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Reply on RC2

Johannes Larson et al.

Author comment on "Predicting soil moisture conditions across a heterogeneous boreal catchment using terrain indices" by Johannes Larson et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-560-AC2, 2022

Author response to Referee 2

Introduction comment from Referee #2: The manuscript rigorously compared the prediction of soil moisture maps via Digital terrain analysis. To this end, the authors made predictions using nine different terrain indices in combination with the available soil wetness maps, at varying resolutions and user-defined thresholds, with a field dataset of soil moisture registered in five classes from a forest survey covering a boreal landscape in Sweden.

It's a cliched but intriguing research topic with new findings that perfectly align with the journal's scope. The manuscript is generally well-written; however, brevity and flow are missing which makes it rather verbose. The artwork is legible and flawless. However, I have some minor concerns regarding some sections.

Author's response: Thank you Referee #2 for providing constructive criticism and suggestions which will improve the next version of the manuscript. In regards to the flow of the brevity of the text we will adjust this in the revised manuscript. Our responses to all the comments of Referee #2 are listed below. All comments from Referee # 2 have been included in this document, followed by our response.

Referee #2: The manuscript neither identifies the gap broadly in the scientific knowledge nor adds new knowledge to the overall body of scientific understanding. The novelty is based on the fact two recent studies (Abowarda et al., 2021; Ågren et al., 2021) of the same nature study area (Sweden) were flawed because the selected model for high-resolution terrain indices was restricted to 16000 plots and 28 maps, while the latter used machine learning which is prone to a vague combination of multiple resolutions and thresholds. Please further elaborate and align the flaws in the direction of gaps which you have covered by this study.

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Author's response: In regards to the comments from Referee #2 about the identification of the knowledge gap addressed in this study we understand the referee's remarks.

Referee #2 mentions two studies using Machine learning for soil moisture mapping, one across Sweden (Ågren et al. 2021) and one in China (Abowarda et al. 2021). Thanks to the remarks from Referee #2 we realize that we should clarify the knowledge gap further and the aim of our study. In regards to the above mentioned studies we see that in the growing field of machine learning there is a need of more process-based understanding of the underlying implications that DEM resolution, user-defined thresholds and parent material have on different terrain indices before making the selection of terrain indices to use. Choosing the wrong index, resolution or threshold can result in incorrect predictors, which we show in our study. With this study and approach using a small study area we can visualize the need to test the performance of terrain indices within any study area of interest. The usefulness and optimal resolutions and user-defined thresholds will depend on the landscape one chooses to study. Whilst the studies cited have accurate mapping of soil moisture as the aim, we wanted to understand the underlying effects of the variables often put into soil moisture mapping models. We suggest to add the following sentences in the revised manuscript:

Line 79-82: ' Due to the large applications, wide uses and availability of terrain indices there is a need of understanding the underlying effects of DEM resolution, user-defined thresholds and landscape types have on the modelled results. Using terrain indices to model soil moisture conditions on inappropriate scales and landscape types may result in inaccurate predictions.'

Referee #2: The abstract is general, please explain your robust findings to the readers as a take-home message.

Author's response: We have revised our abstract and suggest the following:

Line 7-23'**Abstract.** Soil moisture has important implications for drought and flooding forecasting, forest fire prediction and water supply management. However, mapping soil moisture has remained a scientific challenge due to forest canopy cover and small-scale variations in soil moisture conditions. When accurately scaled, terrain indices constitute a good candidate for modelling the spatial variation of soil moisture conditions in many landscapes. In this study, we evaluated seven different terrain indices at varying digital elevation model (DEM) resolutions and user-defined thresholds as well as two available soil moisture maps, using an extensive field dataset (398 plots) of soil moisture conditions registered in five classes from a survey covering a (68 km^2) boreal landscape. We found that the variation in soil moisture conditions could be explained by terrain indices and the best predictors within the studied landscape was Depth to water index (DTW) and a machine learning generated map. Furthermore this study showed a large difference between terrain indices in the effects of changing DEM resolution and user-defined thresholds which severely affected the performance of the predictions. For example the commonly used Topographic wetness index (TWI) performed best on a resolution of 16 m while TWI calculated on higher than 4 m DEM resolutions gave inaccurate results. In contrast the Depth to water (DTW) and Elevation above stream (EAS) were more stable and performed best on 1-2 m DEM resolution. None of the terrain indices performed best on the highest DEM resolution of 0.5 m. In addition this study highlights the challenges caused by heterogeneous soil types within the study area and shows the need of local knowledge when interpreting the modelled results. The results from this study clearly demonstrate that when using terrain indices to represent soil moisture conditions, modelled results need to be validated, as selecting unsuitable DEM resolution or user-defined threshold can give ambiguous and even incorrect results. **'**

Referee #2: Please explain the freezing temperature range, duration, minimum tree height

and canopy cover as this feature explain the boreal forests.

Author's response: We agree with Referee #2 that the paper would benefit from a more detailed site description. We suggest to add the following two sentences in the site description:

Line 98-99: 'Due to forest management, Krycklan is a complex mosaic of forest stands of different age classes and species composition.'

Line 94-97: 'The climate is characterized as a cold temperate humid type with persistent snow cover during the winter season (Laudon et al., 2020). The 30 year mean annual temperature (1986-2015) is 2.1°C, with the highest monthly mean temperature in July and lowest in January (14.6 and -8.6 respectively). The mean annual precipitation equals 619 mm where more than 30% falls as snow.'

Referee #2: The discussion must be strong enough to support your findings. In its current form, it way weak and only convinces the readers regarding the consistency of findings with previously observed results. Please focus on the differences in climate, landscape types and soil texture, and terrain indices.

Author's response: Thank you Referee #2 for providing constructive criticism and suggestions which will improve the next version of the manuscript. We suggest adding the following sentences to clarify the implications of our findings in relation to previous studies.

Line 392-394: 'No previous study has been able to provide such detailed data at catchment scale, amount of terrain indices in combination with an extensive field survey which clearly demonstrates the importance of selection of terrain index, DEM resolution and index-specific thresholds.'

Line 419-424: 'However, this is in contrast to a recent study by (Riihimäki et al., 2021) where they thoroughly investigated the effect of DEM resolution and flow accumulation algorithms on TWI calculations in a 300 ha area of the northwestern Fennoscandian mountain tundra. Their conclusion was that Dinf reached its maximum explanatory power at 3 m resolution. This highlights that the optimal DEM resolution for predicting soil moisture conditions using TWI cannot just be taken from literature as it varies from site to site and it's necessary to investigate the optimal resolution for each landscape.'

Line 461-467: This study highlights the necessity of adapting soil moisture predictions to local soil conditions. These underlying factors need to be taken into consideration when modelling soil moisture conditions on any level from catchment, regional and national scale. One such attempt was the SLU soil moisture map which was constructed for the entire country of Sweden using vast amounts of field data from 16 000 field-plots across the country as training data and several digital terrain indices at multiple resolutions and thresholds. Even so, when evaluated on the Krycklan catchment the SLU soil moisture map ranked second among the top predictors for soil moisture (Figure 2 and 3) and did not outperform several of the more simple terrain indices.

Line 484: We, therefore, stress the importance of evaluating the modelled terrain index results for the area of interest and not extrapolating the optimum terrain indices for our study areas directly or to blindly use the DEM of the highest resolution available.

Referee #2: Figs. 2 and 3 are excellent but I would suggest combining these two figures for convenience. It will help the readers to understand the performance of each index. Similarly, please explain all details of the concerned figure once and all, the switching confuses the readers.

Author's response: We understand the remarks from Referee #2, however we believe figure 2 already contains the amount of information that a reader can grasp. The figures would also need to be named a) and b) and, would therefore in our opinion, not change the issue raised by the referee. We leave it up to the editor to decide if the figures are sufficient as they are in the preprint.