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Interactive comment on "Climate change, re-/afforestation, and urbanisation impacts on evapotranspiration and streamflow in Europe" *by* Adriaan J. Teuling et al.

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Note to the editor and authors: As part of an introductory course to the Master programme Earth & Environment at Wageningen University, students get the assignment to review a scientific paper. Since several years, students have been reviewing papers that are in open online discussion for Copernicus Journals, and the top students in the class have been asked to submit their reports to the discussion in order to help the review process. While these reports are written in the form of official (invited) reviews, they were not requested for by the editor, and we leave it up to the editor and authors to use these reports to their advantage. We hope that these reports will posi-

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tively contribute to the scientific discussion and to the quality of papers published. This report/review was supervised by Prof. Wouter Peters.

Introduction

The paper of Teuling et al. (2019) elaborates on the new gained insight of the impacts of decadal changes in climate and land use on the amount and distribution of water resources availability across Europe since the 1950s. Therefore, the Budyko model was combined with a high-resolution historical land use reconstruction and a gridded observation of key meteorological variables to simulate the distribution of green and blue water. Overall the simulations agree well with the observations. According to Teuling et al 2019, the results show strong shifts in continental-scale patterns of evapotranspiration and streamflow since the 1950s.

Overall merit

It is an engaging paper. Until now assessments of past and future changes in streamflow have either focused on land use, climate contributions or on smaller catchments under particular climate conditions. The combined method, used in this paper, checks the boxes of relevance and novelty and is therefore an addition to existing literature. The advantage of understanding past and future changes in water availability is that it can contribute to better water resources management and planning. The authors state that land use impacts and climate change impacts, should be accounted for in future to prevent regional over or underestimation of changes in water availability. The paper focuses on the understanding of the impacts of changes in climate and land use on the amount and distribution of water resources availability, which addresses to the scope of HESS (Hydrological and Earth System Sciences).

Overall, the paper is well written. The methods, results and discussion have a clear structure and are easy to follow. The different sections are described in a thorough manner to support their argumentation, without loosing themselves in the details. Although the paper is of quality, some choices in the methodology are in my opinion not

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yet up to standard and are in need of adjusting or clarification. Therefore, some major and minor revisions are requested before acceptance. These are elaborated in the next section.

Critique

Major arguments

The first major comment is about the Thornthwaite method mentioned on page 5 line 1. It is used for calculating PET and requires only the temperature as input (Thornthwaite, 1948). Since there is a warming trend since the 1950s, this choice of method is questionable. Multiple studies, such as Trajkovic and Kolakovic (2009), have found that the radiation-based methods more accurate reproduce reference PET than temperature-based methods. Fisher et al (2011) mention that temperature based models estimated 20–30% less than the radiation based models averaged across all their researched sites. It was even stated: "The choice of evapotranspiration model and input data is likely to have a bearing on model fits and predictions when used in analyses of species richness and related phenomena at geographical scales of analysis" (Fisher et al., 2011). Shaw and Riha (2011) state that the Priestley–Taylor equation (a primarily radiation-based model) consistently explained more of the variation in PET than temperature-based methods. The paper of Teuling et al (2019) acknowledges that Thornthwaite method does not always gives the strongest increase in PET values in a warming climate. Considering that the paper aims to understand the effect of climate change on green and blue water fluxes, the effect of a warming trend on the calculated PET values should not be overlooked. The temperature-based PET values will affect the main part of the paper, since it in used in the Budyko model to determine how the average precipitation is portioned between evapotranspiration and streamflow. To improve the quality of the paper, please switch to a radiation based model or add substantial argumentation, on why they picked the Thornthwaite method to calculate the PET over radiation-based methods.

The second major comment is about the observations in this study, which come from lysimeter stations according to P5 Line 23. These lysimeters are assumed to behave similar to landscape elements of 10e6 m2. The locations of these stations, are not evenly spread throughout Europe but mainly constrained central-west, as can be seen in Fig A1. The model forcing is based on interpolated observation from weather stations. The paper states that local land cover impacts on climate, such as enhanced temperature or cloud formation, should not be represented in the forcing dataset. The stations should indeed be carefully selected. WMO (2003) states “Observations of evapotranspiration should be representative of the plant cover and moisture conditions of the general surroundings of the station”. Still, the interpolation of lysimeter stations should be representative for the whole of Europe, can this be achieved if the stations are only concentrated in the central-west? It can result in incorrect values near the edges of the maps of Fig 2-7. Please expand the amount and the spread of lysimeter stations or otherwise show the statistics to support the used method.

The third major comment is about the temporal scale. In the method section on page 7 (line 7) it was stated that changes over the intermediate 10-year periods (1955–1965 and 2005–2015) were analysed. It was stated “the trends were generally found to be monotonic”. Therefore they calculated 10-year climate averages. These were used to force the Budyko model and calculate changes in evapotranspiration and water yield, so it influences the main part of the paper. The simulated continental scale patterns depend on these 10-year climate averages. The choice of words on line 9: “the trends were generally found to be monotonic” raises questions. What were the exceptions? Did this choice of temporal scope have significant effect on the calculated changes in evapotranspiration and water yield? As Zang et al (2004) states, the climatic variables precipitation, temperature, solar radiation and humidity have a large spatial en temporal variability. They interact with the catchment characteristics such as vegetation cover, which is of interest for Teuling et al. Therefore, please choose a smaller temporal scale in which the trends are all found to be monotonic or show the statistics of the trends over the 10-year periods to verify the choice to average them.

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The fourth major comment is about correlation mentioned on page 8 line 9. The paper mentions that their approach is able to reproduce the overall pattern of observed changes in streamflow. It was stated “In spite of the difference in units and the fact that individual basins might have shorter record lengths, the correlation in trends between the basins is 0.34.” However, a correlation of 0.34 leaves room for questions, is this correlation sufficient? It means that a large part of the data remains unexplained. The paper states that, the validation shows that their simplified approach is able to capture continental-scale patterns in mean and changes of blue and green water fluxes. Can the correlation of the pattern of observed changes in streamflow be improved by adjusting the input, such as the PET values calculated with a radiation-based model (Considering my first comment)? Please change in input to optimize the correlation or show more elaborate statistics and argumentation on why this correlation is sufficient.

Minor Arguments

P1 Line 5: Please replace the term ‘green and blue water fluxes’ with evapotranspiration and streamflow, to make it understandable without having to read the introduction.

P8 Line 24: simulated ET is shown in figure 5b while it is referenced to 5a

P8 Line 25: Observed ET is shown in figure 5a while it is referenced to 5b

P9 Line 25: Table 3 list the Europe-wide changes not table 2

P12 Line 1: Change ‘Therefor’ into Therefore

P11 Line 3: ‘WMO recommendations’ please include a reference

P21 Fig 1: needs revising and clarification:

a. The caption does not fully describe what is displayed in the figure. Please elaborate on the w* values.

b. Yellow line is hardly noticeable, consider changing it to another colour to improve readability

c. The legend on the left indicates the colours orange, light and dark green. However, it does not include red and yellow, what do those colours indicate?

d. In the end of the results, it was mentioned that the colours indicate the forest stand age, this should also be mentioned in the caption

e. The caption should include describing the grey dashed line as energy limit, to improve the understandability.

P23 Fig 3: needs revising and clarification:

a. The missing values (NA) are indicated by the colour white, however white is already used to indicate another fraction. This brings confusion what the colour is indeed indicating. Please indicate the missing values with another colour.

P24 Fig 4: needs revising and clarification:

a. Fig 4b and 4d indicate the change for evapotranspiration and streamflow. The change is indicated with green and blue colours to match the evapotranspiration (green) and streamflow (blue). They mention in the caption that they chose to reverse the colour scheme on purpose. However, it works confusing and counterintuitive. My recommendation is to choose a different colour scheme's to match the change in both the figures, without green and blue, to avoid confusion.

P25 Fig 5: needs revising and clarification:

a. In P8L24 and P8L25 there are references to figure 5, I mention below that they reference to the wrong part of the figure. However, one can also consider keeping the reference in that way, and change the order in the figure. In 5a and 5c the observation-based ET are shown and in 5b and 5d the simulated ET is shown. When the simulated ET figures are switched to the left, it will fit more clearly in the story line.

References:

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