

Abstract

The Tana River basin (TRB) is both vulnerable and prone to hydrological extremes of floods and droughts. Yet, the TRB is an extensive agricultural area that also contributes to more than half of Kenya's hydropower production. The basin is thus a contributor to the population's food security in this region and to Kenya's economy in general. This calls for proper understanding of the basin's hydrometeorology as a means of managing and mitigating the impacts of the extremes mentioned above. This PhD study contributes to a qualified and improved knowledge of the basin's atmospheric-terrestrial water balance. This is achieved through the application of the regional climate model Weather Research and Forecasting (WRF) and the coupled WRF-Hydro modeling system to this area. The WRF model's ability to reproduce the 4-year (2011-2014) precipitation and temperature basin's climatology is analysed. The simulation results are compared with Tropical Rainfall Measuring Mission (TRMM), Climate Hazards Group Infrared Precipitation with Station data (CHIRPS), Climate Research Unit (CRU), Global Land Evaporation Amsterdam Model (GLEAM) and station data. Further, the uncoupled WRFHydro model is calibrated in order to identify a set of parameters in which it can mimic the hydroclimatology of the upper TRB. The calibration is based on stream flow data from the Tana Rukanga's river gauge station (RGS) 4BE10 at the outlet of the delineated Mathioya-Sagana subcatchment (3279 km²). The WRF's model ability to reproduce the TRB's 4-year precipitation and temperature climatology is investigated in two stages: the identification of suitable configuration of set of parameterizations and the better configuration based on the impact of two different land use classifications i.e., the Moderate Resolution Imaging Spectroradiometer (MODIS) and the U.S Geological Survey (USGS) at two horizontal resolutions (50 km and 25 km). The parameterizations investigated are three cumulus convection schemes: Kain-Fritsch (KF), Grell Freitas (GF) and Bett Miller Janjic (BMJ); two microphysics schemes: WRF Single Moment 6-class (WSM6) and Lin et al. (LIN) while other schemes are uniform for all the 6 configurations. The KF, WSM6, ACM2 (KWA) configuration provides more reasonable results in simulating the seasonal and annual amounts of precipitation. In case of temperature all the considered six configurations simulate similar results with a cold bias compared to both station and CRU temperature. The land-use impact-based experiments show that all WRF simulations capture well the annual as well as the interannual and spatial distribution of precipitation in the TRB according to station data and the TRMM estimates. The results show that by increasing the horizontal resolution of the WRF model from 50 km to 25 km, together

with the use of the MODIS land use classification, a significant improvement in the precipitation results can be achieved. However, in the case of temperature, there is no discernible difference between the various experiments. In general, the WRF model reproduces reasonably the spatial patterns and seasonal cycle with a systematic cold bias with respect to both station and CRU data. The results from this study thus contribute to the identification of suitable and regionally adapted regional climate models (RCMs) for East Africa. The WRF and coupled WRF-Hydro simulations focusing on the Mathioya-Sagana subcatchment at 5 km horizontal resolution show good results in terms of precipitation, streamflow and evapotranspiration ET. The simulated precipitation is slightly closer to that derived from CHIRPS than TRMM. For ET, the WRF and coupled WRF-Hydro captures the temporal evolution of GLEAM dataset, although with some underestimation. The coupled WRF-Hydro accumulated discharge (323 mm/yr) is very close to that of observed discharge (333 mm/yr), however with a low but acceptable Nash-Sutcliffe efficiency (NSE) equal to 0.02 and a good ratio of the root mean-square error to the standard deviation of measured data (RSR) of 0.99 at daily time step. Finally, a method is developed to investigate the joint atmospheric-terrestrial water balance of the Mathioya-Sagana subcatchment based on the WRF and WRF-Hydro simulations. The analysis shows that the coupled WRF-Hydro slightly reduces precipitation, evapotranspiration and the soil water storage, but increases runoff, as compared to WRF. The precipitation recycling and efficiency measures between WRF and coupled WRF-Hydro are very close and comparatively small. This suggests that most of the precipitation in the region comes from moisture advection from the outside of the analysis domain, so that potential land-precipitation feedback mechanisms may have only small impacts in this region.