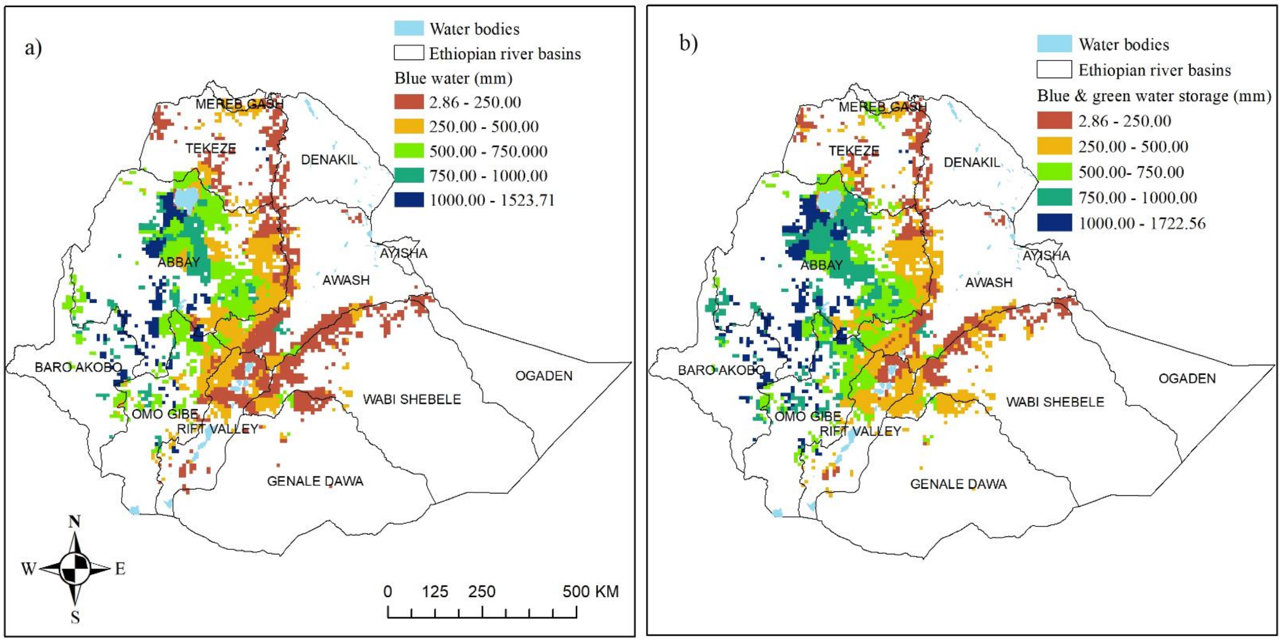

Figure 1. Potentially available water resources for small scale irrigation over agricultural fields in Ethiopia; a) blue water, and b) blue water plus green water storage. The white areas represent other none rainfed land use types such as grassland, bushland, forest, urban, etc. These areas are not considered for irrigated agriculture since they are already providing other ecosystem services.

Recommendations

This study centered on the rainfed agricultural land to upgrade its productivity using small scale irrigation. While conventional studies focus on estimating only blue water resources, this study estimated potentially available blue and green water storage across Ethiopia to produce fodder crop using irrigation during the dry season. Integrated blue and green water management has been considered critical to address the issue of water shortage and build water resilience for sustainable development and poverty reduction in rainfed agricultural systems (Rockstrom et al., 2009). Blue water management is helpful to plan irrigated agriculture systems for food and feed production; on the other hand, consumptive use of water in the rainfed agriculture is largely green water (Falkenmark and Rockstrom, 2004). Green water management is helpful to bridge rainfall variability and thereby build water resilience in Ethiopia (Rockstrom et al., 2009). Green water management includes soil, crop, and water management strategies, which enhances soil water availability, and maximizes plant water uptake capacity (Rockstrom et al., 2009). Unlike investments in blue water management which require storage infrastructure, green water management is relatively cheap to implement. This made the green water management attractive to upgrade rainfed agriculture in sub-Saharan Africa (Rockstrom et al., 2010). Moreover, since the rainfed agriculture in the sub-Sharan Africa is characterized by fragmented land tenure, accounting green water in water resources management may yield a higher dividend. Therefore, the use of small scale irrigation that integrates both blue water and green water can better enhance livestock productivity in Ethiopia without significantly compromising either of the water resources.

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