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## Reply on RC1

Johannes Larson et al.

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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-AC1>, 2022

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### Author response to Referee 1

**Referee #1 introductory comment:** The paper by Larson and colleagues deals with the important aspect of predicting soil moisture classes in a study catchment in Sweden. In general, the paper is well written and properly structured and the methods that the authors used to derive various terrain indices are sound. Also worth commending is the large number of field observations  $n = 398$  which were used in the statistical analysis.

**Author's response:** We thank Referee #1 for the overall positive comments. Our responses to all the comments of Referee #1 are listed below in the order they appear.

**Referee #1:** A concern for me, however, is the use of the term 'soil moisture' throughout the manuscript. Soil moisture and soil moisture classes are not the same thing, in my opinion. Soil moisture is a soil property with both a spatial (lateral and vertical) and a temporal dimension. The soil moisture classes that the authors used (described in line 105 – 133) have only a spatial (and only lateral) dimension. It is therefore rather a mapping unit or a soil association than a soil property.

**Author's response:** We appreciate the concern raised by Referee #1 regarding the use of the term soil moisture. To clarify that we mean soil moisture conditions we suggest to change the title from "soil moisture" to "soil moisture conditions". We will also suggest clarifying the use of the term soil moisture/soil moisture conditions in the introduction and method section (see following comments).

Line 84-87: 'We did this by examining which digital terrain index provided the best prediction of field determined soil moisture classes within a heterogeneous but well-studied landscape in the boreal region, the Krycklan Catchment study (Laudon et al., 2020).'

**Referee #1:** The qualitative description of the soil classes also appears to be biased e.g.,

possible to walk over and keep dry feet...shortly after snowmelt. Surely this will depend on the size of the person and how long 'shortly' is. Also, the topographic descriptions of the soil moisture classes are raising questions about potential *circular reasoning*. How important are these topographic attributes in determining the soil moisture class? If they are a key determining factor, then surely you are not assessing whether the terrain indices are predicting soil moisture, but rather are the terrain indices able to predict *terrain indices*. So, in my opinion, the authors did not predict soil moisture, making the title and a lot of the discussion misleading.

**Author's response:** In relation to the previous comment Referee #1 raises concern about the definitions of the soil moisture classes. This is understandable in the current state of the manuscript. We have failed to describe that it is foremost the estimated average depth to groundwater during the vegetation period which determines the soil moisture class. This should be clearly stated in the first section of the description of the soil moisture field classification. To clarify this we suggest the following additions:

Line 117-122: 'Soil moisture classes were registered in the field following the protocol of the Swedish national forest inventory (NFI) (Fridman et al., 2014), based on an estimation of each plot's average depth to groundwater level during the vegetation period estimated from its position in the landscape, vegetation patterns and soil type. This approach reduces the discrepancies caused by seasonal variation and provides an indicator of the general soil moisture conditions, which is the focus of this study. Survey plots were categorized into five classes dry, mesic, mesic-moist, moist and wet, which are described and presented below and can be found in more detail in the field instruction (Swedish NFI, 2014).'

Referee #1 also observantly raises concern regarding the potential of "*circular reasoning*". The depth to groundwater table was estimated with guidance from surrounding topography, eventual presence of groundwater in small depressions, soil types and vegetation. This system is an established method and more detailed descriptions can be found in the field handbook of the Swedish national forest inventory which we now cite above. The descriptions in the text of the previous version are more of a general description of the soil moisture classes and not what determines the classification on site. We see our error here and hope that our adjusted version and added citation will be satisfactory. Thanks to Referee #1 we suggest to further develop the short soil moisture class descriptions with emphasis on the groundwater level as follows:

Line 124-150:

- Dry soils have an average groundwater table more than 2 metres below the soil surface. They tend to be coarse-textured and can be found on hills, eskers and ridges. The soils are mainly leptosols, arenosols, regosols or podzols (with thin organic and bleached horizons).
  
- Mesic soils have an average groundwater table between 1-2 metres below the soil surface. Podzol is the dominating soil type with a thin (4-10 cm) organic mor layer covered mainly by dryland mosses (e.g. *Pleurozium schreberi*, *Hylocomium splendens*, *Dicranum scoparium*). They can be walked on dry-footed even directly after rain or shortly after snowmelt.

- Mesic-moist soils have an average groundwater table depth less than 1 metre. Mesic-moist areas are often located on flat ground in lower lying areas, or lower parts of hillslopes. The soils tend to wet up on a seasonal basis. Whether you can cross in shoes and remain with dry feet depends on the season and the time since the last heavy rain or snow melting event. Patches of wetland mosses (e.g. Sphagnum sp., Polytrichum commune) are common and trees commonly tend to grow on humps. Podzols are commonly found, but often with a thicker organic layer compared to mesic sites. The organic layer is often classified as peaty mor.
- Moist soils have an average groundwater table depth less than 1 metre. The groundwater table is often visible in depressions. Areas classified as moist are found on lower grounds, at the lowest parts of slopes and flat areas below larger hills. One can cross in shoes and keep one's feet dry by utilizing tussocks and higher lying areas. When stepping in depressions, water should form around the feet even after dry spells. The vegetation includes wetland mosses (e.g. Sphagnum sp., Polytrichum commune, Polytrichastrum formosum). Trees often grow on small mounds and the soil type is most often histosol, regosol or gleysol.
- Wet soils are areas where the groundwater table is close to the soil surface and permanent pools of surface water are common. These areas are often located on open peatlands. Drainage conditions are very poor and it is not possible to cross these areas in shoes without ending up with wet feet. Coniferous trees only seldom develop into stands. The soil type is most often histosol or gleysol.'

Line 404-407: 'We used field-mapped soil moisture classes based on estimated depth to groundwater from the soil surface guided by surrounding topography and vegetation patterns as a proxy for average soil moisture conditions, thus reducing the uncertainty associated with the large temporal and small-scale spatial variability of soil moisture'

**Referee #1:** With this being said, the prediction of soil moisture classes (soil associations) is still novel, and the paper makes a contribution to international literature. An important outcome is that a finer detailed DEM does not necessarily imply better predictions of soil moisture classes.

**Author's response:** We thank Referee #1 for these positive comments

**Referee #1:** The article would benefit by adding an improved description of the climate under section.

**Author's response:** We agree with Referee #1 that the paper would benefit from a more detailed description of the climate. We suggest to add the following three sentences:

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.'