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Comment on hess-2021-151

M. van Noordwijk (Referee)

Referee comment on "Land use and climate change effects on water yield from East African forested water towers" by Charles Nduhiu Wamucii et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-151-RC1, 2021

General

1. The manuscript provides an interesting comparative study of the 'water towers' in East Africa and the change in terms of a simple water balance that can be inferred from a combination of various spatial data sources

2. The description of the quantitative framework can be improved, including a more consistent use of acronyms (especially for actual evapotranspiration) and equations
3. The study relies heavily on the use of a link between NDVI and the omega parameter in the Budyko framework, while the text acknowledges many factors (including soil, topography and seasonality) influence the relationship. At least in the discussion this needs some further work to see how much this could have influenced results and conclusions.

4. The eight water towers are most described as 'replicates', rather than each having a specific geographic, ecological and social context: this may be the limit of what is currently possible, but at least some of the contrasts noted call for further analysis and attribution (e.g. in relation to human population density within and surrounding the water tower.

5. It would help the paper if sharper questions would be formulated at the end of the introduction that gives structure to the subsequent discussion

6. Beyond the supply of blue water to downstream parts of the watershed, the high actual evapotranspiration in water towers plays a role in regional rainfall recycling -- at least some discussion of this aspect would be relevant.

Minor
p1, Line 17 Mention 'steady state' assumption of Budyko framework at an annual time scale
p1, Line 24 'non-resilient' suggests a binary classification, is there a more gradual description on the degree of resilience
p1, Line 29 but mountains also cause 'rainshadows' that don't get the rainfall they might have had without the presence of a mountain...

p1, Line 31 more quantitative criteria are needed to get the type of delineation that you use here
p1, Line 34 in glaciated mountain chains water flow depends primarily on temperature, without ice cap on recent rainfall -- so the temporal variability will differ and dependence on land cover increase
p1, Line 35 'receive' is a rather passive description -- isn't it 'convert atmospheric moisture into rainfall'
p1, Line 37 Some reference to Africa as geologically old shield, but rift valley plate tectonics are associated with younger and higher mountains
p1, Line 39-40 If you introduce more quantitative P/Epot criteria in line 31, this discussion on E African water towers becomes more meaningful, as it relates to both the P and the Epot side of the ratio.
p1, Line 41 rainfall distribution is meager? what do you mean
p1, Line 42 Early work on rainfall in Sudan (El Tom, 1972) showed that the standard deviation of annual rainfall is nearly independent of mean annual value, showing that dry areas are highly variable in relative terms, with decadal variation super-imposed (Hulme, 1990) and not easily distinguishable from trended global climate change.

p2, Line 5 Please unpack the sentence
p2. Line 6 Possibly relevant: ET estimates for SS Africa
p2, Line 8 For corrections on common deforestation discourses, see Aleman et al. 2018
p2, Line 16 The methods of Ma et al. 2010, 2014 combine these two categories by running rainfall statistics and recorded land-use change patterns in reverse order in calibrated process-based models
P2 Line 22 Maybe mention the steady state assumptions at annual time-scale upfront. A simple equation might help here.
p2 Line 26 It would help the subsequent discussion if you formulate some clear questions here that you try to answer in the results section
P2 line 30 if you want to avoid use of 'we', please find a less abstract passive formulation...

Fig. 1 As 'montane forests' and 'water towers' only partially overlap, please give the quantitative definitions of both;
Public discussion on the Mau forests in Kenya described these as 'water towers', you don't; again clarifying the quantitative criteria can help

Table 1 In the Dewi et al. water tower delineation no fixed contour was used for the delineation, but one relative to the watershed as a whole. Please clarify your choice here, esp regarding the two (Aberdare and Bale) that were adjusted to the surrounding areas...

p3 Line 11 Here you seem to shift from PET to ET or ETa -- the preceding paragraph only mentions Epot.
p3 Line 14 This section may be clearer if you first present a water balance equation...
p3 Line 17 Deserts tend to have wadi's -- even in zones with low average rainfall, runoff occurs and rainfall intensity exceeds instantaneous infiltration capacity. Your Budyko-based description here needs some empirical adjustment (and scale considerations)
p3 Line 17 Not only under very dry conditions... About 50% of tropics has a P/PET ratio below 0.65; only a quarter has P/PET above 1.0
p3 line 31 Fu in stead of FU
p3 Equation 1 -- please specify the time step (1 year?)
Wouldn't it be better to include a DeltaS storage term, and then make explicit that you assume this is zero at the time scale of your analysis (but this is a considerable source of uncertainty and error...)
Fig 1A please settle on a single acronym for AET = ETa = ET
p3 Line 37 The seasonality effect is linked to the DeltaS term that you're hiding...
p4 line 6 As this is an empirical result, please describe the data set on which it was

calibrated (from which it was derived)
p4 Line 8 So what about other influences on omega (soil types, and topography, climate seasonality, ...) that you just mentioned? You assume that these are at the average values in the Li et al. dataset? This will require some further justification, especially as you operate in the relatively rare bimodal rainfall part of the world.
p4 Line 17 Please remove ;
p4 line 12 Please indicate what you treat as 'known' inputs here and what as parameters to be estimated
p4 Line 36 So the EIBud is based on the NDVI relationship? It would help if you give more formal definitions of the terms here
p4 Line 6 Is the DeltaEI here the same as d in Eq 5?

p5 Wouldn't it be easier and more informative to present the ETa/PET ratios?

p7 line 1 where omega values 'observed'? maybe 'derived'

Fig 7 How can Q estimates of 1000 mm/year be obtained for places with P hardly above 1000 mm/year?

p14 Discussion: A clearer structure of the discussion is needed.
p14 Line 19 As you used NDVI data, you used land cover rather than land use change as basis...
p14 Line 21 The sensitivity to land cover change reflects the limited degree of actual change (due to existing institutional arrangements) rather than the lack of response if such rules would be relaxed. Please distinguish these two aspects.
p14 line 24. An alternative to describing deviations along the Y axis (vertical) is to attribute them along the X-axis (horizontal): would such an approach be feasible?
p14 Discussion: Can you imagine doing the same analysis on the basis of ET/PET ratios attributed to NDVI, rather than the more complex Budyko route that involves P in the estimation of omega?
p14 Line 27: what do you mean by naturally occurring oscillations in this context? Does the occurrence of fire (partially anthropogenic) play a role: it changes NDVI for one or more years, increasing water yield; it may be more common on e.g. Mt Kenya and in the Imatong mountains
p15 Line 4 Please clarify 'resilience' as bouncing back in relation to 'elasticity' that refers to the degree of initial change, rather than its temporal dimension.

p15 line 10 Isn't this a consequence of the way water towers are defined?

Suggested additional references

Aleman, J.C., et al. 2018. Forest extent and deforestation in tropical Africa since 1900. Nature ecology & evolution, 2(1), pp.26-33.
El Tom, M.A., 1972. The reliability of rainfall over the Sudan. Geografiska Annaler: Series A, Physical Geography, 54(1), pp.28-31.
Hulme, M., 1990. The changing rainfall resources of Sudan. Transactions of the Institute of British Geographers, pp.21-34.
Ma, X. et al. 2014. Attribution of climate change, vegetation restoration, and engineering measures to the reduction of suspended sediment in the Kejie catchment, southwest China. Hydrology and Earth System Sciences, 18(5), pp.1979-1994.
Ma, X. et al. 2010. Sensitivity of streamflow from a Himalayan catchment to plausible changes in land cover and climate. Hydrological Processes: An International Journal, 24(11), pp.1379-1390.

Marshall, M. et al. 2013. Improving operational land surface model canopy evapotranspiration in Africa using a direct remote sensing approach. Hydrology and Earth System Sciences, 17(3), pp.1079-1091.