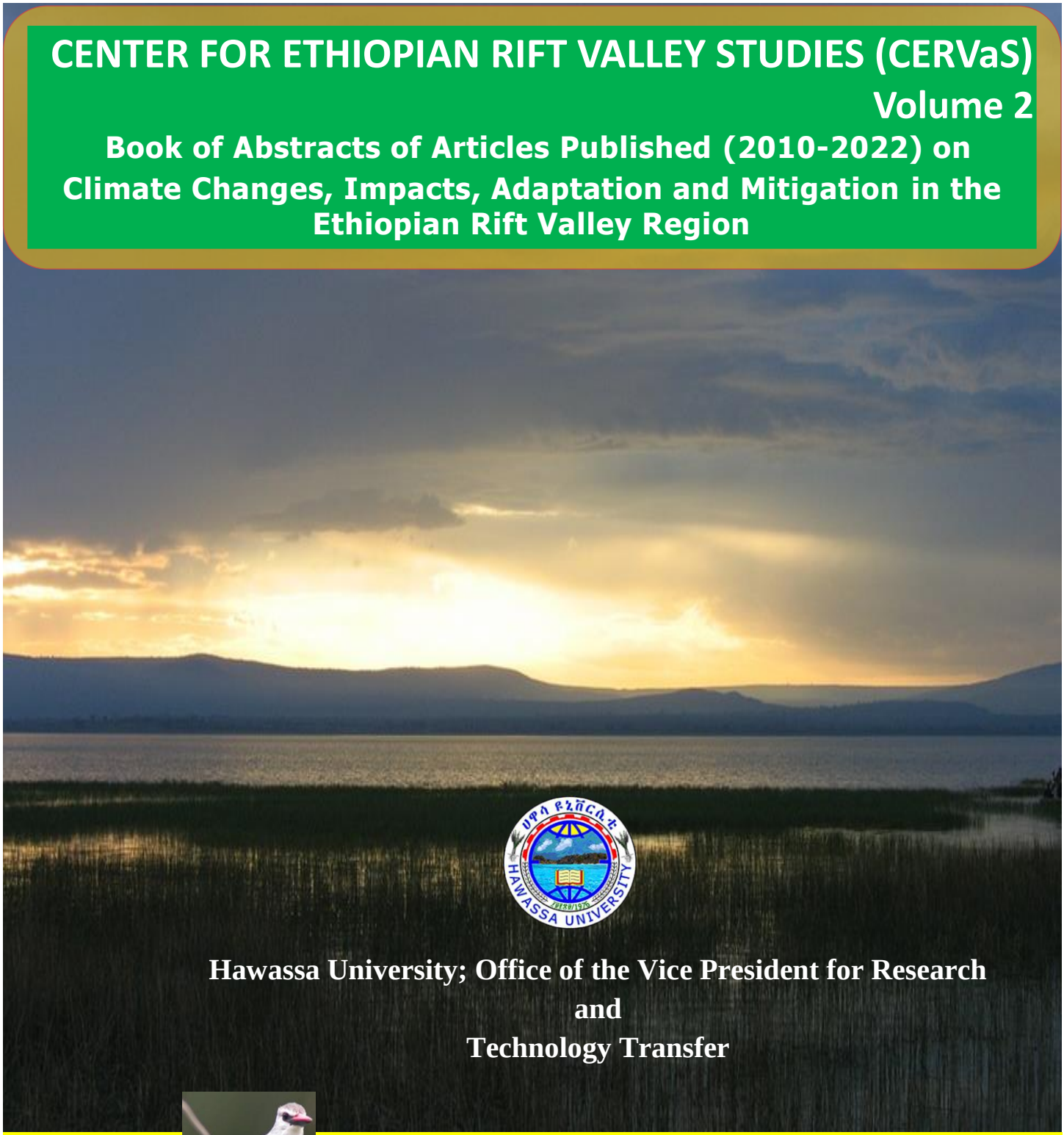
CENTER FOR ETHIOPIAN RIFT VALLEY STUDIES (CERVaS)

Volume 2

Book of Abstracts of Articles Published (2010-2022) on Climate Changes, Impacts, Adaptation and Mitigation in the Ethiopian Rift Valley Region



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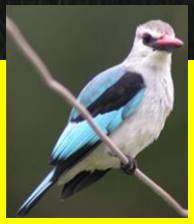

"Joining Hands to Reverse the Alarming Situations"

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Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia

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Abstract

Background: The agricultural sector remains the main source of livelihoods for rural communities in Ethiopia, but faces the challenge of changing climate. This study investigated how smallholder farmers perceive climate change, what adaptation strategies they practice, and factors that influence their adaptation decisions. Both primary and secondary data were used for the study, and a multinomial logit model was employed to identify the factors that shape smallholder farmers' adaptation strategies. Results: The results show that 90% of farmers have already perceived climate variability, and 85% made attempts to adapt using practices like crop diversification, planting date adjustment, soil and water conservation and management, increasing the intensity of input use, integrating crop with livestock, and tree planting. The econometric model indicated that education, family size, gender, age, livestock ownership, farming experience, frequency of contact with extension agents, farm size, access to market, access to climate information and income were the key factors determining farmers' choice of adaptation practice. Conclusion: In the Central Rift Valley of Ethiopia, climate change is a pressing problem, which is beyond the capacity of smallholders to respond to autonomously. Farmers' capacity to choose effective adaptation options is influenced by household demography, as well as positively by farm size, income, access to markets, access to climate information and extension, and livestock production. This implies the need to support the indigenous adaptation strategies of the smallholder farmers with a wide range of institutional, policy, and technology support; some of it targeted on smaller, poorer or female-headed households. Moreover, creating opportunities for non-farm income sources is important as this helps farmers to engage in those activities that are less sensitive to climate change. Furthermore, providing climate change information, extension services, and creating access to markets are crucial.

Keywords: Climate change, Adaptation, Diversification, Livelihoods, Multinomial logit model, Smallholder farmers

Belay, A., Recha, J. W., Woldeamanuel, T., & Morton, J. F. (2017). Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agriculture & Food Security*, *6*(1), 1-13, DOI 10.1186/s40066-017-0100-1.

Exploring climate change impacts and adaptation options for maize production in the Central Rift Valley of Ethiopia using different climate change scenarios and crop models

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Abstract

Exploring adaptation strategies for different climate change scenarios to support agricultural production and food security is a major concern to vulnerable regions, including Ethiopia. This study assesses the potential impacts of climate change on maize yield and explores specific adaptation options under climate change scenarios for the Central Rift Valley of Ethiopia by mid-century. Impacts and adaptation options were evaluated using three General Circulation Models (GCMs) in combination with two Representative Concentration Pathways (RCPs) and two crop models. Results indicate that maize yield decreases on average by 20 % in 2050s relative to the baseline (1980–2009) due to climate change. A negative impact on yield is very likely, while the extent of impact is more uncertain. The share in uncertainties of impact projections was higher for the three GCMs than it was for the two RCPs and two crop models used in this study. Increasing nitrogen fertilization and use of irrigation were assessed as potentially effective adaptation options, which would offset negative impacts. However, the response of yields to increased fertilizer and irrigation will be less for climate change scenarios than under the baseline. Changes in planting dates also reduced negative impacts, while changing the maturity type of maize cultivars was not effective in most scenarios. The multi-model based analysis allowed estimating climate change impact and adaptation uncertainties, which can provide valuable insights and guidance for adaptation planning.

Kassie, B. T., Asseng, S., Rotter, R. P., Hengsdijk, H., Ruane, A. C., & Van Ittersum, M. K. (2015). Exploring climate change impacts and adaptation options for maize production in the Central Rift Valley of Ethiopia using different climate change scenarios and crop models. *Climatic change*, *129*(1), 145-158.

Assessing the Adaptive Capacity of Households to Climate Change in the Central Rift Valley of Ethiopia

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Abstract

This paper explores the different components of the adaptive capacity of households in the Central Rift Valley (CRV) of Ethiopia and quantifies their relative contributions. The data were derived from a survey of 413 households randomly selected from four Kebeles (the smallest government administrative units) in the CRV. The adaptive capacity of the households was assessed using the Local Adaptive Capacity (LAC) framework and measured in terms of both aggregate and composite indices, with sixty indicators distributed across five major components and subcomponents. The index score for major components shows that intangible variables such as institutions and entitlements, knowledge and information, and innovation contributed to adaptive capacity better than decision–making and governance and asset–base. The composite indices for sub–components showed that the contribution of woodlands to adaptive capacity was positive and superior to other natural assets. Grazing land was the next best contributor, while farmland and water resources made a much lower contribution. The findings of this study are useful to better understand the nature of adaptive capacity and its components at the household level. This study suggests the need for an integrated assessment and enhancement of adaptive capacity with all its components rather than focusing only on asset possession as an indicator of adaptive capacity.

Keywords: adaptive capacity; component; index; household; Central Rift Valley

Mesfin, D., Simane, B., Belay, A., Recha, J. W., & Schmiedel, U. (2020). Assessing the adaptive capacity of households to climate change in the Central Rift Valley of Ethiopia. *Climate*, *8*(10), 106, **https://doi.org/10.3390/cli8100106**.

Analysis and Mapping of Climate Change Risk and Vulnerability in Central Rift Valley of Ethiopia

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Abstract

There is growing demand for spatially explicit information among stakeholders across public and private institutions regarding vulnerability to climate change at the local scale. This study was conducted over 16 districts in Central Rift Valley (CRV) of Ethiopia, to determine the degree of climate risk and the relative vulnerability of the districts, to climate change and, thereby identify vulnerable hotspots. A biophysical and socio-economic indicator based integrated vulnerability assessment technique was used to map climate change vulnerability. Indicators were generated and analysed under three components of vulnerability, namely exposure, sensitivity and adaptive capacity; and finally aggregated into a single vulnerability index. The values of all indicators were normalised by considering their functional relationship with vulnerability, and expert judgment was then used to assign weights to all indicators. Aggregate vulnerability index (VI) was finally determined from the weighted sum of all indicators and mapped over the 16 districts. Selti, Dodotana-Sire and Tiyo districts had relatively high vulnerability to climate change; while Arsinegele, Adamitulu-Jido-Kombolcha and Dugda-Bora were the least vulnerable. The rest of the districts had medium vulnerability to changing climate. This study shows that vulnerability mapping is crucial in determining the varying degrees of vulnerability of different localities, and generating information that can help researchers, policy makers, private and public institutions in formulating site-specific adaptation strategies and prioritising adaptation investments to the most vulnerable hotspots.

Keywords: Socio-economic indicators, vulnerability index

Gizachew, L., & Shimelis, A. (2014). Analysis and mapping of climate change risk and vulnerability in Central Rift Valley of Ethiopia. *African crop science journal*, *22*, 807-818.

Assessing Weather Forecasting Needs of Smallholder Farmers for Climate Change Adaptation in the Central Rift Valley of Ethiopia

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Abstract

In Ethiopia, climate change is set to hit the agricultural sector adversely and cause considerable negative impacts particularly for smallholder farmers. Weather information is one of the requirements for effective climate change adaptation in Ethiopia, where Agriculture is the back bone of the economy. This study made during 2011/12 investigates whether smallholder farmers, development agents and organizations in the Central Rift Valley of Ethiopia have access to weather information and consequently use it in their agricultural activities to overcome adverse impacts of climate change. For this study, data were collected and analyzed from 200 randomly selected households, 34 development agents and 18 experts of different organizations in four districts (Meki, Melkassa, Miesso and Ziway) representing the same agro-ecological settings in the Central Rift Valley of Ethiopia. The result revealed that the adaptation capacity of farmers in using weather information are constrained by language problems, difficulty in understanding forecast terminology, absence of a center for coordination and downscaling weather information at local level and inconsistency in the time of information provision were the common problems identified in the study area. A new weather information delivery system is proposed which enables effective and location and purpose specific weather information delivery to farming communities and other stakeholders in the agricultural sector.

Keywords: Central rift valley; Climate change adaptation; Ethiopia; Needs assessment; Smallholder farmers; Weather information

Feleke, H. G. (2015). Assessing weather forecasting needs of smallholder farmers for climate change adaptation in the Central Rift Valley of Ethiopia. *Journal of Earth Science and Climate Change*, *6*(10), 1-8, http://dx.doi.org/10.4172/2157-7617.1000312.

Assessing the Adaptive Capacity of Households to Climate Change in the Central Rift Valley of Ethiopia

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Abstract

This paper explores the different components of the adaptive capacity of households in the Central Rift Valley (CRV) of Ethiopia and quantifies their relative contributions. The data were derived from a survey of 413 households randomly selected from four Kebeles (the smallest government administrative units) in the CRV. The adaptive capacity of the households was assessed using the Local Adaptive Capacity (LAC) framework and measured in terms of both aggregate and composite indices, with sixty indicators distributed across five major components and subcomponents. The index score for major components shows that intangible variables such as institutions and entitlements, knowledge and information, and innovation contributed to adaptive capacity better than decision–making and governance and asset–base. The composite indices for sub–components showed that the contribution of woodlands to adaptive capacity was positive and superior to other natural assets. Grazing land was the next best contributor, while farmland and water resources made a much lower contribution. The findings of this study are useful to better understand the nature of adaptive capacity and its components at the household level. This study suggests the need for an integrated assessment and enhancement of adaptive capacity with all its components rather than focusing only on asset possession as an indicator of adaptive capacity.

Keywords: adaptive capacity; component; index; household; Central Rift Valley

Mesfin, D., Simane, B., Belay, A., Recha, J. W., & Schmiedel, U. (2020). Assessing the adaptive capacity of households to climate change in the Central Rift Valley of Ethiopia. *Climate*, *8*(10), 106, doi:10.3390/cli8100106.

The Effect of Climate Change on Loss of Lake Volume: Case of Sedimentation in Central Rift Valley Basin, Ethiopia

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Abstract

Evaluating the impact of climate change on sediment yield has become one of the major topics in climate research. The purpose of this study was to investigate sediment yield contribution to lake volume change under changing climatic conditions in the Central Rift Valley Basin. The ensemble mean of five regional climate models (RCMs) in the coordinated regional climate downscaling experiment (CORDEX)-Africa was considered for the purpose of this study. The climate variables (precipitation, minimum and maximum temperatures) in RCMs were bias corrected against observed data (1985–2016) using linear scaling (LS), power transformation (PT), variance of scaling (VS), and quantile mapping (QM). Two emission scenarios, the Representative Concentration Pathways, RCP4.5 and RCP8.5, were considered for the future scenario period (2041–2070). Better results were obtained when the ensemble values of the bias correction methods were used. Hence, the projected values of climate variables after bias correction were used in the Soil and Water Assessment Tool (SWAT) hydrological model to estimate the sediment yield contribution to lake volume change due to climate change. The results show that the average projected precipitation will decrease by 7.97% and 2.55% under RCP4.5 and RCP8.5, respectively. On average, the maximum temperature will increase by 1.73 °C and 2.36 °C under RCP4.5 and RCP8.5, respectively, while the minimum temperature will increase by 2.16 °C and 3.07 °C under RCP4.5 and RCP8.5, respectively. The average annual sediment yield contributions to Lake Ziway were 431.05 ton/km^2 and 322.82 ton/km^2 for the Meki and Ketar rivers, respectively, in the historical period (1985–2010). The study also reveals that the annual sediment yield that was estimated for the Meki River was 323 ton/km^2 and 382 ton/km^2 under RCP4.5 and under RCP8.5, respectively. The sediment estimations for the Ketar River were 157 ton/km^2 and 211 ton/km^2 under RCP4.5 under RCP8.5, respectively. This will decrease the rate of volume change in Lake Ziway by 38% under RCP4.5 and by 23% under RCP8.5. The results show that the life expectancy of the lake is likely to increase under climate change scenarios. This will help water resources managers make informed decisions regarding the planning, management, and mitigation of the river basins. View Full-Text

Keywords*:* climate change; CORDEX-Africa; lake volume; sediment; SWAT; Ziway

Gadissa, T., Nyadawa, M., Behulu, F., & Mutua, B. (2018). The effect of climate change on loss of lake volume: case of sedimentation in central rift valley basin, Ethiopia. *Hydrology*, *5*(4), 67, https://doi.org/10.3390/hydrology5040067.

Adapting to climate change for food security in the Rift Valley dry lands of Ethiopia: supplemental irrigation, plant density and sowing date

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Summary

Studies on climate impacts and related adaptation strategies are becoming increasingly important to counteract the negative impacts of climate change. In Ethiopia, climate change is likely to affect crop yields negatively and therefore food security. However, quantitative evidence is lacking about the ability of farm-level adaptation options to offset the negative impacts of climate change and to improve food security. The MarkSim Global Climate Model weather generator was used to generate projected daily rainfall and temperature data originally taken from the ECHAM5 general circulation model and ensemble mean of six models under high (A2) and low (B1) emission scenarios. The FAO AquaCrop model was validated and subsequently used to predict maize yields and explore three adaptation options: supplemental irrigation (SI), increasing plant density and changing sowing date. The maximum level of maize yield was obtained when the second level of supplemental irrigation (SI2), which is the application of irrigation water when the soil water depletion reached 75% of the total available water in the root zone, is combined with 30 000 plants/ha plant density. It was also found that SI has a marginal effect in good rainfall years but using 94–111 mm of SI can avoid total crop failure in drought years. Hence, SI is a promising option to bridge dry spells and improve food security in the Rift Valley dry lands of Ethiopia. Expected longer dry spells during the shorter rainy season (Belg) in the future are likely to further reduce maize yield. This predicted lower maize production is only partly compensated by the expected increase in CO2 concentration. However, shifting the sowing period of maize from the current Belg season (mostly April or May) to the first month of the longer rainy season (Kiremt) (June) can offset the predicted yield reduction. In general, the present study showed that climate change will occur and, without adaptation, will have negative effects. Use of SI and shifting sowing dates are viable options for adapting to the changes, stabilizing or increasing yield and therefore improving food security for the future.

Muluneh, A., Stroosnijder, L., Keesstra, S., & Biazin, B. (2017). Adapting to climate change for food security in the Rift Valley dry lands of Ethiopia: supplemental irrigation, plant density and sowing date. *The Journal of Agricultural Science*, *155*(5), 703-724, DOI: https://doi.org/10.1017/S0021859616000897.

Comparative Phylogeography of Ethiopian anurans: impact of the Great Rift Valley and Pleistocene climate change

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Abstract

Background: The Ethiopian highlands are a biodiversity hotspot, split by the Great Rift Valley into two distinct systems of plateaus and mountains. The Rift Valley is currently hot and dry and acts as a barrier to gene flow for highland-adapted species. It is however unlikely that the conditions in the Rift were inhospitable to highland species during the entire Pleistocene. To assess the significance of the Ethiopian Rift as a biogeographic barrier as well as the impact Pleistocene climatic changes have had on the evolution of Ethiopian organisms, we performed phylogeographic analyses and developed present and past niche models on seven anuran species with different elevational and ecological preferences.

Results: We found that highland species on the east and the west sides of the Rift are genetically differentiated and have not experienced any detectable gene flow for at least 0.4 my. In contrast, species found at elevations lower than 2500 m do not show any population structure. We also determined that highland species have lower effective population sizes than lowland species, which have experienced a large, yet gradual, demographic expansion, starting approximately half a million year ago.

Conclusions: The pattern we report here is consistent with the increasingly warmer and drier conditions of the Pleistocene in East Africa, which resulted in the expansion of savanna, the fragmentation of forests and the shrinking of highland habitats. Climatic niche models indicated that the Rift is currently non suitable for most of the studied species, but it could have been a more permeable barrier during the Last Glacial Maximum. However, considering the strong genetic structure of highland species, we hypothesize that the barrier mechanisms at the Rift are not only climatic but also topographical.

Keywords: East Africa, Ethiopia, Great Rift Valley, Phylogeography, Anura, Tomopterna, Amietia, Leptopelis, Ptychadena

Freilich, X., Anadón, J. D., Bukala, J., Calderon, O., Chakraborty, R., & Boissinot, S. (2016). Comparative Phylogeography of Ethiopian anurans: impact of the Great Rift Valley and Pleistocene climate change. *BMC evolutionary biology*, *16*(1), 1-19, DOI 10.1186/s12862-016-0774-1.

Effect of Climate Change on Runoff Generation: Application to Rift Valley Lakes Basin of Ethiopia

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Abstract

In this paper, an attempt has been made to investigate the potential impact of climate change on runoff generation at two agricultural watersheds. Climate change and key future signals of its variability were assessed using general circulation models (GCMs). Given that GCMs are operating at coarser resolution, the statistical downscaling model was applied to reduce large-scale atmospheric variables into localized weather variables from the Bjerknes Center for Climate Research–Bergen Climate Model 2.0 and Commonwealth Scientific and Industrial Research Organization (CSIRO) Mark (MK) 3.0 GCM outputs. As precipitation variables are composed of biases, both linear and power transformation bias correction methods were applied to obtain bias-corrected daily precipitation. Bias-corrected daily precipitation and temperature variables were used to simulate runoff for current and future climate scenarios using the Soil and Water Assessment Tool (SWAT) model. The statistical downscaling model, followed by bias correction, effectively reproduced the current weather variables. Increased extreme daily precipitation and temperature events prevailed for future scenarios. Dry spell length increased during the driest months and remained stable during wet seasons. There was no defined future precipitation change pattern. At two watersheds in the Rift Valley Lakes Basin in Ethiopia, the simulated runoff varied from -4 to 18% and -4 and 14%, respectively. Simulated average annual runoff showed slight variation between the GCMs at both watersheds.

Wagesho, N., Jain, M. K., & Goel, N. K. (2013). Effect of climate change on runoff generation: Application to Rift Valley Lakes basin of Ethiopia. *Journal of Hydrologic Engineering*, *18*(8), 1048-1063, https://doi.org/10.1061.

Smallholder farmers' awareness and perceptions of climate change in Adama district, central rift valley of Ethiopia

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Abstract

Rural smallholder farmers, who exercise rain fed agriculture for their livelihoods, make up the largest proportion in Ethiopia. This article examined the awareness and perception of rural smallholder farmers about climate change in Adama district, central rift valley region of Ethiopia. Primary data were collected from 351 sample smallholder farmers through questionnaires. Focus group discussions and key informant interviews were also employed. The result revealed that though the majority of smallholder farmers reported that they were aware of climate change, it has been found out that they have limited knowledge about climate change impacts and threats posed to various climate sensitive sectors, for example, agriculture, water, energy etc. The result also indicated that majorities of the respondents perceived that climate is changing. Smallholder farmers of rural areas should get relevant and up-to-date climate change information services. It has also been recommended that national meteorological agency and agricultural office of the district should reach the mass and provide training for the rural farming communities.

Keywords: Adama district; Awareness; Climate change; Farmers; Perception; Smallholders

Hundera, H., Mpandeli, S., & Bantider, A. (2019). Smallholder farmers' awareness and perceptions of climate change in Adama district, central rift valley of Ethiopia. *Weather and Climate Extremes*, *26*, 100230, https://doi.org/10.1016/j.wace.2019.100230.

Assessment of climate change impact on water availability of bilate watershed, Ethiopian rift valley basin

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Abstract

Nowadays climate change is expected to affect society in a number of ways ranging from food security to water resources. Water plays an important role in the socio-economic development of any society. Thus, this study mainly deals with assessing climate change impact on water availability of Bilate watershed, Ethiopian Rift Valley Basin. The watershed is situated in Ethiopian Rift Valley Basin and covers an area of about 3643 km ^{2} in which Bilate river is the main river flowing throughout the year. To project the probable impact of climate change on the available water, Hadley Centre Coupled Model, version 3 (HadCM3) atmosphere-oceans Global circulation Model (GCM) was used since it is the only GCM model that has grid box containing the study area for Statistical Downscaling Model (SDSM). The output of HadCM3 coupled atmosphere-ocean GCM model for the A2a and B2a Special Report on Emission Scenarios (SRES) were used to produce future scenarios of precipitation and temperature. Climate change scenarios of precipitation and temperature were developed at two upper and lower stations of the watershed for three periods namely; 2020s (2011–2040), 2050s (2041–2070) and 2080s (2070–2099 and their respective changes were determined as deltas (for temperature) and as percentages (for precipitation) from the base period values. The future climate variable such as daily precipitation, maximum and minimum temperature found as an output from the GCM model and downscaled by the SDSM model and the likely change in land use were given directly as an input to the Soil and Water Assessment Tool (SWAT) model. The SWAT simulation of future average annual flow shows a decreasing trend in 2011–2040 periods and an increasing trend in 2041–2070 periods. The average total annual flow at outlet of the watershed might decrease up to 3.7% for A2a scenario and 1.5% for B2a scenario for the 2011–2040 periods but for 2041–2070 periods it might increase up to 2.6% for A2a scenario and 3.7% for B2a scenario. The decrease in the future flow of 2011–2040 periods might be insufficient in some months to meet future demands for water of the ever increasing population with in and around the watershed. Adopting water storage options to store the excess water flowing during the rainy period is crucial.

Keywords: Bilate , Climate , Scenario , SDSM , SWAT

Tekle, A. (2015, September). Assessment of climate change impact on water availability of Bilate watershed, Ethiopian Rift Valley Basin. In *AFRICON 2015* (pp. 1-5). IEEE, **DOI:** 10.1109/AFRCON.2015.7332041

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Hydrological Responses of Climate Change on Lake Ziway Catchment, Central Rift Valley of Ethiopia

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Abstract

This study predicts future runoff conditions under changing climate using multi model outputs from Coupled Model Intercomparison Project Phase 5 (CMIP5) over Lake Ziway Catchment. The River system is located in the Central Rift Valley of Ethiopia which serves for wide range of socio-economic activity, but recently different water use sectors are increasing their pressure on the water balance of the catchment. Bias corrected precipitation, maximum and minimum temperature data from three climate models HadGEM2-ES, CSIRO-MK-3-6-0 and CCSM4 under representative concentration pathways RCP 8.5 and RCP 4.5 were used as input for the hydrologic model. A calibrated and validated HBV model is used to simulate the future inflow from Katar River and Meki River towards Lake Ziway. The result revealed that the maximum and minimum temperature increased under RCP 8.5 and RCP 4.5 scenarios. However, precipitation showed a decreasing trend. The percentage change in monthly average precipitation showed extremes for HadGEM2-ES model which range between -51.19% during January 2050s and +23.15% during February 2080s under RCP 8.5. The model output showed an annual decrement in runoff depth on Katar River up to 19.45% during RCP 8.5 on CSIRO MK-3-6-0 model and maximum reduction was recorded for RCP 4.5 at 17.49% for CCSM4 model. Meki River has shown maximum annual reduction of 20.28% during 2080s on RCP 8.5 for HadGEM2-ES model and seasonally during Bulg maximum increment was recorded for the same model which ranges up to 10.23% on 2050s for RCP 4.5. However seasonal maximum reduction is obtained from Bulg season by 40.27% on HadGEM2-ES model during 2050s. From the study, a reduction in rainfall has brought larger effects on runoff reduction than evapotranspiration components. Due to future reduction of River flow on the region optimal allocations for water use purposes at all levels of water resource development projects are crucial for future water planning and management.

Keywords: CMIP5; HBV model; Lake Ziway catchment; RCP; Runoff; estimation

Abraham, T., Woldemicheala, A., Muluneha, A., & Abateb, B. (2018). Hydrological responses of climate change on Lake Ziway catchment, Central Rift Valley of Ethiopia. *J. Earth Sci. Clim. Change*, *9*(6), 474, DOI: 10.4172/2157-7617.1000474.

Impact of climate change on soil water balance, maize production, and potential adaptation measures in the Rift Valley drylands of Ethiopia

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Abstract

The dominant effect of climate change in Africa will be in altered water balances. The objectives of this study were: 1) to assess the impact of climate change on soil water balance and maize production, 2) to evaluate the effect of tied-ridges and increased fertilizer use as potential adaptation options during 2021–2050 & 2066–2095 periods. The MarkSimGCM daily weather generator was used to generate projected climate data using the outputs from ECHAM5 and ensemble mean of six GCMs. AquaCrop model was used for modeling soil water balance and evaluating adaptation options. During the 2021–2050 & 2066–2095 projection periods, the maize growing season (March–September) reference evapotranspiration (ETo) increased by 5% and 14%, respectively. During the two projected periods, there was a decrease in runoff & transpiration and an increase in evaporation. The maize yield projected to decrease by about 9% during both periods. The combined effect of tied ridges and increased fertilizer under elevated CO_2 concentration increased the crop yield by almost 90% during the 2021–2050 climate projection periods. The yield increase was a result of decreased evaporation and runoff and an increase in transpiration from tied ridges and increased soil fertility as well as carbon dioxide (CO_2) fertilization effect.

Keywords: AquaCrop; Climate change; Climate change adaptation; Maize yield; Soil water balance

Muluneh, A. (2020). Impact of climate change on soil water balance, maize production, and potential adaptation measures in the Rift Valley drylands of Ethiopia. *Journal of Arid Environments, 179*, 104195, https://doi.org/10.1016/j.jaridenv.2020.104195.

Impact of predicted changes in rainfall and atmospheric carbon dioxide on maize and wheat yields in the Central Rift Valley of Ethiopia

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Abstract

This study assesses potential impacts of climate change on maize and wheat yields in the Central Rift Valley (CRV) of Ethiopia. We considered effects of elevated atmospheric carbon dioxide (CO_2) and changes in rainfall during the main (Kiremt) and the short (Belg) rainfall cropping seasons during the two future periods (2020–2049 and 2066–2095). The MarkSimGCM daily weather generator was used to generate projected rainfall and temperature data using the outputs from ECHAM5 general circulation model and ensemble mean of six models under A2 (high) and B1 (low) emission scenarios. Crop yield simulations were made with the FAO's AquaCrop model. The projected rainfall during Kiremt increases by 12–69 % while rainfall during Belg decreases by 20–68 %. The combined effect of elevated CO_2 and projected climate factors increases maize yield by up to 59 % in sub-humid/humid areas of the CRV, but could result in a decrease of up to 46 % in the semiarid areas under ECHAM5 model. However, the maize yield increases in all parts of the CRV under the ensemble mean of models. Wheat yield shows no significant response to the projected rainfall changes, but increases by up to 40 % due to elevated CO_2. Our results generally suggest that climate change will increase crop yields in the sub-humid/humid regions of the CRV. However, in the semi-arid parts the overall projected climate change will affect crop yields negatively.

Muluneh, A., Biazin, B., Stroosnijder, L., Bewket, W., & Keesstra, S. (2015). Impact of predicted changes in rainfall and atmospheric carbon dioxide on maize and wheat yields in the Central Rift Valley of Ethiopia. *Regional Environmental Change*, *15*(6), 1105-1119.

Climate change and health vulnerability in informal urban settlements in the Ethiopian Rift Valley

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Abstract

Climate change in Ethiopia is occurring against a backdrop of rapid population growth and urbanization, entrenched poverty and a heavy burden of disease, and there is little information on specific health risks with which to approach adaptation planning and strengthen adaptive capacity. Using detailed household surveys (400 households, 1660 individuals, 100% participation) and focus groups in two informal urban communities in the Southern city of Shashemene, we identified locally relevant hazards and found that climate change is likely to intensify existing problems associated with poverty. We also showed that despite their proximity (situated only 1 km apart) the two communities differ in key characteristics that may affect climate change vulnerability and require nuanced approaches to adaptation. Detailed, community-level research is therefore necessary, especially where other sources of data are lacking, to ensure that adaptation activities in the world's poorest communities address relevant risks.

Keywords: climate change, vulnerability, health impacts, community adaptation, Ethiopia, poverty

Bambrick, H., Moncada, S., & Briguglio, M. (2015). Climate change and health vulnerability in informal urban settlements in the Ethiopian Rift Valley. *Environmental Research Letters*, *10*(5), 054014, doi:10.1088/1748-9326/10/5/054014.

Climate change adaptation strategies of maize producers of the Central Rift Valley of Ethiopia

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Abstract

The impacts of climate change are considered to be strong in countries located in tropical Africa that depend on agriculture for their food, income and livelihood. Therefore, a better understanding of the local dimensions of adaptation strategies is essential to develop appropriate measures that will mitigate adverse consequences. Hence, this study was conducted to identify the most commonly used adaptation strategies that farm households practice among a set of options to withstand the effects of climate change and to identify factors that affect the choice of climate change adaptation strategies in the Central Rift Valley of Ethiopia. To address this objective, Multivariate Probit model was used. The results of the model indicated that the likelihood of households to adapt improved varieties of crops, adjust planting date, crop diversification and soil conservation practices were 58.73%, 57.72%, 35.61% and 41.15%, respectively. The Simulated Maximum Likelihood estimation of the Multivariate Probit model results suggested that there was positive and significant interdependence between household decisions to adapt crop diversification and using improved varieties of crops; and between adjusting planting date and using improved varieties of crops. The results also showed that there was a negative and significant relationship between household decisions to adapt crop diversification and soil conservation practices. The paper also recommended household, socioeconomic, institutional and plot characteristics that facilitate and impede the probability of choosing those adaptation strategies.

Keywords: climate change, adaptation strategies, multivariate, maize, Ethiopia

Ahmed, M. H. (2016). Climate change adaptation strategies of maize producers of the Central Rift Valley of Ethiopia. *Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS)*, *117*(1), 175-186.

Review of the natural conditions and anthropogenic threats to the Ethiopian Rift Valley rivers and lakes

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Abstract

This review article considers the lakes found within the Ethiopian Rift Valley system and the rivers draining from the highlands towards them. The Ethiopian Rift Valley system extends in a north-east–south-west direction, bisecting the Ethiopian highlands. They differ in sizes and hydrological and hydrogeological settings. The lakes support a variety of flora and fauna, mainly fishes, reptiles, birds and mammals. The lakes and their feeder rivers, however, are currently being subjected to more human use pressure than previously experienced, attributable mainly to water abstractions for irrigation, household water supply and industrial activities in the catchments. Soil erosion, primarily attributable to the lack of soil conservation practices on farm lands, overgrazing and deforestation, along with unregulated irrigation practices, are generating large quantities of silt reaching the lakes. Improper utilization of water and land resources in the catchments, along with population growth and climate change impacts, is escalating the threats to the health of the lake and river ecosystems. As a result, some of the lakes exhibited reduced water levels and increased salinity. This article reviews the major environmental changes happening to these lakes and their feeder rivers. Visits were made to the area to update previous information while also consolidating the trends of change in the aquatic systems and the watersheds attributed to intense development practices.

Lemma, B., & Desta, H. (2016). Review of the natural conditions and anthropogenic threats to the Ethiopian Rift Valley rivers and lakes. *Lakes & Reservoirs: Research & Management*, *21*(2), 133-151, https://doi.org/10.1111/lre.12126.

Assessing the Effect of Land/Use Land Cover and Climate Change on Water Yield and Groundwater Recharge in East African Rift Valley using Integrated Model

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Abstract

Study region

East African Rift Valley basin.

Study focus

Water availability in the rift valley relies heavily on the discharge from the highlands to rivers that run to the rift floor. This research explores the effect of Land use/Land cover (LULC) and climate change on water yield and groundwater recharge (WYGR) using coupled SWAT-MODFLOW, which integrates Soil and Water Assessment Tool (SWAT) and Newton Modular Finite Difference Groundwater Flow (MODFLOW-NWT). The LULC change was analyzed using artificial neural network-based cellular automata.

New hydrological insights

The dominant LULC is cultivated land and expanded by 5% to the forest and grassland areas. The average temperature and precipitation are expected to rise by 8–11% and 3–6%, respectively. Climate change affects the spatiotemporal distribution of WYGR significantly, while LULC change has a trivial effect. Under the baseline scenario, the recharge was 10% of the average annual precipitation, but climate change is projected to reduce it by 47–53%. Water yield reduction up to 48% and change of perennial rivers to intermittent are expected in the coming decades. The region will experience water scarcity, emerging mainly from climate change.

Keywords: Climate change; Land use/Land cover change; Rift Valley; SWAT-MODFLOW

Water yield; Groundwater recharge

Yifru, B. A., Chung, I. M., Kim, M. G., & Chang, S. W. (2021). Assessing the effect of land/use land cover and climate change on water yield and groundwater recharge in East African Rift Valley using integrated model. *Journal of Hydrology: Regional Studies*, *37*, 100926, https://doi.org/10.1016/j.ejrh.2021.100926.

A scenario-based modeling of climate change impact on the hydrology of Ketar watershed, Central Rift Valley Basin, Ethiopia

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Abstract

Global climate change poses uncertainties and unpredictability to the watershed hydrologic processes in many parts of the world. In line with global climate change prediction and local studies, sets of scenarios were adapted with warming between 2.5 °C and 4 °C upon ending of 21 century and up to ± 20% variation in annual precipitation in the watershed. This study presents scenario-based modeling of climate variables on hydrologic processes of the Ketar watershed in the Central Rift Valley Basin, Ethiopia. The WEAP hydrologic model, a physically based model, was applied to assess the response to altering climate in the watershed. It is a lumped continuous model with a one-dimensional, two-layer soil water dynamic accounting system. The method used empirical functions to describe the hydrologic components of the watershed. In comparison with the baseline years, a 20% surge in annual precipitation and with a respective advance in temperatures would increase by 14–15% evapotranspiration, 34–36% interflow, 213–2001% surface runoff, and 34–36% recharge, respectively. In contrast, a 20% downward trend in mean annual precipitation amount with a respective increase in temperatures would decrease evapotranspiration, interflow, surface runoff, and recharge by 16–17, 37–38, 83, and 37–38%, respectively. The annual groundwater recharge shows high sensitivity to variation in precipitation and modest for temperature change. These findings will have implications on groundwater recharge and its vulnerability to climate at the watershed, and its effect on the water system (lakes and groundwater) in the low-lying rift floor region.

Abdi, D. A., & Ayenew, T. (2022). A scenario-based modeling of climate change impact on the hydrology of Ketar watershed, Central Rift Valley Basin, Ethiopia. *Modeling Earth Systems and Environment*, *8*(3), 3473-3486, https://orcid.org/0000-0003-3288-6240.

Climate variability and change in the Central Rift Valley of Ethiopia: challenges for rainfed crop production

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Summary

Ethiopia is one of the countries most vulnerable to the impacts of climate variability and change on agriculture. The present study aims to understand and characterize agro-climatic variability and changes and associated risks with respect to implications for rainfed crop production in the Central Rift Valley (CRV). Temporal variability and extreme values of selected rainfall and temperature indices were analysed and trends were evaluated using Sen's slope estimator and Mann–Kendall trend test methods. Projected future changes in rainfall and temperature for the 2080s relative to the 1971–90 baseline period were determined based on four General Circulation Models (GCMs) and two emission scenarios (SRES, A2 and B1). The analysis for current climate showed that in the short rainy season (March–May), total mean rainfall varies spatially from 178 to 358 mm with a coefficient of variation (CV) of 32–50%. In the main (long) rainy season (June–September), total mean rainfall ranges between 420 and 680 mm with a CV of 15–40%. During the period 1977–2007, total rainfall decreased but not significantly. Also, there was a decrease in the number of rainy days associated with an increase (statistically not significant) in the intensity per rainfall event for the main rainy season, which can have implications for soil and nutrient losses through erosion and run-off. The reduced number of rainy days increased the length of intermediate dry spells by 0·8 days per decade, leading to crop moisture stress during the growing season. There was also a large inter-annual variability in the length of growing season, ranging from 76 to 239 days. The mean annual temperature exhibited a significant warming trend of 0·12–0·54 °C per decade. Projections from GCMs suggest that future annual rainfall will change by +10 to −40% by 2080. Rainfall will increase during November–December (outside the growing season), but will decline during the growing seasons. Also, the length of the growing season is expected to be reduced by 12–35%. The annual mean temperature is expected to increase in the range of 1·4–4·1 °C by 2080. The past and future climate trends, especially in terms of rainfall and its variability, pose major risks to rainfed agriculture. Specific adaptation strategies are needed for the CRV to cope with the risks, sustain farming and improve food security.

Kassie, B. T., Rötter, R. P., Hengsdijk, H., Asseng, S., Van Ittersum, M. K., Kahiluoto, H., & Van Keulen, H. (2014). Climate variability and change in the Central Rift Valley of Ethiopia: challenges for rainfed crop production. *The Journal of Agricultural Science*, *152*(1), 58-74, DOI: https://doi.org/10.1017/S0021859612000986.

Living with Climate Change: Assessment of the Adaptive Capacities of Smallholders in Central Rift Valley, Ethiopia

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Abstract

Farms less than 2 hectares have constituted almost 90% of the total number offarms in Ethiopia. These small farms are rain fed and are vulnerable to climate change and variability extremes such as droughts. This in turn under- mined the ability of smallholders' farmers to feed themselves and the growing population. A questionnaire survey was conducted with a random sample of 355 smallholder farmers distributed in three agro-ecologies, namely, lowland, midland, and highland in central rift valley of Ethiopia (Arsi Negele district). This was supplemented with 18 focus group discussions and 30 key informant interviews. How do smallholder farmers live with climate change and variability challenges? On the basis of this question, this study has assessed the factors that determine the adaptive capacities, strategies and livelihoods of smallholders to climate change and variability; and the role of climate capacities and landscape functions for sustainable adaptation in response to climate change and variability. The results showed that even if most respondents (>95%) have the perception and intention of climate change; it was nearly 3% of them have higher adaptive capacity to adapt to climate change impacts. Adaptive capacity of smallholders and the potential impact exerted by climate change risks were negatively correlated ($r = -0.134$ and $p < 0.02$). The results showed that farmers have made some evolution in their livelihoods as an adaptation strategy. Adaptation strategies explicitly depend on adaptive capacity-human, natural, financial, social and physical resources. Indeed, the results indicated limited climate-specific and climate-relevant capacities at the local level which suggests a need to strengthen climate capacities. Moreover, it has been implicated that maintaining the landscapes, which provide landscape production functions that build the well-being and adaptive capacity of farmers, could help to sustain farmers' livelihood and build their adaptive capacity to withstand the challenges of climate change.

Keywords: Adaptation; Climate Capacity; Income Inequality; Potential Impacts; Landscapes Functions; Smallholder

Mekonnen, Z., & Kassa, H. (2019). Living with climate change: assessment of the adaptive capacities of smallholders in central rift valley, Ethiopia. *American Journal of Climate Change, 8*(02), 205, https://doi.org/10.4236/ajcc.2019.82012

Characterizing the spatiotemporal distribution of meteorological drought as a response to climate variability: The case of rift valley lakes basin of Ethiopia

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Abstract

Climate variability and recurrent meteorological droughts frequently affect the rain-dependent Ethiopian agriculture, where the rift valley lakes basin is one of the most drought-prone regions in the country. The aim of this study was to evaluate climate variability and characterize the spatiotemporal distribution of meteorological droughts using a merged satellite-gauge rainfall across the major agroecological zones (AEZs) of the rift valley lakes basin. To this end, coefficient of variation (CV) and standardized rainfall anomaly (SRA) were used to evaluate rainfall variability; Mann-Kendell test was used to examine trends of temperature and rainfall; and a grid-rainfall based standardized precipitation index (SPI) was used to assess the spatiotemporal distribution and severity of meteorological droughts. The SPI was computed for 37 years over 1981–2017 at 3-month and 4-month timescales for the bimodal rainy seasons. Finally, a higher inter-annual and spatial variability of rainfall and frequent meteorological droughts were found across the basin. Compared to the nationally documented historical drought years in the country, more frequent drought events were found in this basin, signifying its higher vulnerability to climate variability. As a result, between 1981 and 2017, the basin has partially experienced at least a moderate drought intensity on average every 1.68 and 1.76 years during the '*Belg'* and '*Kiremt'* season, respectively. Drought frequency was higher at the *'Kolla'* AEZ, characterized by the highest CV of rainfall. Furthermore, these frequent droughts were accompanied by significant rising trends in monthly temperature. Such a warming trend, in this inherently warm area, coupled with expected global climate change scenarios could further aggravate drought conditions in the future. Moreover, the spatiotemporal distribution of drought events was found to be variable between and within AEZs in the basin so that more localized drought adaptation strategies could help to alleviate potential impacts. Thus, the drought history of each agroecological zone and the spatiotemporal distributions of recent droughts, this study has delivered, could enhance the awareness of concerned decision makers in tracing frequently affected locations, which could in turn enable them to design and implement improved water management techniques as a means of drought mitigation strategy.

Keywords: Climate variability; Drought; Mann-Kendall test; Merged satellite-gauge rainfall;

Rift valley lakes basin; SPI

Tesfamariam, B. G., Gessesse, B., & Melgani, F. (2019). Characterizing the spatiotemporal distribution of meteorological drought as a response to climate variability: The case of rift valley lakes basin of Ethiopia. *Weather and Climate Extremes*, *26*, 100237, https://doi.org/10.1016/j.wace.2019.100237.

Factors affecting farmers' coping and adaptation strategies to perceived trends of declining rainfall and crop productivity in the central Rift valley of Ethiopia

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Abstract

Background: Farmers apply several and often different farmer-specific strategies to cope with and adapt to the perceived trend of declining rainfall and crop productivity. A better understanding of the factors affecting farmers' coping and adaptation strategies to counteract both trends is crucial for policies and programs that aim at promoting successful rainfed agriculture in Ethiopia. The objective of this study was to identify the major factors that affect farmers' coping and adaption strategies to rainfall variability and reduction in crop yield in the central Rift valley (CRV) of Ethiopia. A survey was conducted among 240 randomly selected farmers within six kebeles in the CRV using structured and pretested questionnaires. Multivariate probit (MVP) regression model was used to identify these key factors that affect farmers' coping and adaptation strategies to the declining trends of rainfall and crop productivity.

Results: Generally, this study identified several factors that affect farmers' choices of certain strategies, which can begrouped in four major factors: (1) livestock and landholdings, (2) availability of labour and knowledge, (3) access to information, and (4) social and cultural factors. Farmers with better resources, labour, knowledge, access to information and social capital had better coping and adaptation strategies to the declining rainfall and crop productivity.

Conclusions: To conclude, improving farmers' asset accumulation, access to information and knowledge are needed. Moreover, strengthening social capital and labour sharing institutions in the CRV is crucial to increase farmers' capacities to cope with and adapt to environmental changes such as rainfall and crop yield variability.

Keywords: Access to information, Asset accumulation, Determinants, Rainfall variability, Social capital

Adimassu, Z., & Kessler, A. (2016). Factors affecting farmers' coping and adaptation strategies to perceived trends of declining rainfall and crop productivity in the central Rift valley of Ethiopia. *Environmental Systems Research*, *5*(1), 1-16, DOI 10.1186/s40068-016-0065-2

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Exploring future global change-induced water imbalances in the Central Rift Valley Basin, Ethiopia

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Abstract

Lake Ziway, the only freshwater lake in Ethiopia's Central Rift Valley basin, has been the source for irrigation, floriculture, fish farming and domestic water supply in the region for the last few decades. This study examined the impacts of the planned future agricultural developments and climate change on the lake water balance by an integrated application of the Soil Water Assessment Tool and Water Evaluation and Planning models. The future projections of precipitation and temperature from the Coordinated Regional Downscaling Experiment, CORDEX-AFRICA, under the Representative Concentration Pathways 4.5 and 8.5 were used for the climate change impact assessment. Nine irrigation development and climate change scenarios were developed and simulated to examine the separate and combined impacts on the lake water balance and supply coverages. The study showed that the planned future agricultural developments could result in a mean annual lake water level decline by about 0.15 m, with a considerable reduction (27% to 32%) in the outflow to the downstream Bulbula River. Climate change could increase evaporation losses from the shallow lake resulting in a drastic decrease in the lake water level, especially during the dry season. It could also significantly reduce (by about 74%) the amount of water flowing out of the lake. The combined impacts of future development and climate change are likely to reduce the supply coverages of most of the competing demands. Approaches need to be studied to minimize the lake water evaporation losses and explore water demand/supply management options.

Musie, M., Momblanch, A., & Sen, S. (2021). Exploring future global change-induced water imbalances in the Central Rift Valley Basin, Ethiopia. *Climatic Change*, *164*(3), 1-19.

Comparative Assessment of the Effect of Climate Change and Human Activities on Streamflow Regimes in Central Rift Valley Basin, Ethiopia

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Abstract

Climate change and anthropogenic activities are the main driving factors for changes in hydrological processes of a given watershed. This research was conducted to assess the relative contribution of climate change and human activities to streamflow change. The ensemble mean of five regional climate models (RCMs) in the coordinated regional climate downscaling experiment (CORDEX)-Africa was considered for the purpose of this study. Two emission scenarios, the Representative Concentration Pathways, RCP4.5 and RCP8.5, were considered for the future scenario period (2041–2070). Streamflow change due to climate change and human activities was assessed using coefficient of elasticity method and SWAT hydrological model. A change due to climate change was further split into change due to precipitation and evapotranspiration. Climate change contributed 46.7% while human activities contributed 53.3% to changes in streamflow. It was found that a 10% decrease in precipitation caused a reduction of 25.1% in streamflow, while 10% increase in potential evapotranspiration caused a reduction of 15.5% in streamflow. The results from ensemble mean of Regional Climate Models (RCMs) show that the average projected precipitation will decrease by 7.97% and 2.55% under RCP4.5 and RCP8.5 respectively. On average, temperature will increase by 1.9°C and 2.7°C under RCP4.5 and RCP8.5 respectively. This corresponds to 4.89%and 6.59% increase in potential evapotranspiration under RCP4.5 and RCP8.5 respectively. Using coefficient of elasticity method, the estimated values of streamflow change were – 26.9% and – 15.8% under RCP4.5 and RCP8.5 respectively. The results of this study show that the reduction in streamflow due to human activities was higher than the reduction due to climate change. The streamflow change induced by anthropogenic factors can be associated with factors such as water abstraction, land use change, ground water abstraction, and the other catchment properties. Hence, further research is recommended to separate changes from these factors.

Keywords: climate change, human activity, streamflow, precipitation, evapotranspiration

Takele Gadissa, Maurice Nyadawa, Benedict Mutua, and Fiseha Behulu, (2019). Comparative Assessment of the Effect of Climate Change and Human Activities on Streamflow Regimes in Central Rift Valley Basin, Ethiopia. American Journal of Water Resources, 7(1): 23-29. doi: 10.12691/ajwr-7-1-4.

Climate Change and Its Effect on Land Use Change in the Central Rift Valley of Ethiopia

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Abstract

Climate change and variability have been one of the challenges to socioeconomic and environmental sustainability in the twenty-first century. Meteorological analyses of historical drought occurrences are common in East Africa, but studies devoted to its effect on land use change are yet limited. This paper aimed to assess the long-term rainfall and temperature variability and its effects on farmers' land use change in the Central Rift Valley of Ethiopia over the past 30-36 years using a combination of meteorological and socioeconomic data. Results show that the overall coefficient of variation for rainfall was more than 35% for rainy seasons. Out of the 36 years, total rainfall of the rainy season showed negative anomalies for about half of these years. Summer season rainfall started after the average time of onset for about 42% of the database years, and it ceased ahead of the average time of the stop for about 56% of these years. As a result of such rainfall shortage and variability, about 82% of the drought-vulnerable farmers had already changed their land use from pastoralist/agropastoralist to mixed farming while 10% have a wish to shift to other land use options in the future. Hence, future policies need to consider strategies that strengthen the adaptation capacity of farmers to climate change in East Africa.

Keywords: 'Belg', coefficient of variation, drought,'Kirmet', rainfall, temperature

Bekele, B., Wu, W., Yirsaw, E., Negussie, W., & Alemayehu, A. (2019). Climate change and its effect on land use change in the Central Rift Valley of Ethiopia. *Applied Ecology and Environmental Research*, *17*(4), 7693-7713, DOI: http://dx.doi.org/10.15666/aeer/1704_76937713.

Rainfall analysis for rain-fed farming in the Great Rift Valley Basins of Ethiopia

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Abstract

Rainfall is the most important source of water for crop production in Ethiopia. However, its temporal and spatial variability is leading to serious food shortages and insecurity in the country. This study was aimed at investigating the characteristics of selected agroclimatic variables over the great Rift Valley regions of Ethiopia. Long term (1981–2010) climate data were analyzed for 17 stations selected based on agroecology representation. Selected descriptors for climate variability and the Mann–Kendall trend test were employed. Onset, cessation, length of growing period (LGP), water requirement satisfaction index and dry spell occurrence during the growing period were determined. The results showed low to very high rainfall variability (14–35%), LGP (20–256 days) and dry spell probability (50–100%) during the main season. Significant ($P \leq 0.05$) annual and seasonal rainfall trends were observed in some stations. The probability of occurrence of a dry spell during the seasons was found to be a challenge for most of the stations in the mid and low altitude areas of the basins. Consequently, seasonal water deficit was observed in these areas which hampered crop production. Area specific recommendations are thus required based on specific challenges in the study region.

Keywords: dry spell, rainfall variability, seasonal water deficit

Ademe, F., Kibret, K., Beyene, S., Getinet, M., & Mitike, G. (2020). Rainfall analysis for rain-fed farming in the Great Rift Valley Basins of Ethiopia. *Journal of Water and Climate Change*, *11*(3), 812-828, https://doi.org/10.2166/wcc.2019.242 .

The effect of drought risk perception on local people coping decisions in the Central Rift Valley of Ethiopia

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Abstract

In an attempt to address the objectives of examining factors influencing smallholders' drought risk perception and coping to climate variability and change, this study utilized household level data collected from 384 households and employed Heckman selection model for its analysis. The study revealed that perceiving climate variability and change does not always guarantee coping and adaptation responses, particularly among the rural people who face more binding constraints that deter adaptation decisions. While educated farmers and those with strong social network are more likely to perceive climate variability and change, it is farmers with better access to weather forecast and extension services who are more likely to respond to the perceived change. Strategies targeted at enhancing smallholder adaptive capacity to the impacts of current and predicted climate change need to focus not only on creating awareness but also on improving enabling conditions through provision of tailored weather forecast and extension services as well as strengthening social network and rural infrastructure.

Keywords: Adaptation, climate, coping, Heckman, perception, smallholder, variability

Yoseph, M., Habtemariam, K., Mengistu, K., Degnet, A., & Ute, S. (2015). The effect of drought risk perception on local people coping decisions in the Central Rift Valley of Ethiopia. *Journal of Development and Agricultural Economics*, *7*(9), 292-302. DOI: 10.5897/JDAE2015.0674

Effect of climate change on streamflow in the Gelana watershed, Rift valley basin, Ethiopia

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Abstract

Climate change is one of the current global threats and the topmost challenges. This study aims to investigate the climate change effect on streamflow in the Gelana watershed using the soil and water assessment tool (SWAT) model for three consecutive periods of 2031–2050, 2051–2070, and 2071–2090. Climate variables were downscaled from two regional climate models (RCMs) (RACMO22T and RCA4) from CORDEX-Africa under representative concentration pathway (RCP4.5 and RCP8.5) scenarios. RCMs were evaluated using four statistical indicators and performed very well. Power transformation and distribution mapping methods were used to correct biases of precipitation and temperatures, respectively. The 19 SWAT model-sensitive parameters were transferred from the gauged donor watersheds to the ungauged watershed outlet by using the principal component analysis coupled with the stepwise multiple linear regression. The ensemble mean of RCMs revealed that the maximum and minimum temperatures and potential evapotranspiration were predicted to increase up to 3.48 °C, 4.19 °C, and 17.85%, respectively, in the period of 2071–2090 under the RCP8.5 scenario. These changes translate to possible reductions in the mean annual rainfall and streamflow up to 15.12 and 44.14%, respectively, with a consequent higher decline of surface runoff by 22.23%, groundwater by 42.54%, and water yield by 35.89% in the period of 2051–2070 under the RCP4.5 scenario. The projected rainfall and streamflow are expected to face a higher decline in wet seasons. Detections of trends in hydro-climatic variables were performed by using the Mann–Kendall test. Hence, these projection scenarios should be of interest to river users and water resource managers in the Gelana watershed.

Keywords: climate change, CORDEX-Africa, Gelana watershed, PCA, RCP, SWAT model

Daniel, H., & Abate, B. (2022). Effect of climate change on streamflow in the Gelana watershed, Rift valley basin, Ethiopia. *Journal of Water and Climate Change*, *13*(5), 2205-2232; doi: 10.2166/wcc.2022.059

Chapter 13 - Assessment of catchment water resources availability under projected climate change scenarios and increased demand in Central Rift Valley Basin

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Abstract

This chapter describes the impact of climate change on available water resources under increasing demand in Central Rift Valley Basin. The study used the ensemble mean of five regional climate models (RCMs) under CORDEX—Africa. Two Representative Concentration Pathways, RCP4.5 and RCP8.5, for current (1985–2016) and scenario period (2041–2070) were considered. The study has revealed that maximum temperature will increase on average by 1.73°C under RCP4.5 to 2.36°C under RCP8.5. Minimum temperature will increase by 2.16°C under RCP4.5 to 3.07°C under RCP8.5. On average, precipitation decreases by 7.97% and − 2.55% under RCP4.5 and RCP8.5, respectively. Moreover, the average streamflow of Meki River will change by − 10.4% and 0.5% under RCP4.5 and RCP8.5, respectively. However, the streamflow of Ketar River will decline by 18.8% and 3.4% on average under RCP4.5 and RCP8.5, respectively. Hence, the available water resources will not meet the projected demand in the scenario period.

Keywords: Climate change; Demand; Stream flow; RCMs; RCP4.5; RCP8.5

Gadissa, T., Nyadawa, M., Behulu, F., & Mutua, B. (2019). Assessment of catchment water resources availability under projected climate change scenarios and increased demand in Central Rift Valley Basin. In *Extreme Hydrology and Climate Variability* (pp. 151-163). Elsevier; https://doi.org/10.1016/B978-0-12-815998-9.00013-0

Searching for evidence of changes in extreme rainfall indices in the Central Rift Valley of Ethiopia

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Abstract

Extreme rainfall events have serious implications for economic sectors with a close link to climate such as agriculture and food security. This holds true in the Central Rift Valley (CRV) of Ethiopia where communities rely on highly climate-sensitive rainfed subsistence farming for livelihoods. This study investigates changes in ten extreme rainfall indices over a period of 40 years (1970–2009) using 14 meteorological stations located in the CRV. The CRV consists of three landscape units: the valley floor, the escarpments, and the highlands all of which are considered in our data analysis. The *Belg* (March–May) and *Kiremt* (June–September) seasons are also considered in the analysis. The Mann-Kendall test was used to detect trends of the rainfall indices. The results indicated that at the annual time scale, more than half (57 %) of the stations showed significant trends in total wet-day precipitation (PRCPTOT) and heavy precipitation days (R10mm). Only 7–35 % of stations showed significant trends, for the other rainfall indices. Spatially, the valley floor received increasing annual rainfall while the escarpments and the highlands received decreasing annual rainfall over the last 40 years. During *Belg*, 50 % of the stations showed significant increases in the maximum number of consecutive dry days (CDD) in all parts of the CRV. However, most other rainfall indices during *Belg* showed no significant changes. During *Kiremt*, considering both significant and non-significant trends, almost all rainfall indices showed an increasing trend in the valley floor and a decreasing trend in the escarpment and highlands. During *Belg* and *Kiremt*, the CDD generally showed increasing tendency in the CRV.

Muluneh, A., Bewket, W., Keesstra, S., & Stroosnijder, L. (2017). Searching for evidence of changes in extreme rainfall indices in the Central Rift Valley of Ethiopia. *Theoretical and Applied Climatology*, *128*(3), 795-809.

Spatial and temporal climate variability and change in the bilate catchment, central Rift Valley lakes region, Ethiopia

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Abstract

The paper explores spatial and temporal variability of rainfall and temperature in Bilate catchment based on monthly data of 11 meteorological stations. Precipitation Concentration Index (PCI) and Pearson product moment correlation were used to estimate monthly concentrations and associations between annual and seasonal rain- fall. Similar methods were used to analyze the association of ENSO with rainfall variability using Eastern Equatorial Pacific (Niño 3.4) data, Sea Surface Temperature (SST), and Southern Oscillation Index (SOI). Rainfall and temperature series were tested for trends using the Mann Kendall test. Rainfall in the catchment is highly seasonal and concentrated in Kiremt (June–September), followed by Belg (February–May). Belg rainfall was highly variable. Annual rainfall was relatively stable in the upper catchment and variable in the lower catchment. PCI values are expected to increase as annual and seasonal rainfall decrease. The middle catchment had significant negative trends in annual and Belg rainfall. November–March SST is strongly associated with Belg rainfall variations throughout the catchment, and ~49% of the variability can be explained by Equatorial Pacific SST. Annual and seasonal temperature significantly increased in middle and lower parts of the catchment in the past 30 years. Warming was ~0.05°C/yr to 0.17°C/yr.

Keywords: Spatial; temporal; climate variability; PCI; ENSO; Bilate catchment

Hessebo, M. T., Woldeamanuel, T., & Tadesse, M. (2021). Spatial and temporal climate variability and change in the bilate catchment, central Rift Valley lakes region, Ethiopia. *Physical Geography*, *42*(3), 199-225

Climate Change Downscaling Using Stochastic Weather Generator Model in Rift Valley Basins of Ethiopia

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Abstract

Agriculture is the mainstay of Ethiopian economy. Developing country like Ethiopia suffers from climate change, due to their limited economic capability to build irrigation projects to combat the trouble. This study generates climate change in rift valley basins of Ethiopia for three time periods (2020s, 2055s and 2090s) by using two emission scenarios: SRA1B and SRB1 for faster technological and environmental extreme respectively. First, outputs of 15 General Circulation Models (GCMs) under two emission scenarios (SRA1 and SRB1) are statistically downscaled by using LARS-WG software. Probability assessment of bounded range with known distributions is used to deal with the uncertainties of GCMs' outputs. These GCMs outputs are weighted by considering the ability of each model to simulate historical records. The study result indicates that LARS-WG 5.5 version model is more uncertain to simulate future mean rainfall than generating maximum and minimum mean temperatures. GCMs weight difference for mean rainfall is 0.83 whereas weight difference for minimum and maximum mean temperatures is 0.09 among GCMs models. The study results indicate minimum and maximum temperatures absolute increase in the range of 0.34℃ to 0.58℃, 0.94℃ to 1.8℃ and 1.42℃ to 3.2℃ and 0.32℃ to 0.56℃, 0.91℃ to 1.8℃ and 1.34℃to 3.04℃ respectively in the near-term (2020s), mid-term (2055s) and long-term (2090s) under both emission scenarios. The expected rainfall change percentage during these three time periods considering this GCMs weight difference into account ranges from −2.3% to 7%, 0.375% to 15.83% and 2.625% to 31.1% in the same three time periods. In conclusion, the study results indicate that in coming three time periods, maximum and minimum temperature and rainfall increase is expected in rift valley of basins of Ethiopia.

Keywords: Climate Change; IPCC AR4; LARS-WG Statistical Downscaling; 15 GCM Ensembles

Disasa, K. , Tura, F. and Fereda, M. (2019) Climate Change Downscaling Using Stochastic Weather Generator Model in Rift Valley Basins of Ethiopia. *American Journal of Climate Change*, **8**, 561-590. doi: 10.4236/ajcc.2019.84030.

Climate-induced yield variability and yield gaps of maize (*Zea mays L.*) in the Central Rift Valley of Ethiopia

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Abstract

There is a high demand for quantitative information on impacts of climate on crop yields, yield gaps and their variability in Ethiopia, yet, quantitative studies that include an indication of uncertainties in the estimates are rare. A multi-model crop growth simulation approach using the two crop models, i.e. Decision Support System for Agro-Technology (DSSAT) and World Food oSTudies (WOFOST) was applied to characterize climate-induced variability and yield gaps of maize. The models were calibrated and evaluated with experimental data from the Central Rift Valley (CRV) in Ethiopia. Subsequently, a simulation experiment was carried out with an early maturing (Melkassa1) and a late maturing (BH540) cultivar using historical weather data (1984–2009) of three locations in the CRV. Yield gaps were computed as differences among simulated water-limited yield, on-farm trial yields and average actual farmers' yields.

The simulation experiment revealed that the potential yield (average across three sites and 1984–2009) is 8.2–9.2 and 6.8–7.1 Mg/ha for the late maturing and early maturing cultivars, respectively; ranges indicate mean differences between the two models. The simulated water-limited yield (averaged across three sites and 1984–2009) is 7.2–7.9 Mg/ha for the late maturing and 6.1–6.7 Mg/ha for the early maturing cultivar. The water-limited yield shows high inter-annual variability (CV 36%) and about 60% of this variability in yield is explained by the variation in growing season rainfall. The gap between average farmers yield and simulated water-limited yield ranges from 4.7 to 6.0 Mg/ha. The average farmers' yields were 2.0–2.3 Mg/ha, which is about 1.1–3.1 Mg/ha lower than on-farm trial yields. In relative terms, average farmers' yields are 28–30% of the water-limited yield and 44–65% of on-farm trial yields. Analysis of yield gaps for different number of years to drive average yields indicates that yield gap estimation on the basis of few years may result in misleading conclusions. Approximately ten years of data are required to be able to estimate yield gaps for the Central Rift Valley in a robust manner.

Existing yield gaps indicate that there is scope for significantly increasing maize yield in the CRV and other, similar agro-ecological zones in Africa, through improved crop and climate risk management strategies. As crop models differ in detail of describing the complex, dynamic processes of crop growth, water use and soil water balances, the multi-model approach provides information on the uncertainty in simulating crop–climate interactions.

Keywords: WOFOST; DSSAT; Crop simulation; Water-limited yield; Yield gap; Ethiopia

Kassie, B. T., Van Ittersum, M. K., Hengsdijk, H., Asseng, S., Wolf, J., & Rötter, R. P. (2014). Climate-induced yield variability and yield gaps of maize (Zea mays L.) in the Central Rift Valley of Ethiopia. *Field Crops Research*, *160*, 41-53, https://doi.org/10.1016/j.fcr.2014.02.010

Vulnerability of Smallholder Farmers to Climate Change in the Central Rift Valley of Ethiopia: A Gender Disaggregated Approach

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Abstract

In Ethiopia agriculture is the dominant sector and a large majority of the population make their living out of it. It is dominated by smallholder production under rain-fed system. Climate change is projected to be a major threat for the sector resulting in variability in smallholder farmers' productivity and income. The impact of climate change is expected to vary greatly among regions, sectors and social groups and communities. It is also expected to vary between gender groups. Therefore, this study will try to address gender differentiated vulnerabilities to climate change in the Central Rift Valley of Ethiopia where moisture stress is relevant. Field data was collected from 290 randomly selected farm households in the representative districts of Adama and Adamitulu-Jidokombolcha. We adopted Vulnerability as expected poverty (VEP) approach was where an individual's vulnerability is the prospect of a smallholder household considering poor and non-poor scenarios. Results of the analysis indicated that men and women headed households vary in terms of their vulnerability to climate change infavor of the latter. It was also found out that the two gender categories vary in terms of the different socio-economic characteristics to face the threat of climate change. Therefore, emphasis is required to reduce vulnerability through gender disaggregated interventions and policy makers need ensure that development policies include gender oriented adaptation options to create resilience to the impacts of climate change.

Abebe, Y., & Bekele, A. (2017). Vulnerability of smallholder farmers to climate change in the central rift valley of Ethiopia: a gender disaggregated approach. *Ethiopian Journal of Agricultural Sciences*, *27*(2), 85-97.

Impacts of Climate Change under CMIP5 RCP Scenarios on the Hydrology of Lake Ziway Catchment, Central Rift Valley of Ethiopia

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Abstract

This study predicts future runoff conditions under changing climate using multi model outputs from Coupled Model Intercomparison Project Phase 5 (CMIP5) over Lake Ziway Catchment in the Central Rift Valley of Ethiopia. Bias corrected precipitation, maximum and minimum temperature data from HadGEM2-ES, CSIRO- MK-3-6-0 and CCSM4 models under representative concentration pathways RCP8.5 and RCP4.5 were used as future climate. Soil and Water Assessment Tool (SWAT) is used to simulate the future inflows from Katar River and Meki River towards Lake Ziway. Maximum and minimum temperature increased under RCP8.5 and RCP4.5 scenarios however, precipitation showed reduction. The percentage change in monthly average precipitation showed extremes for HadGEM2-ES model which range between -51.19% during 2050s and +23.15% during 2080s under RCP8.5. The model output showed an annual decrement in runoff depth from Katar River up to 19.45% on RCP8.5 on CSIRO MK-3-6-0 model and maximum reduction was recorded on RCP4.5 at 17.49% for CCSM4 model. Meki River showed maximum annual reduction of 20.28% during 2080s on RCP8.5 for HadGEM2-ES model. Due to future reduction of River flow on the region optimal allocations for water use purposes at all levels of water resource development projects are crucial for future water planning and management.

Keywords: CMIP5; Lake Ziway Catchment; RCP; Runoff Estimation; SWAT model

Abraham, T., Abate, B., Woldemicheal, A., & Muluneh, A. (2018). Impacts of Climate Change under CMIP5 RCP Scenarios on the Hydrology of Lake Ziway Catchment, Central Rift Valley of Ethiopia. *J. Environ. Earth Sci*, *8*(7).

Adapting to Climate Variability and Change: Experiences from Cereal-Based Farming in the Central Rift and Kobo Valleys, Ethiopia

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Abstract

Small-holder farmers in Ethiopia are facing several climate related hazards, in particular highly variable rainfall with severe droughts which can have devastating effects on their livelihoods. Projected changes in climate are expected to aggravate the existing challenges. This study examines farmer perceptions on current climate variability and long-term changes, current adaptive strategies, and potential barriers for successful further adaptation in two case study regions—the Central Rift Valley (CRV) and Kobo Valley. The study was based on a household questionnaire, interviews with key stakeholders, and focus group discussions. The result revealed that about 99 % of the respondents at the CRV and 96 % at the Kobo Valley perceived an increase in temperature and 94 % at CRV and 91 % at the Kobo Valley perceived a decrease in rainfall over the last 20–30 years. Inter-annual and intraseasonal rainfall variability also has increased according to the farmers. The observed climate data (1977–2009) also showed an increasing trend in temperature and high inter-annual and intra-seasonal rainfall variability. In contrast to farmers' perceptions of a decrease in rainfall totals, observed rainfall data showed no statistically significant decline. The interaction among various bio-physical and socio-economic factors, changes in rainfall intensity and reduced water available to crops due to increased hot spells, may have influenced the perception of farmers with respect to rainfall trends. In recent decades, farmers in both the CRV and Kobo have changed farming practices to adapt to perceived climate change and variability, for example, through crop and variety choice, adjustment of cropping calendar, and in situ moisture conservation. These relatively low-cost changes in farm practices were within the limited adaptation capacity of farmers, which may be insufficient to deal with the impacts of future climate change. Anticipated climate change is expected to impose new risks outside the range of current experiences. To enable farmers to adapt to these impacts critical technological, institutional, and market-access constraints need to be removed. Inconsistencies between farmers' perceptions and observed climate trends (e.g., decrease in annual rainfall) could lead to sub-optimal or counterproductive adaptations, and therefore must be removed by better communication and capacity building, for example through Climate Field Schools. Enabling strategies, which are among others targeted at agricultural inputs, credit supply, market access, and strengthening of local knowledge and information services need to become integral part of government policies to assist farmers to adapt to the impacts of current and future climate change.

Kassie, B. T., Hengsdijk, H., Rötter, R., Kahiluoto, H., Asseng, S., & Van Ittersum, M. (2013). Adapting to climate variability and change: experiences from cereal-based farming in the Central Rift and Kobo Valleys, Ethiopia. *Environmental Management*, *52*(5), 1115-1131.

Social capital, trust, and adaptation to climate change: Evidence from rural Ethiopia

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Abstract

Climate change is expected to have particularly severe effects on poor agrarian populations. Rural households in developing countries adapt to the risks and impacts of climate change both individually and collectively. Empirical research has shown that access to capital—financial, human, physical, and social—is critical for building resilience and fostering adaptation to environmental stresses. Little attention, however, has been paid to how social capital generally might facilitate adaptation through trust and cooperation, particularly among rural households and communities. This paper addresses the question of how social capital affects adaptation to climate change by rural households by focusing on the relationship of household and collective adaptation behaviors. A mixed-methods approach allows us to better account for the complexity of social institutions—at the household, community, and government levels—which drive climate adaptation outcomes. We use data from interviews, household surveys, and field experiments conducted in 20 communities with 400 households in the Rift Valley of Ethiopia. Our results suggest that qualitative measures of trust predict contributions to public goods, a result that is consistent with the theorized role of social capital in collective action. Yet qualitative trust is negatively related to private household-level adaptation behaviors, which raises the possibility that social capital may, paradoxically, be detrimental to private adaptation. Policymakers should account for the potential difference in public and private adaptation behaviors in relation to trust and social capital when designing interventions for climate adaptation.

Keywords: Climate change; Trust; Social capital; Adaptation; Ethiopia

Paul, C. J., Weinthal, E. S., Bellemare, M. F., & Jeuland, M. A. (2016). Social capital, trust, and adaptation to climate change: Evidence from rural Ethiopia. *Global Environmental Change*, *36*, 124-138, https://doi.org/10.1016/j.gloenvcha.2015.12.003

Integrated water availability modelling to assess sustainable agricultural intensification options in the Meki catchment, Central Rift Valley, Ethiopia

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Abstract

The Meki catchment in the Central Rift Valley basin of Ethiopia is currently experiencing irrigation expansion and water scarcity challenges. The objective of this study is to understand the basin's current and future water availability for agricultural intensification. This was done by simulating scenarios through an integrated SWAT-MODFLOW model to assess the water balance. The scenarios were co-developed with communities who reflected their aspiration for agricultural intensification in conjunction with projected climate change. The results show that with the present land use and climate, the catchment is already water stressed and communities cannot meet their irrigation water demand particularly in the first irrigation season (October January). However, in the second irrigation season (February – May) water resource availability is better and increasing irrigated area by 50% from the present is possible. With climate change scenario that favors more rainfall and shallow groundwater use, agricultural intensification is feasible to some extent.

Keywords: agricultural intensification; community-based scenarios; Meki catchment; SWAT-MODFLOW; water budget

Taye, M. T., Ebrahim, G. Y., Nigussie, L., Hagos, F., Uhlenbrook, S., & Schmitter, P. (2022). Integrated water availability modelling to assess sustainable agricultural intensification options in the Meki catchment, Central Rift Valley, Ethiopia. *Hydrological Sciences Journal*, https://doi.org/10.1080/02626667.2022.2138403

Prediction of flood frequency under a changing climate, the case of Hare watershed, Rift Valley Basin of Ethiopia

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Abstract

Climate change is causing unpredictable fluctuation in the rainfall patterns and, frequent heavy rainfall that led to catastrophic flooding and a significant risk on Hare watershed biodiversity in the Rift Valley of Ethiopia. Prediction of flood frequency under changing climate in the Hare watershed has not been well-studied in spite of the risk it poses to the human environment. Thus, this study aimed to predict flood frequency under changing climate in the Hare watershed relevant for effective flood management and early warning systems. The Soil Water Assessment Tool (SWAT) was used to simulate monthly stream flow. The model was calibrated and validated for the period of 1994 to 1998 and 1999 to 2001, respectively. The stationarity of annual peak flow was analyzed using Pettitt's test. Flood Frequency Distribution (FFD) software package was deployed to determine the flood magnitude and frequency curve for the baseline period (1980–2009) and a predicted period (2021–2050). The result of the SWAT model performance evaluation statistics showed a high potential in the prediction of future streamflow. In addition, the goodness-of-fit test result showed that the Gumbel and Generalized Extreme Value (GEV) were the best-fit probability distribution for baseline and future flood events, respectively. The predicted annual peak flow results show an increasing trend by 60 and 106% under RCP 4.5 and RCP 8.5 emission scenarios, respectively. The future design flood may increase between 6.5 and 119.0% when compared to the baseline period. The study provides valuable information for policy and decision makers during the implementation of different flood events adaptation and mitigation measures for the Hare watershed.

Yisehak, B. (2021). Prediction of flood frequency under a changing climate, the case of Hare watershed, Rift Valley Basin of Ethiopia. *Sustainable Water Resources Management, 7*(1), 1-15

Potential impact of climate change on streamflow of major Ethiopian rivers

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Abstract

In this study, HSPF (Hydrologic Simulation Program-FORTRAN) was used to analyze the potential impact of climate change on the streamflow of four major river basins in Ethiopia: Awash, Baro, Genale, and Tekeze. The calibrated and validated HSPF model was forced with daily climate data of 10 CMIP5 (Coupled Model Intercomparison Project phase 5) Global Climate Models (GCMs) for the 1971–2000 control period and the RCP4.5 and RCP8.5 climate projections of 2041–2070 (2050s) and 2071–2100 (2080s). The ensemble median of these 10 GCMs projects the temperature in the four study areas to increase by about 2.3 °C (3.3 °C) in 2050s (2080s), whereas the mean annual precipitation is projected to increase by about 6% (9%) in 2050s (2080s). This results in about 3% (6%) increase in the projected annual streamflow in Awash, Baro, and Tekeze rivers whereas the annual streamflow of Genale river is projected to increase by about 18% (33%) in the 2050s (2080s). However, such projected increase in the mean annual streamflow due to increasing precipitation over Ethiopia contradicts the decreasing trends in mean annual precipitation observed in recent decades. Regional climate models of high resolutions could provide more realistic climate projections for Ethiopia's complex topography, thus reducing the uncertainties in future streamflow projections.

Gizaw, M. S., Biftu, G. F., Gan, T. Y., Moges, S. A., & Koivusalo, H. (2017). Potential impact of climate change on streamflow of major Ethiopian rivers. *Climatic Change*, *143*(3), 371-383.

Performance evaluation of CORDEX-Africa regional climate models in simulating climate variables over Ethiopian main rift valley: Evidence from Gidabo river basin for impact modeling studies

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Abstract

Measuring the simulation skill of regional climate models (RCMs) is vital in selecting the best performing model that can be used for climate change studies. To that end, the performance of eleven Coordinated Regional Climate Downscaling Experiment (CORDEX) Africa RCMs were evaluated against observed datasets from 1991 to 2005 over Gidabo river basin (GRB), main Ethiopian rift valley. RCMs' outputs were evaluated using coefficient of variation (CV), percent of bias (PBIAS), Root Means Square Error (RMSE), Pearson's correlation coefficient (r), revised R-squared (RR^2), Taylor Skill Score (TSS), Mann-Kendall (MK) trend test and Sen's slope estimator. The results confirm the difference of RCMs in capturing the annual and seasonal climate variables. In relation to the spatial pattern of the rainfall, RACMO22T (EC-EARTH) strongly reproduced the mean annual rainfall. CCLM4–8 (MPI) and mean ensemble reproduced the annual patterns of the observed rainfall despite the fact with varying rainfall amounts reproduced. The seasonal rainfall pattern was satisfactorily captured by RACMO22T (EC-EARTH), CCLM4–8 (MPI) and REMO2009 (MPI). The agreement between the observed and modeled rainfall is superior in CCLM4–8 (MPI) and RACMO22T (EC-EARTH) at station level. CRCM5 (MPI) satisfactory replicated the patterns of both minimum and maximum temperature. RACMO22T (EC-EARTH) showed best performance in simulating annual and seasonal rainfall trends in GRB. In overall, models that performs better in replicating the observed climatology include RACMO22T (EC-EARTH), CCLM4–8 (MPI), CRCM5 (MPI), CCLM4–8 (CNRM), and REMO2009 (EC-EARTH). The study underscored the use of the mean ensemble of model simulation did not always guarantee better agreement with observation than individual models. Therefore prior to climate impact study, it is advisable to correct the systematic bias and employ the multi-model ensemble of best performing models for climate change impact and adaptation studies in the GRB.

Girma, R., Fürst, C., & Moges, A. (2022). Performance evaluation of CORDEX-Africa regional climate models in simulating climate variables over Ethiopian main rift valley: Evidence from Gidabo river basin for impact modeling studies. *Dynamics of Atmospheres and Oceans*, *99*, 101317, https://doi.org/10.1016/j.dynatmoce.2022.101317

Hydrological Impacts of Climate Change in Tikur Wuha Watershed, Ethiopian Rift Valley Basin

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Abstract

According to Intergovernmental Panel on Climate Change (IPCC) rising of global surface temperature, sea level rises, arctic and land ice decrease, erratic precipitation and increase of CO2 concentration are the main indicators of climate change. The main objectives of the study was to investigate the possible hydrological impacts of climate change on stream flow and sedimentation in Tikur Wuha watershed, by downscaling canESM2 (Canadian Earth System Model of second generation) global climate model using Statistical Downscaling Model (SDSM). Based on IPCC recommendation baseline periods (1987–2016) were used for baseline scenario analysis. Future scenario analysis was performed for the 2020s, 2050s, and 2080s. canESM2 model consists of Representative Concentration Pathway (RCP) RCP2.6, RCP4.5 and RCP8.5 scenarios. Impact assessment on stream flow and sediment yield was done by Soil and Water Assessment Tool (SWAT) hydrological model. SWAT model performance in simulating monthly stream flow for the study area was satisfactory with R2 (0.77 and 0.87), NSE (0.70 and 0.77) and D (-16 and -9) for calibration and validation periods respectively. The result of downscaled precipitation and temperature reveals a systematic increase in all future time periods for all three scenarios; RCP2.6, RCP4.5 and RCP8.5 scenarios. These increases in climate variables are expected to result in increase in mean annual stream flow of 8%, 13%, and 15 % for RCP2.6 scenario, 17%, 24%, and 31% for RCP4.5 scenario and 14%,24% and 35% for RCP8.5 scenario for the 2020s, 2050s, and 2080s, respectively. This leads to increment of sediment yield from different sub watershed. The estimated soil loss rate from different sub-watersheds had ranged from 0.42 tons/ha/yr to 28.31 tons/ha/year (1987-1999), whereas the annual weighted average soil loss rate from the watershed was estimated 16.80 tons/ha/year (2000-2100). Future work need to consider studying the effects of different climate change adaptation strategies.

Keywords: Climate change Scenarios; Ethiopia; Hydrological impact; SWAT model

Mohammed, M., Biazn, B., & Belete, M. D. (2020). Hydrological impacts of climate change in Tikur Wuha watershed, Ethiopian Rift Valley Basin. *J Environ Earth Sci*, *10*(2), 28-49, DOI: 10.7176/JEES/10-2-04

The Current and Future Trend of Rainfall and Its Variability in Adami-Tulu Jido-Kombolcha Woreda, Central Rift Valley of Ethiopia

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Abstract

The seasonality and availability of water in Ethiopia are influenced by the steep climatic gradients and physiographic contrasts. While large population of the country heavily relies on rain fed agriculture, the anomaly in rainfall has direct implications on the crop production and further food sufficiency. This study investigates the current and future trends of rainfall and its variability in Adami-Tulu Jido Kombolcha woreda, central Rift Valley of Ethiopia. Statistical tools like; PCI, CV, and SRA method were used to identify the variability of rainfall concentration test, the degree of variability of rainfall and characterize the drought frequency and intensity. Sen's estimator and Mann-Kendall's statistical tests were employed for trend detection. The HadCM3 A2 and B2 scenarios experiments were used for the climate projection. The current annual rainfall has increasing trends for all stations except Bulbula. However, the projection of future rainfall conditions suggest that the annual and seasonal rainfall in Adami Tulu Jido Kombolcha is most likely to decrease for both HadCM3-A2 and HadCM3-B2 scenarios, and found to be statistically insignificant at 5% significance level. The average annual precipitation concentration index (PCI) showed irregular distribution of annual rainfall for most stations except Bulbula that highlights the seasonality in rainfall distribution. Most of the stations showed moderate variation in annual rainfall (CV ranging from 20 to 30%) except for Ziway station, which has less variations (CV% < 20%). Generally, the rainfall trends in the study area are not uniform and consistent in both time and space until end of 2090.

Keywords: trend analysis, Climate Change, GCM, Scenarios, SDSM, Coefficient of Variation, HadCM3

Gemechu, T., Wakbulcho, G., Rao, G. N., & Adamu, T. (2015). The current and future trend of rainfall and its variability in Adami-Tulu Jido-Kombolcha Woreda, Central Rift Valley of Ethiopia. *J. Environ. Earth Sci*, *5*, 22.

Error propagation of climate model rainfall to streamflow simulation in the Gidabo sub-basin, Ethiopian Rift Valley Lakes Basin

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Abstract

This study assesses bias error of rainfall from climate models and related error propagation effects to simulated streamflow in the Gidabo sub-basin, Ethiopia. Rainfall is obtained from a combination of four global and regional climate models (GCM-RCMs), and streamflow is simulated by means of the Hydrologiska Byråns Vattenbalansavdelning (HBV-96) rainfall-runoff model. Five bias correction methods were tested to reduce the rainfall bias. To assess the effects of rainfall bias error propagation, percent bias (PBIAS), difference in coefficient of variation (CV), and 10th and 90th percentile indicators were applied. Findings indicate that the bias of the uncorrected rainfall caused large errors in simulated streamflow. All five bias correction methods improved the HBV-96 model performance in terms of capturing the observed streamflow. Overall, the findings of this study indicatethat the magnitude of the error propagation varies subject to the selected performance indicator, bias correction method and climate model.

Keywords: Bias correction; climate change; error propagation; HBV model; systematic error

Worako, A. W., Haile, A. T., Rientjes, T., & Woldesenbet, T. A. (2022). Error propagation of climate model rainfall to streamflow simulation in the Gidabo sub-basin, Ethiopian Rift Valley Lakes Basin. *Hydrological Sciences Journal*, https://doi.org/10.1080/02626667.2022.2072220

Natural and anthropogenic sources of salinity in the Awash River and Lake Beseka (Ethiopia): Modelling impacts of climate change and lake-river interactions

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Abstract

Study region: Awash River Basin, Ethiopia: Study focus

Many river basins in sub-Saharan Africa have become vulnerable due to the impact from climate change, weak governance and high levels of poverty. One of the primary concerns is the elevated salinity and the degradation of water quality in the Awash River. Located in the Great Rift Valley in Ethiopia, the Awash River has unique hydrochemistry due to water-rock interactions. However, in recent years, increasing anthropogenic activities including the discharge from saline Lake Beseka into the Awash River has caused some concern. This study used an Integrated Catchment Model to simulate chloride concentration in the Awash River Basin by taking both natural and anthropogenic sources of salinity into consideration. Future scenarios of climate change and Lake Beseka discharge were examined to assess the impact to the river water quality.

New hydrologic insights

Results show that Lake Beseka has made significant contribution to the rise of the salinity in the Awash River. If the trend of human interference (e.g. increased irrigation and unregulated water transfer) continues, the river downstream of Lake Beseka could see Cl increases up to 200 % in the near future (2006–2030). The modeling results are essential for generating long term plans for proper utilization of water resources especially in the region where the resources and the economic capacity to meet the water demand is lacking.

Jin, L., Whitehead, P. G., Bussi, G., Hirpa, F., Taye, M. T., Abebe, Y., & Charles, K. (2021). Natural and anthropogenic sources of salinity in the Awash River and Lake Beseka (Ethiopia): modelling impacts of climate change and lake-river interactions. *Journal of Hydrology: Regional Studies*, *36*, 100865, https://doi.org/10.1016/j.ejrh.2021.100865

Climate change and its effects on vegetation phenology across ecoregions of Ethiopia

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Abstract

Vegetation phenology is an integrative environmental indicator of climate change and long-term observations of the changes in plant phenology using remote sensing technologies help us to understand climate change trends over space and time. However, such trends and their implications for ecosystem health have been poorly explored in Ethiopia. In this paper we examine the temporal changes in the phenology of vegetation in relation to climatic drivers across Ecoregions in Ethiopia using satellite images. To do this, the MODIS 8-day NDVI product, MODIS surface temperature and emissivity, and pentad based rainfall data from Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) for the 14 year period 2002–2015 were used. The aggregated time series NDVI, temperature and rainfall data were generated for each Ecoregion in the Google Earth Engine (GEE) Environment followed by Fourier smoothing to overcome various noises. The phenology of each Ecoregion was constructed using the intra-annual NDVI variability. Major events in the vegetation cycle or phenophases were identified using sigmoid vegetation growth functions and inflection point detection techniques. The relationships between rainfall and NDVI and between temperature and NDVI were investigated and multiple regression models were developed as regressors to NDVI. Our results indicated that, over the 14 years, the start of the growing period became earlier, and the growing period elongated for most of the Ecoregions in Ethiopia, except for the Somali Acacia-Commiphora bushlands and thickets (SACBT) Ecoregion, in which the start of the growing period was delayed. The widening of the growing period indicates an increase in ecosystem productivity, increment of evapo-transpiration, and disturbance to the water and energy balance of the region. Rainfall and NDVI were positively and strongly correlated but with one-month lag time, whereas temperature and NDVI were negatively correlated for all the Ecoregions. This appears to be due to the variation in timing of the high rainfall season and the decreasing trends of temperature with respect to the variation in the angle of the sun and the subsequent movements of the ITCZ in the region. The overall study indicates that climate variability is affecting the phenology of vegetation across all Ecoregions in Ethiopia. Shifts in crop growing seasons should be considered to efficiently utilize the summer rain for crop production.

Keywords: Phenology; Phenophase; NDVI; Rainfall; Temperature; Ecoregions

Workie, T. G., & Debella, H. J. (2018). Climate change and its effects on vegetation phenology across ecoregions of Ethiopia. *Global Ecology and Conservation*, *13*, e00366, https://doi.org/10.1016/j.gecco.2017.e00366

Application of CORDEX-AFRICA and NEX-GDDP datasets for hydrologic projections under climate change in Lake Ziway sub-basin, Ethiopia

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Abstract

Study region

Lake Ziway sub-basin, Central Rift Valley basin, Ethiopia.

Study focus

This study evaluated the applicability of the NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP) and the Coordinated Regional Downscaling Experiment (CORDEX-AFRICA) datasets for climate change impact assessment. It also evaluated the hydrologic impact of climate change in the sub-basin. The hydrologic model Soil and Water Assessment Tool (SWAT) was forced with the climate datasets to simulate the reference and future period streamflows under RCP 4.5 and RCP 8.5 scenarios. The seasonality and volumetric deviations of the average annual streamflows simulated using the climate models were used as criteria for selecting members of the ensemble.

New hydrological insights for the region

All the climate models in the bias-corrected NEX-GDDP datasets failed to satisfy the criteria. The ensemble average annual streamflows, simulated using the CORDEX-AFRICA dataset, are expected to increase towards the end of the century under both the climate scenarios. However, the ensemble average dry season streamflows are projected to decrease during the mid- and end-periods of the century. The expected decreases in streamflows during the dry and pre-wet seasons, along with excessive abstractions of water from Lake Ziway, would exacerbate water scarcity in the basin. Approaches need to be developed to capture the increase in water availability during the wet season to alleviate water scarcity during the dry season.

Keywords: Climate change; SWAT model; Lake Ziway; Central Rift Valley basin; CMIP5

Musie, M., Sen, S., & Srivastava, P. (2020). Application of CORDEX-AFRICA and NEX-GDDP datasets for hydrologic projections under climate change in Lake Ziway sub-basin, Ethiopia. *Journal of Hydrology: Regional Studies*, *31*, 100721, https://doi.org/10.1016/j.ejrh.2020.100721

Human migration, climate variability, and land degradation: hotspots of socio-ecological pressure in Ethiopia

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Abstract

In Ethiopia, human migration is known to be influenced by environmental change—and vice versa. Thus, degradation of environmental conditions can contribute to out-migration, and in-migration can cause environmental changes at the immigrants' destination. The aim of our study was to systematically identify regions in which socio-ecological pressures can arise from high population densities, migration, land degradation, and/or rainfall variability. We combined population census data at the district level with high-resolution remote sensing data regarding rainfall variability, land degradation, and land cover. We identified districts in which high population density is coupled with both a steep decline in net primary production (NPP) and large precipitation variability. The affected regions are mainly cropping regions located in the northern highlands and in the central part of the Great Rift Valley. We consider these regions to be particularly prone to environmental changes; moreover, high population density places additional stress on local natural resources. Next, we identified districts in which high in-migration is coupled with both a strong decline in NPP and low rainfall variability, proposing that land degradation in these regions is likely to have resulted from human activity rather than climatic factors. The affected regions include parts of the Awash Valley, regions surrounding Lake Tana, and the mountainous regions between Addis Ababa, Bedele, and Jima. We found these hotspots of in-migration and land degradation are dominantly grasslands regions, which have been characterized by significant cropland expansion during the period studied. Whereas exploring causal relationships between migration, environmental change, and land cover change is beyond the scope of our study, we have pinpointed regions where these processes coincide. Our findings suggest that at the regional scale, deteriorating environmental conditions can be both the cause and the effect of migration.

Hermans-Neumann, K., Priess, J., & Herold, M. (2017). Human migration, climate variability, and land degradation: hotspots of socio-ecological pressure in Ethiopia. *Regional Environmental Change*, *17*(5), 1479-1492.

Integrated water resources management under climate change scenarios in the sub-basin of Abaya-Chamo, Ethiopia

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Abstract

In this study, the impact of climate change on surface water availability and its allocation system was carried out within Bilate watershed in the Abaya-Chamo sub-basin of Rift Valley Lakes Basin in Ethiopia. Predicted rainfall and temperature time series data were obtained from regional climate outputs of Coordinated Regional Climate Downscaling Experiment (CORDEX)-Africa for the three representative concentration pathways (RCP) scenarios (RCP2.6, RCP4.5, and RCP8.5) for the four time periods (2015–2020, 2021–2025, 2026–2030 and 2031–2035). The result revealed that the future maximum and minimum temperature can be increased during all three scenarios. However, precipitation showed an increase or decreasing trend in future scenarios at different time scales. Further, SWAT model was calibrated and validated to simulate the future streamflow under RCP2.6 and RCP8.5 scenarios. WEAP model was employed for integrated water resources allocations under selected climate change scenarios. The SWAT model performance was found satisfactory during calibration [correlation coefficient (R^2) = 0.77, Nash–Sutcliffe efficiency (NSE) = 0.755, percent deviation (D) = 2.558] and validation period (R^2 = 0.798, NSE = 0.778, D= − 3.93). The model output shows that there may be an annual decrease in flow upto − 12.1 and − 16.21% for RCP2.6 and RCP8.5 scenarios. The annual surface water availability was found to be 570 million cubic meter (MCM) in the Bilate watershed for the current accounted year 2015. However, the current utilization of these resources is very limited about 51.49 MCM (9.03%) in the basin including domestic, livestock and minor agricultural activities. Furthermore, four scenarios were developed based on different set of assumptions in the basin up to 2035. It was estimated that total annual consumption will be around 14.53, 20.43, 37.47 and 44.46% for the reference, scenario one, two and three, respectively. This study also determines the environmental flow requirements (25% of the mean annual flow volume) to maintain the basic ecological functioning in the basin and regulate flow for downstream uses. This study was found that integrated water resources management strategy in the basin could utilize water resources potential effectively in the future. Therefore, this study is useful for the different stakeholders in the study region for the optimal allocation of water resources under climate change scenarios.

Hussen, B., Mekonnen, A., & Pingale, S. M. (2018). Integrated water resources management under climate change scenarios in the sub-basin of Abaya-Chamo, Ethiopia. *Modeling Earth Systems and Environment*, *4*(1), 221-240.

Simulation of Hydro Climatological Impacts Caused by Climate Change: The Case of Hare Watershed, Southern Rift Valley of Ethiopia

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Abstract

Ethiopia will be more vulnerable to climate change. Because of the less flexibility to adjust the economic structure and being largely dependent on agriculture, the impact of climate change has far reaching implication in Ethiopia. Simulation models of watershed hydrology and water quality are extensively used for water resources planning and management. The study aims to Simulate Hydro Climatological impacts caused by Climate Change: the case of Hare Watershed, Southern Rift Valley of Ethiopia. In the study the daily data values of rainfall and discharge for the current period of 1980-2006 were used. Historical Representative Concentration Pathway (RCPs) data of precipitation and temperature were used to extract raw climate variables. The raw RCPs data were corrected using a bias correction method. The downscaled climate data such as, RCP4.5 and RCP8.5 scenarios was used for the future period assessment. Soil water assessment tool (SWAT) models were used to Simulate Hydro Climatological impacts caused by Climate Change. Calibration and validation of the model output were performed by comparing predicted streamflow with corresponding measurements from the Hare river outlet for the periods 1991-2002 for calibration and 2003-2006 for validation. The models' calibration results show a good agreement with the observed flow with the coefficient of determination is 0.85 and a Nash Sutcliffe efficiency is 0.73. The result of mean monthly percentage changes of climate variables from the baseline period were used to simulate future projections of stream flow. Stream flow projections for future time periods showed that mean monthly stream flow may increase by 12.2, 8.0, and 13.9% at 2020s, 2050s, and 2080s, respectively, from the baseline period for RCP4.5 scenario, whereas for RCP8.5 scenario, it will be expected to increase by 7.3, 13.4, and 15.4% for 2020s, 2040s, and 2080s, respectively.The model simulations considered only future climate change scenarios assuming all spatial data constant. But change in land use scenarios other climate variables will also contribute some impacts on future stream flow.

Keywords: Climate change; Climate projection; RCPs; Streamflow; Bias correction; Hare watershed

Menna, B. Y. (2017). Simulation of Hydro Climatological Impacts Caused by Climate Change: The Case of Hare Watershed, Southern Rift Valley of Ethiopia. *Hydrol Current Res*, *8*(276), 2.DOI: 10.4172/2157-7587.1000276

Recharge variability and sensitivity to climate: The example of Gidabo River Basin, Main Ethiopian Rift

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Abstract

Study region

Gidabo River Basin, located in the south eastern Main Ethiopian Rift (MER).

Study focus

The focus is to characterize the spatial and temporal variability of groundwater recharge, identify the drivers that govern its distribution, and to improve the understanding of its sensitivity to precipitation and temperature in the MER by applying the semi-distributed hydrological model, Soil and Water Assessment Tool (SWAT).

New hydrological insights for the region

The average annual recharge for 1998–2010 reveals a remarkable decrease from the highland (410 mm/year) towards the rift floor (25 mm/year). Both the spatial and temporal recharge variability is mainly controlled by the climate. In the rift floor, recharge is found to occur only when annual precipitation exceeds a threshold of approximately 800 mm. A sensitivity analysis reveals that annual recharge is very sensitive to variations in precipitation and moderately sensitive to temperature changes. The relative sensitivity increases from the highland to the rift floor across the watershed. Increases in both precipitation and temperature, as suggested by climate change projections for Ethiopia, appear to have an overall positive impact on recharge in the majority of the catchment. These findings have implications also for other catchments where recharge is spatially nonuniform and provide a basis for further investigations into the assessment of groundwater resources and their vulnerability to climate change at the watershed and sub-watershed scale.

Keywords: Recharge variability; Recharge sensitivity; Ethiopian rift; SWAT

Mechal, A., Wagner, T., & Birk, S. (2015). Recharge variability and sensitivity to climate: the example of Gidabo River Basin, Main Ethiopian Rift. *Journal of Hydrology: Regional Studies*, *4*, 644-660, https://doi.org/10.1016/j.ejrh.2015.09.001

Vegetation coverage changes driven by a combination of climate change and human activities in Ethiopia, 2003–2018

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Abstract

Climate change often leads to the vulnerability of vegetation cover, while the impact of human activities on vegetation cover is undoubtedly more complex in this context, especially in Ethiopia. This paper analyzed the spatiotemporal dynamics of vegetation growth in Ethiopia from 2003 to 2018 by the enhanced vegetation index (EVI) based on different time scales and explored the coefficient of variation and driving factors of the fractional vegetation coverage (FVC). The results indicated that the EVI mainly presents a "double peak" pattern, with large spatiotemporal differences between quarters and months in Ethiopia. The FVC increased by 0.0005 per year, but vegetation showed a browning trend after 2013. The FVC degraded area accounted for 43.9% of the total area, of which the significantly degraded area accounted for 7.51% due to human activities, mainly in northern, central, and southern Ethiopia. The effects of precipitation and maximum temperature on vegetation differed on time scales. Spatially, the vegetation on the northwest side of the Main Ethiopian Rift Valley (MERV) was dominated by a combination of maximum temperature and precipitation, while vegetation on the southeast side of MERV was mainly influenced by precipitation. However, the spatial overlay analysis with degraded and healthy vegetation zones revealed that human activities were the key driver of vegetation cover change rather than climate change. This study provides support for further development of vegetation health conservation policies in Ethiopia and monitoring of vegetation dynamics in other countries around the world.

Keywords: Fractional vegetation coverage; Ethiopia; Climate change; Human activity

Spatiotemporal dynamic

Yang, S., Song, S., Li, F., Yu, M., Yu, G., Zhang, Q., ... & Wu, Y. (2022). Vegetation coverage changes driven by a combination of climate change and human activities in Ethiopia, 2003–2018. *Ecological Informatics*, *71*, 101776.https://doi.org/10.1016/j.ecoinf.2022.101776

Spatial Analysis of Climate variability and Change in the Great Ethiopian Rift Valley Basins

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Abstract

The generally high temporal and spatial climate variability and change in most parts of Ethiopia, where rainfed farming is the main form of crop production, has been the main cause of food insecurity in significant areas of the country. Spatial variations in selected climate variables were investigated for the great Rift Valley regions of Ethiopia during the baseline (1981-2010) and projected (2021-2100) periods. Baseline climate data from 16 stations that represent different agroecology were obtained from National Meteorology Agency of Ethiopia (NMA) (http://www.ethiomet.gov.et). Corresponding projected data grided over 0.5^{o} X 0.5^{o} were retrieved from eight GCM-RCM combinations under two Representative concentration pathways (RCPs) from CORDEX database (http://www.cordex.org). First order Markov chain model was used for missing rainfall data filling. Coefficient of variation and standardized anomaly index descriptors were used in the analysis of climate data for each station. Spatial maps were then generated from station values using the ordinary kriging method of interpolation. The result indicated that rainfall of the study basins showed both spatial and temporal variabilities. The total annual rainfall showed variation in the year-to-year variability ranging from low in the southern half to high in the northern half of the basins. Seasonal rainfall showed high to very high variability which is challenging to rainfed agriculture. For the projected periods, majority of the climate models projected a decline in annual rainfall and increase in temperature. HadGEM2-ES_RCA4 model simulation suggested precipitation change varying from +4.2 to -16% and +3.8 to -18% for near period under RCP4.5 and RCP8.5 emission scenarios, respectively. Mean temperature is projected to rise from +0.7 to +1.25 ºC under RCP4.5 to +0.9 to +1.6 ºC under RCP8.5 across the GRVB in the near future and further warming was projected in the mid and end centuries. Rainfed crop production in the region, which is already impacted by the current climate variability, is likely to be further challenged with future climate change. As a consequence, specific impact -based adaptation strategies are essential to reduce the vulnerability of rainfed crop production in the area.

Keywords: Climate models, growing season, Rift Valley, seasonal water deficit, dry spell

Ademe, F., & Eshetu, M. (2021). Spatial Analysis of Climate variability and Change in the Great Ethiopian Rift Valley Basins, DOI: 10.7176/JEES/11-16-01

Multiple Indices Based Agricultural Drought Assessment in the Rift Valley Region of Ethiopia

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Abstract

Climate extreme like drought significantly affect the quality of the environment and threaten food availability in developing countries like Ethiopia. In this study, satellite-based agricultural drought assessments were conducted in the 0main crop growing season (June to September) using Landsat 8 images of five periods (2015 to 2019) in the Rift Valley Region of Ethiopia. To assess the agricultural drought we used Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST), Vegetation Condition Index (VCI), Temperature Condition Index (TCI), and Vegetation Health Index (VHI). The results indicate that the main crop growing season was experienced by drought and wet which vary from extremely dry to extremely wet. The value of VHI, the cumulative effects of TCI and VCI, revealed that 2016 was the most drought-prone while 2019 was the wettest year. Results of NDVI and LST showed a negative correlation. Results showed that drought was more severe in the lowland areas than highland areas in the study area. Accordingly, high drought was observed in the northern and central parts of the study area. It is obvious that the lowland areas face a precipitation deficit because of high temperature and evapotranspiration. This study suggests that satellite-based indices were crucial to provide early warning systems for the farming communities and to suggest adaptation options that minimize the potential impacts of agricultural droughts on people's livelihoods and wellbeing. Moreover, further research should be conducted by incorporating other social and biophysical factors to enhance the understanding of agricultural drought and its effect on the economy of the agricultural communities.

Keywords: Drought monitoring; Ethiopia; Multispectral; Vegetation health index

Wolteji, B. N., Bedhadha, S. T., Gebre, S. L., Alemayehu, E., & Gemeda, D. O. (2022). Multiple indices based agricultural drought assessment in the Rift Valley region of Ethiopia. *Environmental Challenges*, *7*, 100488,https://doi.org/10.1016/j.envc.2022.100488

Water Quality Threats, Perceptions of Climate Change and Behavioral Responses among Farmers in the Ethiopian Rift Valley

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Abstract

This work aims to assess water quality for irrigated agriculture, alongside perceptions and adaptations of farmers to climate change in the Main Ethiopian Rift (MER). Climate change is expected to cause a rise in temperature and variability in rainfall in the region, reducing surface water availability and raising dependence on groundwater. The study data come from surveys with 147 farmers living in the Ziway–Shala basin and water quality assessments of 162 samples from groundwater wells and surface water. Most groundwater samples were found to be unsuitable for long term agricultural use due to their high salinity and sodium adsorption ratio, which has implications for soil permeability, as well as elevated bicarbonate, boron and residual sodium carbonate concentrations. The survey data indicate that water sufficiency is a major concern for farmers that leads to frequent crop failures, especially due to erratic and insufficient rainfall. An important adaptation mechanism for farmers is the use of improved crop varieties, but major barriers to adaptation include a lack of access to irrigation water, credit or savings, appropriate seeds, and knowledge or information on weather and climate conditions. Local (development) agents are identified as vital to enhancing farmers' knowledge of risks and solutions, and extension programs must therefore continue to promote resilience and adaptation in the area. Unfortunately, much of the MER groundwater that could be used to cope with declining viability of rainfed agriculture and surface water availability, is poor in quality. The use of saline groundwater could jeopardize the agricultural sector, and most notably commercial horticulture and floriculture activities. This study highlights the complex nexus of water quality and sufficiency challenges facing the agriculture sector in the region, and should help decision-makers to design feasible strategies for enhancing adaptation and food security.

Keywords: climate change; perception; adaptation; irrigation water quality; agriculture; smallholder farmers; Ethiopia Rift Valley

Godebo, T. R., Jeuland, M. A., Paul, C. J., Belachew, D. L., & McCornick, P. G. (2021). Water quality threats, perceptions of climate change and behavioral responses among farmers in the Ethiopian Rift Valley. *Climate*, *9*(6), 92, https://doi.org/10.3390/cli9060092

Local level rainfall and temperature variability in drought-prone districts of rural Sidama, central rift valley region of Ethiopia

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Abstract

The purpose of this study is to examine local level spatiotemporal rainfall and temperature variability in drought-prone districts of rural Sidama, Central Rift Valley region of Ethiopia. The study used 129 gridded monthly rainfall and temperature data of 32 years (1983–2014). The gridded rainfall and temperature records were encoded into GIS software and evaluated through different statistical and geospatial techniques. Mann-Kendal rank test and F distribution tests were used to test temporal and spatial statistical significance, respectively, of the data. The analysis revealed that *Belg* and *Kiremt* are the main rainfall seasons, constituting 81% of the annual rainfall. Although annual, *Kiremt*, and *Belg* rainfall amounts appear to have decreased over time, the decreasing trend is statistically significant only for *Belg* rainfall records. On the other hand, rainfall standard anomaly results indicated seven droughts of different magnitudes: one extreme, two severe, and four moderate. The study also revealed increasing temperature trends over the years under consideration that are statistically significant. The findings of this study on rainfall contradict other findings obtained around the study area. Thus, climate change adaptations need to focus on location-specific climate data analysis so that the intended adaptive interventions can be successful.

Keywords: Rainfall; temperature; drought-prone districts; rural Sidama; central rift valley region; Ethiopia

Matewos, T., & Tefera, T. (2020). Local level rainfall and temperature variability in drought-prone districts of rural Sidama, central rift valley region of Ethiopia. *Physical Geography*, *41*(1), 36-53, https://doi.org/10.1080/02723646.2019.1625850

Modeling multivariate standardized drought index based on the drought information from precipitation and runoff: a case study of Hare watershed of Southern Ethiopian Rift Valley Basin

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Abstract

Drought is below-normal availability of rainfall, runoff, and or soil moisture for a prolonged period in a given region. Modeling drought index using multiple variables is important for future hydrological drought monitoring and sustainable water resource management. This study aimed to model multivariate standardized drought index (MSDI) based on the drought information from precipitation and runoff. Long year (1980–2014) monthly observed precipitation and runoff data were used to analyzed standardized precipitation index (SPI) and standardized runoff index (SRI) respectively. The best-fit copula family was selected to construct the joint probability distribution (JPD) of the SPI and SRI, and MSDI was developed. SPI, SRI, and MSDI at 6 and 12-month drought time scales were analyzed to characterize hydrological drought properties. The correlation among three drought indices (SPI, SRI, and MSDI) were analyzed using the Pearson correlation method. The goodness-of-fit test result showed that the Clayton copula was found the best-fitted copula function in describing JPD the two drought indices. The MSDI showed that the drought onset most likely similar to the SPI. Moreover, MSDI showed the maximum duration of drought occurred with varying severities about 26–28-months, while the duration of drought is extensive, but the frequency of drought less relative to SPI and SRI. The developed model, MSDI had a high correlation with SPI and SRI (R>0.7and$R$2>0.5,p∼0.0) compared to the correlation between SPI and SRI. Therefore, modeling hydrological drought using multiple variables is better than estimated with a single variable.

Yisehak, B., & Zenebe, A. (2021). Modeling multivariate standardized drought index based on the drought information from precipitation and runoff: a case study of Hare watershed of Southern Ethiopian Rift Valley Basin. *Modeling Earth Systems and Environment*, *7*(2), 1005-1017.

Effect of climate change on water availability in Bilate catchment, Southern Ethiopia

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Abstract

This study aims to evaluate the effect of climate change on water availability in the Bilate catchment, Southern Ethiopia. The bias-corrected outputs of five climate models and their ensemble mean were used for the baseline (1976–2005), the 2050s, and 2080s under Representative Concentration Pathways (RCP) for both RCP4.5 and RCP8.5 scenarios. A semi-distributed physically-based Hydrologic Engineering Center of Hydrologic Modeling System (HEC-HMS) was used to perform rainfall-runoff simulation after sensitivity analysis, calibration, and validation. The forecasted temperatures of the watershed will increase in the future. The forecasting from all the climate models indicated that rainfall of the watershed will increase by 34% in the 2050s and 21% in 2080s under RCP4.5 and RCP8.5 respectively. The discharge projection for almost all climate models shows an increment up to 27% whereas it will decline up to 30% under RCP 4.5 and RCP8.5 respectively in the 2050s. In the 2080s, nearly all climate models will show an increment up to 25% in discharge whereas it will decrease up to 32% under RCP4.5 and RCP8.5 respectively. This research paves the way to reduce the impacts of changing climate for sustainable water resources management.

Keywords: Water availability; Bilate watershed; Climate change; HEC-HMS; RCP

Edamo, M. L., Bushira, K. M., Ukumo, T. Y., Ayele, M. A., Alaro, M. A., & Borko, H. B. (2022). Effect of climate change on water availability in Bilate catchment, Southern Ethiopia. *Water Cycle*, *3*, 86-99, https://doi.org/10.1016/j.watcyc.2022.06.001

Climatic change recorded in the sediments of the Chew Bahir basin, southern Ethiopia, during the last 45,000 years

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Abstract

East African paleoenvironments are highly variable, marked by extreme fluctuations in moisture availability, which has far-reaching implications for the origin, evolution and dispersal of *Homo sapiens* in and beyond the region. This paper presents results from a pilot core from the Chew Bahir basin in southern Ethiopia that records the climatic history of the past 45 ka, with emphasis on the African Humid Period (AHP, ~15–5 ka calBP). Geochemical, physical and biological indicators show that Chew Bahir responded to climatic fluctuations on millennial to centennial timescales, and to the precessional cycle, since the Last Glacial Maximum. Potassium content of the sediment appears to be a reliable proxy for aridity, showing that Chew Bahir reacted to the insolation-controlled humidity increase of the AHP with a remarkably abrupt onset and a gradual termination, framing a sharply defined arid phase (~12.8–11.6 ka calBP) corresponding to the Younger Dryas chronozone. The Chew Bahir record correlates well with low- and high-latitude paleoclimate records, demonstrating that the site responded to regional and global climate changes.

Foerster, V., Junginger, A., Langkamp, O., Gebru, T., Asrat, A., Umer, M., ... & Schaebitz, F. (2012). Climatic change recorded in the sediments of the Chew Bahir basin, southern Ethiopia, during the last 45,000 years. *Quaternary International*, *274*, 25-37, https://doi.org/10.1016/j.quaint.2012.06.028

Performance evaluation of GPM-IMERG early and late rainfall estimates over Lake Hawassa catchment, Rift Valley Basin, Ethiopia

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Abstract

High resolutions of satellite rainfall products have been widely used for hydrometeorological and hydroclimatological studies over the globe. However, the performance of satellite rainfall estimates varies and is affected by topography and atmospheric characteristics. The assessment of satellite rainfall products is important over different regions. In this study, Integrated Multi-SatellitE Retrievals' performance for the Global Precipitation Mission version 6 (GPM-IMERG v6) was evaluated before and after bias correction, over the Lake Hawassa catchment. A linear scaling bias correction approach was used to correct the bias of GPM-IMERG early and late rainfall products. The satellite rainfall products were also compared with ground observed rainfall data in the Lake Hawassa catchment. Statistical performance assessing methods were used to evaluate both raw and bias-corrected IMERG early and late rainfall products. The percentage of bias (PBIAS) for early and late rainfall estimates was 91.54 and 77.03, respectively, for the entire periods before bias correction. It indicates that GPM-IMERG overestimated rainfall relative to ground-gauged rainfall. The results show that IMERG rainfall products are in good agreement with ground observed rainfall after bias correction. The correlation values (*R*) for IMERG early and late is 0.86 and 0.85, respectively, indicating a good correlation between IMERG's estimated rainfall and observed rainfall after bias correction. The performance of IMERG rainfall estimates varies with the seasons. The bias correction for only rainy season shows a good match with observed rainfall compared to all seasons. Bias-correction resulted in a good match between estimated and observed rainfall. Generally, evaluation of GPM-IMERG satellite rainfall products is essential prior to use for hydrological modeling and forecasting in data-scarce areas.

Kawo, N. S., Hordofa, A. T., & Karuppannan, S. (2021). Performance evaluation of GPM-IMERG early and late rainfall estimates over Lake Hawassa catchment, Rift Valley Basin, Ethiopia. *Arabian Journal of Geosciences*, *14*(4), 1-14.

Rainfall retrieval and drought monitoring skill of satellite rainfall estimates in the Ethiopian Rift Valley Lakes Basin

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Abstract

Satellite-based rainfall products are essential for retrieving rainfall, particularly in data-scarce and drought-prone countries like Ethiopia. However, their quality needs to be validated prior to their use. Therefore, we evaluated the performance of the Climate Hazards group Infrared Precipitation with Stations version 2.0 (CHIRPS), the Tropical Applications of Meteorology using Satellite data version 3.0 (TAMSAT3), and the African Rainfall Climatology version 2 (ARC2) satellite rainfall estimates in the Ethiopian Rift Valley Lakes Basin. Their skill of retrieval was evaluated against ground-measured rainfall at dekadal, monthly, and seasonal scales across agroclimatic zones over 2001 to 2017. Finally, these satellite products have demonstrated different levels of agreement with the reference data, being the highest for CHIRPS and the lowest for ARC2. At all timescales and agroclimatic zones, ARC2 has severely underestimated the actual rainfall while TAMSAT3 has persistently overestimated it. However, TAMSAT3 has demonstrated better performance than ARC2. Generally, except for its slightly larger dekadal false alarm ratio, CHIRPS has achieved the highest and most consistent agreement with the reference data at all the timescales and agroclimatic classes. Consequently, CHIRPS was further assessed for its suitability of drought monitoring, and it has exhibited promising skill in detecting specific historical drought events. Therefore, to overcome the scarcity of ground-measured rainfall data in the study area, we recommend the CHIRPS rainfall estimate to be used as an alternative data source for drought monitoring. Conversely, owing to its overestimation tendency, TAMSAT3 could be used for flood monitoring in this region

Tesfamariam, B. G., Melgani, F., & Gessesse, B. (2019). Rainfall retrieval and drought monitoring skill of satellite rainfall estimates in the Ethiopian Rift Valley Lakes Basin. *Journal of Applied Remote Sensing*, *13*(1), 014522, https://doi.org/10.1117/1.JRS.13.014522

Analysis of observed and perceived climate change and variability in Arsi Negele District, Ethiopia

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Abstract

Climate change and variability has been detected in Ethiopia. Smallholder and subsistence farmers, pastoralists and forest-dependent households are the most hit by climate-related hazards. They have to have perception of climate change in order to respond it through making coping and/or adaptation strategies. Local perceptions and coping strategies provide a crucial foundation for community-based climate change adaptation measures. This study was specifically designed to (1) assess households' perception and knowledge in climate change and/or variability, and (2) establish the observed changes in climate parameters with community perceptions and climate anomalies. Purposive stratified random sampling method has been used to gather information from 355 sample households for individual interviews supplemented by group discussion and key informants interviews. The analysis of observed and satellite climate data for the study district showed that mean maximum and minimum temperature for the period 1983–2014 has increased by 0.047 and 0.028 °C/year, respectively. However, the total rainfall has declined by 10.16 mm per annum. Seasonally, the rainfall has declined by 2.198, 4.541, 1.814 and 1.608 mm per annum for Ethiopian summer, spring, autumn and winter seasons, respectively. Similarly, the mean maximum temperature of the study area had showed an increment of 0.035, 0.049, 0.044 and 0.065 °C per year for spring, winter, autumn and summer seasons, respectively. The observed climate variation has been confirmed by people's perception. Considering what had been the existed situations before 30 years ago as normal, an increase in temperature, an increase in drought frequency, a decrease in total rainfall, erratic nature of its distribution and the tardiness of its onset had been perceived by 88, 70, 97, 80 and 94% of the respondents, respectively, at current time—2015. Deforestation as a casual factor of climate change and variability had been perceived by 99.7% of the respondents. This had been also confirmed by scientific studies as it emits carbon dioxide and is the main driver of climate change and variability. Indigenous knowledge, including climate predictions, has been used by people to implement their day-to-day agricultural activities. Therefore, science should be integrated with the perception and indigenous knowledge of people to come up with concrete solution for climate change and variability impacts on human livelihoods.

Mekonnen, Z., Kassa, H., Woldeamanuel, T., & Asfaw, Z. (2018). Analysis of observed and perceived climate change and variability in Arsi Negele District, Ethiopia. *Environment, Development and Sustainability*, *20*(3), 1191-1212.

Determinants of smallholder farmers' choice of coping and adaptation strategies to climate change and variability in the central highlands of Ethiopia

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Abstract

This study presents analysis of determinants of smallholder farmers' choice of coping and adaptation strategies to climate change and variability in the central highlands of Ethiopia. A distinction was made between coping and adaptation, as short-term responses to shocks and long-term responses to stressors, respectively. Binary logistic regression modeling was used based on a survey of 200 farmers. Socio-demographic, economic, biophysical, and institutional and infrastructural characteristics of the study setting and sample households were considered to identify key determinants of farmers' choice of coping and adaptation strategies. This is premised on the fact that understanding significant determinants of farmers' choice of coping and adaptation strategies is useful to design impactful adaptation interventions in the locality. The results showed that the significant factors affecting choice of adaptation strategies include perceived soil fertility status, perception of land tenure security, access to extension service, and ages of household heads. For the choice of coping options, agroecological zone, access to markets, farmer-to-farmer extension, landholding size, access to information on climate change, rainfall amount, and educational level of household heads were the significant determinants. Agroecological zone had negative influence to use selling livestock as coping strategy while the other variables had positive influences on farmers' choice of coping and adaptation strategies. Off-farm income, community participation, ownership of livestock and temperature on the other hand had no significant influence on the choice of coping and adaptation strategies to climate change. Adaptation planning for the study locality should take into account the potential influence of these determinant factors into account.

Alemayehu, A., & Bewket, W. (2017). Determinants of smallholder farmers' choice of coping and adaptation strategies to climate change and variability in the central highlands of Ethiopia. *Environmental Development*, *24*, 77-85, https://doi.org/10.1016/j.envdev.2017.06.006

Regionalization of catchments for flood frequency analysis for data scarce Rift Valley Lakes Basin, Ethiopia

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Abstract

Study region

Rift Valley Lakes Basin, Ethiopia

Study focus

We performed regionalization of catchments using K-means method based on variety of catchment characteristics and tested hydrological homogeneity of the regions using flood statistics. Following that, flood frequency analysis (FFA) for the identified regions was computed using regional flow data.

New hydrological insights for the region

Four hydrologically homogeneous regions were identified. Generalized extreme value (GEV), Lognormal (LN2), Wakeby, and Generalized Pareto (GP) were the best fitted distribution models for regions; one up to four respectively. Maximum likelihood was chosen as the most efficient parameter estimation method for regions two, three, and four, whereas the method of moment was chosen for region one. Region one contained one gauged catchment, therefore regression equation was not developed for this region. The linear regression between mean annual flood (MAF) and catchment characteristics performed well (R^2 = 0.827, 0.899 and 0.994) for regions two, three and four respectively. The relative errors between observed and estimated MAF in the pseudo ungauged catchments resulted 0.511, 0.039 and 0.166 for regions two, three and four respectively. Hence, the developed regional frequency curves and regression equations can be used for flood estimation at the required return period (T) in the homogeneous regions of the basin.

Keywords: Rift Valley Lakes Basin; Regionalization; Flood frequency analysis; Regression equation

Kebebew, A. S., & Awass, A. A. (2022). Regionalization of catchments for flood frequency analysis for data scarce Rift Valley Lakes Basin, Ethiopia. *Journal of Hydrology: Regional Studies*, *43*, 101187, https://doi.org/10.1016/j.ejrh.2022.101187

Evaluating spatial and temporal variations of rainfall erosivity, case of Central Rift Valley of Ethiopia

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Abstract

Land degradation in many Ethiopian highlands occurs mainly due to high rainfall erosivity and poor soil conservation practices. Rainfall erosivity is an indicator of the precipitation energy and ability to cause soil erosion. In Central Rift Valley (CRV) of Ethiopia, where the climate is characterized as arid and semiarid, rainfall is the main driver of soil erosion that in turn causes a serious expansion in land degradation. In order to evaluate the spatial and temporal variability of rainfall erosivity and its impact on soil erosion, long-term rainfall data (1980–2010) was used, and the monthly Fournier index (FI) and the annual modified Fournier index (MFI) were applied. Student's *t* test analysis was performed particularly to examine statistical significances of differences in average monthly and annual erosivity values. The result indicated that, in a similar spatial pattern with elevation and rainfall amount, average annual erosivity is also found being higher in western highlands of the valley and gradually decreased towards the east. The long-term average annual erosivity (MFI) showed a general decreasing trend in recent 10 years (2000–2010) as compared to previous 20 years (1980–1999). In most of the stations, average erosivity of main rainy months (May, June, July, and August) showed a decreasing trend, whereby some of them (about 33.3 %) are statically significant at 90 and 95 % confidence intervals but with high variation in spatial pattern of changes. The overall result of the study showed that rainfall aggression (erosivity) in the region has a general decreasing trend in the recent decade as compared to previous decades, especially in the western highlands of the valley. Hence, it implies that anthropogenic factors such as land use change being coupled with topography (steep slope) have largely contributed to increased soil erosion rate in the region.

Meshesha, D. T., Tsunekawa, A., Tsubo, M., Haregeweyn, N., & Adgo, E. (2015). Evaluating spatial and temporal variations of rainfall erosivity, case of Central Rift Valley of Ethiopia. *Theoretical and Applied Climatology*, *119*(3), 515-522.

Water Resources Allocation Systems under Irrigation Expansion and Climate Change Scenario in Awash River Basin of Ethiopia

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Abstract

Rational allocation of water resources is very essential to cope with water scarcity. The optimal allocation of limited water resources is required for various purposes to achieve sustainable development. The Awash River Basin is currently faced with a scarcity of water due to increasing demands, urbanization, irrigation expansion, and variability of climates. The excessive abstraction of water resources in the basin without proper assessing of the available water resources contributed to water scarcity. This paper aimed to develop a water evaluation and planning (WEAP) model to allocate the water supplies to demanding sectors based on an economic parameter to maximize the economic benefits. The water demands, water shortages, and supply alternatives were analyzed under different scenarios. Three scenarios were developed, namely reference (1981–2016), medium-term development (2017–2030), and long term development (2031–2050) future scenarios with the baseline period (1980). The results of this study showed that the total quantity of water needed to meet the irrigation demands of all the stations was 306.96 MCM from 1980 to 2016. Seasonally, March, April, May, and June require the maximum irrigation water demand. However, July, August, and September require minimum demand for water because of the rainy season. The seasonal unmet demand is observed in all months, which ranged from 6 × 106 m3 to 35.9 × 106 m3 in August and May respectively. The trend of streamflow in Melka Kuntre was a statistically significant increasing trend after 2008 (Z = 5.33) whereas the trends in other gauge stations showed a relatively decreasing trend. The results also showed that future water consumption would greatly increase in the Awash River Basin. The prevention of future water shortages requires the implementation of water-saving measures and the use of new water supply technologies. The findings of this study will serve as a reference for water resources managers and policy and decision makers.

Keywords: water allocation; WEAP model; scenario; climate change; Awash River Basin

Gedefaw, M., Wang, H., Yan, D., Qin, T., Wang, K., Girma, A., ... & Abiyu, A. (2019). Water resources allocation systems under irrigation expansion and climate change scenario in Awash River Basin of Ethiopia. *Water*, *11*(10), 1966. doi:10.3390/w11101966

Climate change posed agricultural drought and potential of rainy season for effective agricultural water management, Kesem sub-basin, Awash Basin, Ethiopia

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Abstract

The Intergovernmental Panel on Climate Change concluded that climate has changed over the past century and the trend is anticipated to continue in the future. This study examines climate change posed drought and potential of rainy season rainfall in Kesem sub-basin. Rainfall variability is examined using statistical descriptors. Also, the onset and cessation dates, length of growing season, and probability of dry and wet spell are analyzed using INSTAT Plus software. On the other hand, long-term drought is analyzed using reconnaissance drought index. Rainfall variability result showed high coefficient of variance (CV) of 46.8 to 179.2% on monthly and 39.1% on annual basis. The mean duration of the main rainy season is 91 days with standard deviation of 18.5 days and CV of 20.4%. The probability of dry decade in the main rainy season is more than 50% for the 16th to 18th and 25th to 27th decades. Whereas probability occurrences of dry decades preceded by dry decades were more than 50% for decades 16th to 18th and 23th to 27th. Potential evapotranspiration showed increment of 25.9 mm from the base period for RCP 4.5 (2020) and 26.7 mm for RCP 8.5 (2020), and 55 mm for RCP4.5 (2050) and 56.8 mm for RCP8.5 (2050). Regarding the long-term drought, there were 9.7% extreme, 6.5% severe, 3.2% moderate, and 48.4% mild drought on the basis of observed data. The inter-annual variability of growing seasons, probability occurrence of dry decade, and drought during growing season are revealed. So, policymakers need to consider supplementary irrigation for crops in the area because there are high probability occurrences of dry decades.

Yadeta, D., Kebede, A., & Tessema, N. (2020). Climate change posed agricultural drought and potential of rainy season for effective agricultural water management, Kesem sub-basin, Awash Basin, Ethiopia. *Theoretical and Applied Climatology*, *140*(1), 653-666.