General comments:

In my opinion, the most concrete contribution that the study can make is to identify and provide key spatial and temporal predictors for data-driven models used in soil moisture mapping. While this aim and contribution is relevant and briefly mentioned, it would benefit from being more explicitly emphasized and clarified throughout the manuscript, particularly in the abstract, introduction, and discussion. Strengthening these sections could better position the study within the broader context of soil moisture research and mapping.

It remains unclear whether the study contributes to understanding the processes driving soil moisture variability. Therefore, it is also doubtful whether the study offers a contribution to the development of physically based models. Such models already incorporate key spatial (e.g., vegetation, soil texture, topography) and temporal (e.g., meteorological forcing) factors, and the manuscript does not address how the findings could enhance these models. Perhaps the authors could emphasize the need for more accurate field and remote sensing data on the identified variables, which could indirectly benefit physically based model approaches that rely on such data.

Although this study may not directly advance our understanding of the processes driving soil moisture variability, the identification of key predictors, many of which are already incorporated in physically based models, presents an opportunity for the authors to discuss how these different methods (process-based and data-driven) could be integrated for soil moisture mapping (e.g. hybrid approaches).

The amount of predictors and scales is impressive, but there are still many limitations to this study (as to any study). It is not a major problem, but the limitations need more attention in the discussion. For instance, topographic and tree shading is neglected, the spatial scales go only up to 30 or 64 m, and temporal extend was only a few months, just to name a few.

RC2.1: We thank Referee #2 for these valuable suggestions.

a) We will more clearly emphasize the aim and concrete contribution of this paper in the abstract, introduction, and discussion to better position our study within soil moisture research and mapping.
b) We acknowledge that our study does not focus on the mechanisms driving soil moisture but rather on identifying key spatial and temporal predictors for data-driven models. As noted in RC1.2a, we will reduce the emphasis on processes and provide concrete examples (e.g., enhanced soil maps) of how our findings could benefit both data-driven and physically based approaches.
c) This is an interesting point. We will expand the discussion to explore potential synergies between data-driven and process-based methods in the context of soil moisture mapping.
d) We will discuss the key study limitations, including the omission of microclimate spatial predictors (RC1.4, RC1.11) and the restriction of our analysis to only one incomplete snow-free season (RC2.4). Additionally, we will directly address the lack of topographic shading by incorporating it into the analysis (see RC1.2b, RC2.9b).

Specific comments:

L33-34: Please add reference to “influence soil nitrogen availability”

RC2.2: The reference to Nogovitcyn et al. (2023), which is already cited in the main text, covers both “soil nitrogen availability” and “needle production”.

L36-39: It would help to have example reference to each of these applications that require soil moisture state.

RC2.3: Thanks for the observation. We have already included references for all the mentioned applications at the end of the sentence (L38-39), with each reference covering one or more applications. To improve clarity, we can either add more references or explicitly match each reference to its corresponding application.

L77-80: This is a good point that topography can have a major role in the early summer. In this study, you basically skipped the period impacted by snowmelt. How do you think the results would differ if full snow-free season was included?

RC2.4: As suggested, we will address this point when discussing the key study limitations (see RC2.1d). Indeed, topography is likely to play a more significant role after snowmelt in our study area as well.

L83-84: I don’t quite understand this sentence. You already described how the impact of topography changes between wet and dry seasons. Perhaps you mean that this may change within the season as well. This could be reformulated. Also please add references to the recent research you’re referring to.

RC2.5: As both Referee #2 and Referee #1 (see RC1.9) highlight, this sentence is unclear. Most studies suggest that topography has a stronger influence on soil moisture during wet periods and a weaker influence during dry periods (L77-83). However, recent research challenges these findings, showing cases where topographic metrics remain equally strong or even become more important during dry periods, or where their influence stays consistently low during wet periods (L83-86). To improve clarity, we will rephrase the sentence as follows: “However, recent research suggests that the influence of topography on soil moisture does not always follow this pattern.” Alternatively, we may integrate this sentence with the following one for better readability. The references for the recent research we are referring to are already included (L85-86).

L135: How were the soil moisture locations decided? They mostly fall in the intensitve monitoring area. How much of them are on peat soils? How much in mineral? Why this subset of the measurements?

RC2.6: We appreciate Referee #2’s comment. As noted in RC1.12, we did not use a formal sampling strategy (e.g., random or stratified sampling) but followed key principles outlined in L137-141. Our primary goal was to mirror the distribution of soil moisture conditions representative of Swedish forests (please see RC1.12 for a more detailed explanation and a graphic visualization). To achieve this, we placed about half of the loggers in the highly heterogeneous central part of the Krycklan catchment. Some loggers were positioned near permanent stations for comparison between different measurement systems, while the rest were distributed to balance spatial coverage and accessibility. We will revise the manuscript to clarify the selection process and add details on the proportion of loggers in peat versus mineral soils. This will also be visible in new supplementary figures showing land cover and soil information in relation to logger locations. (see RC1.3b and RC2.9).

L137: I was surprised not to see any fully saturated measurements on peat soils (peat soil porosity is around 0.90). Were there no peatlands (or peatlands with measurements) where the water table was near the surface? Hence, I don't think these measurements "capture the full spectrum of soil moisture levels across the Swedish landscape."

RC2.7: Thanks for this observation. Our loggers were placed across a wide range of soil moisture conditions, including very wet peat soils with water tables near the surface. However, our measurements of volumetric water content (VWC) range from 0 to 0.60 rather than 0 to 1 because VWC accounts for the total volume of soil, including solid particles, water, and air. Even in fully saturated peat, VWC does not reach 100% because soil particles occupy a portion of the total volume. The observed maximum values (~60%) are consistent with expectations for saturated peat soils, considering their high porosity (~90%) and the inherent structure of organic material. To clarify this point, we will refine our description in the methods section and/or in the caption of Figure 2.

L167.: While citing for details is understandable, it would be good to elaborate a bit more on how the topographic indices were defined. For example, it makes a difference which method is used (e.g. D8 vs. Dinf). Please describe also the site quality index.

RC2.8: We thank Referee #2 for pointing this out. As the definition of variables – not only the topographic indices but also all other predictors – is a major shared concern with Referee #1 (see RC1.2b and RC1.3a), we will provide a detailed description of each variable in the supplement, including the methods used to calculate the topographic indices. This will ensure transparency and accuracy, allowing readers to interpret the results correctly.

Sect. 2.2.2: Please consider adding spatial predictor figure in supplement. It would give the reader a better idea how the landscape looks like. It is an impressive number of predictors, but one obvious one is missing: topographic shading.

RC2.9: Thanks for the suggestions.

a) We agree that adding maps illustrating some of the predictors would provide a better spatial context for the study landscape. As suggested by Referee #1, we will include supplementary maps of topography, vegetation, land cover, and soil (see RC1.3b).
b) Both Referee #2 and Referee #1 (RC1.2b) identified topographical variation in solar radiation, including the effect of topographic shading, as an important variable that is currently missing. Therefore, we will rerun the analysis with this additional variable and revise the manuscript accordingly.

Sect. 3.2. repeats many of the things already described in the methods (Sect. 2.3., which is great by they way). Perhaps the chapter in 3.2. can be integrated to 2.3.?

RC2.10: Thanks for this comment. In Section 2.3, we provide the statistical background of the OPLS analysis, describe the different models created, and outline the metrics used for evaluation. In Section 3.2, however, our focus is on the visualization aspect, helping readers interpret the figures by explaining plot elements such as shapes, colors, and loading positions. This prevents repetitions when describing the results in the following subsections and is particularly useful for readers unfamiliar with the method. We believe that placing this explanation at the beginning of the results section, where the OPLS plots are presented, enhances readability. However, we acknowledge the reviewer's concern and will refine the text to improve conciseness and avoid redundancy between sections 2.3. and 3.2.

L349: What is a vegetation period? Analysis starts from July something, growing season starts earlier.

RC2.11: This is a good point. Indeed, the growing season starts earlier in Krycklan, making the term not entirely appropriate in this case. As mentioned in RC1.5, we will instead use broader terms like "study period" or "summer." When more detail is needed, we will specify "three snow-free months in 2022."

L370: "forest boreal landscape" -> "boreal forest landscape"

RC2.12: Thanks for identifying this mistake. We will make the correction accordingly.

L394: Kemppinen et al. study site (tundra) is quite different to Krycklan.

RC2.13: We thank Referee #2 for the comment, which echoes a remark from Referee #1 (RC1.19). As noted earlier, we will revise this sentence to avoid a direct comparison between the two study areas (L393-397).

L420: Consider replacing "performed poorly" with "correlated poorly with soil moisture" or something similar.

RC2.14: As suggested, we will replace "performed poorly" with "showed weak correlation with soil moisture."

Code and data availability: Better practice would be to share the data in an openly available repository. Or has the data already been shared in the cited literature?

RC2.15: We appreciate this suggestion. The data for nearly all variables used in the analysis have already been made publicly available in the cited literature. The only exceptions are the field data from SLU (2021) and the soil moisture data from the TOMST loggers. We will create a data repository for these two datasets and update the data availability statement accordingly.