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Discussions

# *Interactive comment on* "Analysis of the combined and single effects of LULC and climate change on the streamflow of the Upper Blue Nile River Basin (UBNRB): Using statistical trend tests, remote sensing landcover maps and the SWAT model" *by* Dagnenet F. Mekonnen et al.

**Dagnenet F. Mekonnen et al.**

dagnfenta@yahoo.com

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Short comments by Dr Elagib elagib@hotmail.com

Page 1 lines 18 to 19. "The LULC change detection findings indicate the conversion of forest land to cultivated land during the period 1973-2010". Comment Analysis of systematic transitions in Jedeb (Teferi et al. 2013), and Tana & Beles (Woldesenbet et al. 2017a) indicated that cultivation land is gained mainly from open grazing land



though natural forest coverages is decreased over times.

Reply from authors: In this study, systematic transition analysis of LULC was not carried out as it is not our primary objective. However, the study result revealed that cultivated land increased and forest coverage decreased from 1973 to 2010 while the other LULC classes remained unchanged or the change is not significant.

Page 1 line 19. "Natural forest decreased from 17.4% to 14.4%, 12.2% and 15.6%" Comment What does 'Natural forest' here means, only natural or does it include plantations? There is a significant area that has undergone eucalyptus plantation, especially at upstream sub-catchments.

Reply from authors: correction accepted and correction will be made on the revised manuscript. Plantation can be on a large scale for afforestation or on small plots as household woodlots for fuel wood, construction material, for charcoal production as a means of income generation. However, community plantations are rarely of sufficient size to distinguish on the image and allow representation of forest. Other large scale plantations were mapped as forests from which they are distinguishable on the images. Hence, Natural forest includes both natural and eucalyptus plantation.

Page 1 lines 23 to 25. "The single effect of LULC change on streamflow analysis suggested that LULC change significantly affects surface run-off and base flow. This could be attributed to the 5.1 % reduction in forest coverage and 4.6% increase in cultivated land." Comment Woldesenbet et al. (2017a) indicated that cultivation land and woody shrubs at Tana and Beles watersheds are the main LULC classes which are significantly affecting surface runoff and groundwater components.

Reply from authors: In this study, the classification was carried out on the basis of the main landcovers (cultivated land, forest land, bushes and shrubs and water). As shown in the LULC change detection analysis, the area coverage of bushes and shrubs remained unchanged or the change is insignificant. Hence, in this study, the change for surface runoff and base flow could be due to the change in forest coverage and cultivated land coverage.

Page 2 lines 3 to 4. "The direct and indirect impacts brought by both LULC and climate change exacerbate the water scarcity of the Nile basin as they are the key factors that can modify the hydrology and water availability of the basin." Comment As your trend analysis for streamflow indicated significantly increasing trend during observed period, how come water is scarce due to LULC and climate change?

Reply from authors: In this study, we carried out both streamflow and rainfall trend analysis only for Upper Blue Nile River Basin (UBNRB), which is less than 5.2 % of the area coverage of the Nile basin. According to (Philip J. et al., 2016), in the year of 2012, 257 million people live within the Nile Basin boundary and the population of Nile Basin countries grew by over four fold in 50 years between 1960 and 2010. As a result, the demand for food, energy and water has been escalating. Per capita water availability has been declining as the population has grown exponentially. For instance, on average 82 Billion Cubic Meter (BCM) of water is withdrawn from Nile waters every year for irrigation. The Growing agricultural production will further increase pressure on land and water resources. The total water demand for Municipal and Industrial uses has been estimated at 12,900 MCM per year for the whole Nile Basin. Population in the Nile basin riparian states is estimated to nearly double by 2030,as a result domestic water demand is expected to grow fivefold during the same period, water demand for irrigation is also expected to increase. It is well known that the temporal and spatial distribution of the rainfall of the Nile basin is highly variable as a result the hydrology of the basin is exhibiting highly seasonal flows. So, storage facilities are needed t to have stable flow but significant water will be lost due to evaporation. At present, on the average an estimated 17.6 BCM of water evaporates from major dams in the Nile Basin(Philip J. et al., 2016).

Under a high Representative Concentration Pathway (RCP), temperature is expected to rise between 3oc to 6 oC at the end of 21st century across much of Africa while projected rainfall change over sub-Saharan Africa in the mid- and late 21st century is



uncertain (IPCC, 2014). As a result of temperature rising more water will be lost due to evaporation and irrigation water requirement will increase . Therefore, the increasing trend of streamflow of the UBNR cannot be a guarantee for water availability of the Nile basin, while water demand continues to rise steadily due to population growth and economic development and due to climate change.

Page 2 31 to 34. "Although, substantial progress has been made in assessing the impacts of LULC and climate change on the hydrology of UBNRB, most studies focused on single aspects i.e., either analysing the statistical trend of precipitation and streamflow or analysing impacts of single factor LULC or climate change on the flow (Gebremicael et al., 2013; Rientjes et al., 2011; Tekleab et al., 2014). Impacts by combined effects of LULC and climate changes are not well understood because their contributions are difficult to separate and vary regionally (Yin et al., 2017)." Comment A very recent study by Woldesenbet et al. (2017a) has assessed the impacts of individual LULC classes on water balance components for Tana and Beles sub-basins. This study is totally overlooked in the present discussion manuscript. Not only combined effect of historical LULC and climate changes, but also combined impacts of future LULC and climate change are not well reported in the upper Blue Nile Basin.

Reply from authors: correction accepted. We found that the mentioned manuscript reinforces the discussion and improve the quality of the paper. We have cited this paper in our revised manuscript.

Page 4 lines 12 to 18. "The soil map developed by the Food and Agriculture Organization of the United Nations (FAO-UNESCO) at a scale of 1:5,000,000 downloaded from (http://www.fao.org/soils-portal/soil-survey/soil-mapsanddatabases/faounesco-soil-map-ofthe-world/en/) was used for SWAT model. The soil information such as soil textural and physiochemical properties needed for the SWAT model was extracted from Harmonized World Soil Database vl.2, a database that combines existing regional and national soil information (http://www.fao.org/soilsportal/soil-survey/soilmaps- and-databases/harmonized-world-soil-databasevl2/en/) in combination with..” Comment Worqlul et al. (2018) indicated that accurate spatial information of soil data is significant in hydrological modeling of LULC change. Federal Ministry of Water Irrigation and Electricity of Ethiopia has better soil map. Besides, the soil physical parameters could also be incorporated from many recent irrigation and hydropower design reports in the basin.

Reply from authors: We understand that the Ministry of Water Irrigation and Electricity of Ethiopia has prepared better soil map. However, it missed soil physical parameters which are crucial for SWAT. If our study was focused on Tana and Beles sub-basins, it would not be a problem to collect soil physical parameters from recently studied irrigation and hydropower design reports, as many of these projects are located in these sub-basins. In our case, it is hardly possible to collect such information from design reports and from measurements due to the large area coverage of the study area and lack of sufficient design reports across the basin. Previous study done by Polanco et al. (2017) used the same sources of soil information for the same study area and achieved good results, which suggests the usefulness of FAO soil map and the Harmonized World Soil Database.

Page 4 lines 23 to 24. “Filling missed or gap records was the first task for any further meteorological data analysis. This task was performed using the inverse distance weighing (IDW) and regression methods, the best performed method was chosen ..” Comment Poor station network and missing records of significant length are one of the problems of meteorological data in the study region. For this region, Woldesenbet et al. (2017b) suggested that the coefficient of correlation method is better than the inverse distance weighting method for filling in gaps in daily rainfall and temperatures. They also indicated that the rainfall and temperature data are not satisfying the preconditions for using multiple linear regressions.

Reply from authors: In this study, spatial interpolation such as the inverse distance weighting method (IDWM) and linear regression techniques (LR) were used for filling gaps as it is mentioned in the manuscript on page 4, L22-24. Similar methods were



also applied in many other studies such as by Uhlenbrook et al. (2010) for the Gilgel Ababy sub-basin of the study area. The selection and quantity of adjacent stations are critically important to the accuracy of the estimated results. As mentioned by Woldesenbet et al. (2017), different authors used different criteria to select neighboring stations. A geographic distance of 100 km were considered to select neighboring stations due to the poor station network. If no station is located within 100 km of the target station, the search distance is increased until the minimum of one suitable station is reached. After the neighboring stations were selected, the two methods (IDWM and LR) were tested to fill in missing hydro-meteorological datasets. The performance of the candidate approaches was evaluated using the statistical metrics such as root mean square error (RMSE), mean absolute error (MAE), correlation coefficient (R2) and Nash-Sutcliffe efficiency coefficient (NSE). Equally weighted statistical metrics is applied to compare the performance of selected approaches at target stations to establish ranking. A score was assigned to each candidate approach according to the individual metrics; e.g. the one achieving the smallest RMSE and MAE, or NSE, has got score 1, and so on. The final score is obtained by summing up the score pertained to each candidate approaches at each stations. The best method is the one having the smallest score.

Page 8 lines 23 to 29. “Finally, after classifying the raw images of Landsat into different landcover classes, change detection which requires the comparison of independently produced classified images (Sing, 1989) was performed by the post-classification method. The post-classification change detection comparison was conducted to determine changes in LULC between two independently classified maps from images of two different dates.” Comment Systematic transition from one LULC classes, net gain, losses and swap (Teferi et al. 2013) might help to understand the changes from one LULC classes to another rather than comparing percentage changes in individual LULC classes (which does not indicate spatial changes).

Reply from authors: As it is clearly indicated the on page 4, L9-13 of the manuscript, the main objective of the study is not to detect the systematic transition of LULC change but rather to detect the combined and single effect of LULC and climate change on streamflow. Hence, we did not carry out a systematic transition of LULC classes as it has no significant impact on our objective. Thank you for your understanding. Your comments are indeed good points. We will add them in our revised manuscript

Page 13 lines 14 to 16. "The highest gain in bushes and shrubs was (0.3%) from 1973 to 1985, while the highest gain in forest coverage (3.4%) was recorded during the period 1995-2010. Water coverage remained unchanged from 1973 to 2010." Comment This might be due to eucalyptus plantation at homestead for fuel consumption or construction poles.

Reply from authors: correction accepted. Yes, it is clearly mentioned in the manuscript on page 19 L4-L9 "The increased forest coverage and the reduction in cultivated land over the period 1995 to 2010 shows that the environment was recovering from the devastating drought and the reduction of forest clearing for firewood and for cultivation due to population growth. This could be due to the afforestation programme initiated by the Ethiopian government. As a result, eucalyptus plantation at homestead level significantly increased for fuel consumption or as income generating goods (for construction material, producing charcoal) ".

Page 13 lines 18 to 19 "The increased forest coverage and the reduction in cultivated land over the period 1995 to 2010 shows that the environment was recovering from the devastating drought and forest clearing for firewood and cultivation due to population growth." Comment Besides, farmers start converting cultivation land to eucalyptus plantation (See Teferi et al. 2013; Woldesenbet et al. 2017a).

Reply from authors: accepted and correction will be made in the revised manuscript.

Page 13 lines 21 to 25. "To summarize, during the period from 1973 to 2010, forest coverage declined by 1.8%, with both bushes and shrubs, as well as cultivated land increasing by 0.8% and 1% respectively from the original 1973 level. This result agrees



well with other local level studies (Gebrernicael et al., 2013; Rientjes et al., 2011; Teferi et al., 2013), which reported the dramatic changes in the natural vegetation cover resulting from the agricultural land." Comment Another recent study (Woldesenbet et al. 2017a) is overlooked.

Reply from authors: accepted and corrected. We will add this in the revised manuscript.

Page 16 lines 28 to 30. "The combined results from three different approaches, namely statistical trend test, semi-distributed SWAT modelling and LULC change analysis, are consistent with the hypothesis that LULC change has modified the run-off generation process, which has caused the increase in streamflow of the UBNRB while the climate has remained unchanged." Comment In fact, the climate of Lake Tana and Beles watersheds have become wetter and warmer for the period 2010-2013 (Woldesenbet et al. 2017b).

Reply from authors: accepted and corrections will be made in the revised manuscript. Studies carried out in the UBNRB such as Mengistu et al. (2014) confirmed that at the annual scale, maximum and minimum temperatures significantly increased in over 33% of the Basin (in northern, central, southern and southeastern parts) at a rate of 0.1 and 0.15 °C per decade, respectively. So, we will correct it in the revised manuscript.

Page 17 lines 2 to 5. The limitation of this study could be due to the uncertainty of the SWAT model, as the SWAT model does not adjust CN2 for slopes greater than 5%, which could be significant in areas where the majority of the area has a slope greater than 5%, such as UBNRB. Therefore, we suggest adjusting the CN2 values for slope > 5% outside of the SWAT model for further research. Comment The steeper the slope, the higher the CN2. On one hand, adjusting the CN2 values for slope greater than 5 % might increase the values of CN2. On the other hand, intensive terracing on the basin might counterbalance the increase in CN2 due to steeper slopes.

Reply from authors: The hypothesis could be true but regretfully we cannot prove the hypothesis as it is beyond the scope of this study. This is a good and very interesting issue to investigate in another future study. Thank you very much.

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