

# A signature-based approach to quantify soil moisture dynamics under contrasting land-uses

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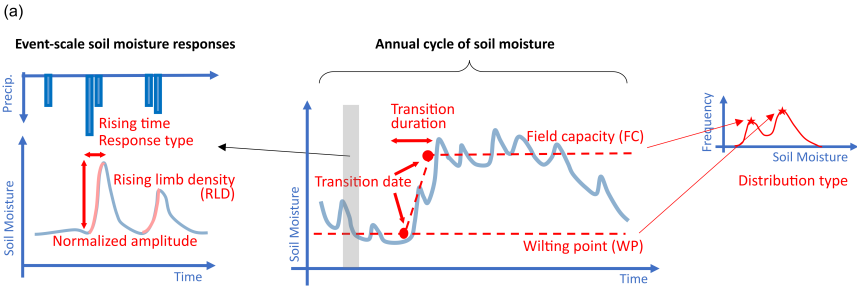
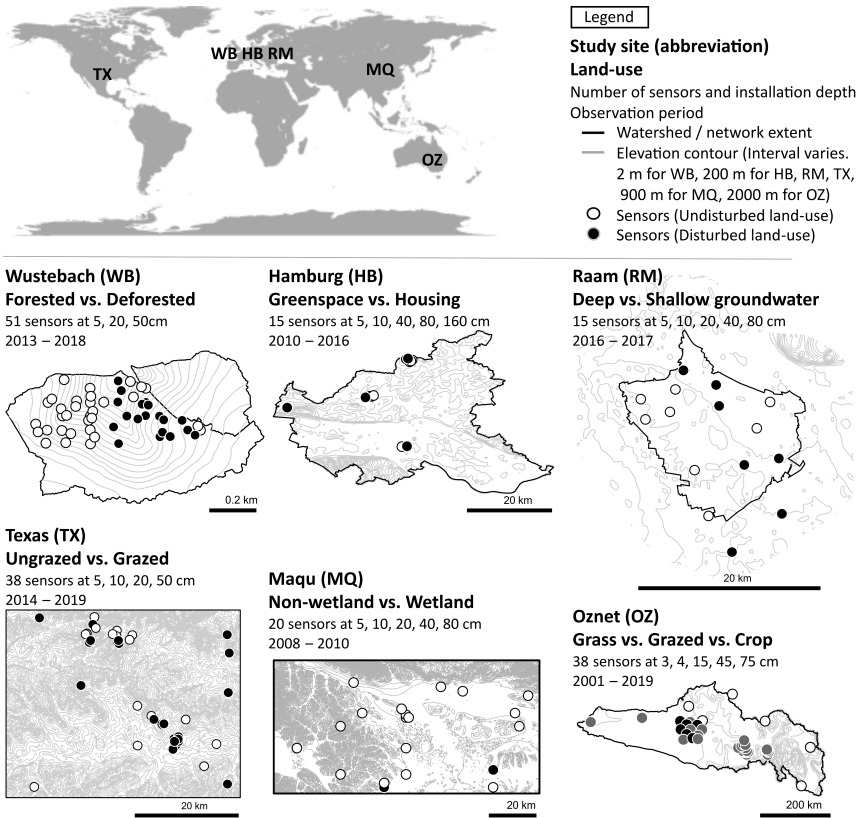
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## Abstract

Soil moisture signatures provide a promising solution to overcome the difficulty of evaluating soil moisture dynamics in hydrologic models. Soil moisture signatures are metrics that quantify the dynamic aspects of soil moisture timeseries and enable process-based model evaluations. To date, soil moisture signatures have been tested only under limited land-use types. In this study, we explore soil moisture signatures' ability to discriminate different dynamics among contrasting land-uses. We applied a set of nine soil moisture signatures to datasets from six in-situ soil moisture networks worldwide. The dataset covered a range of land-use types, including forested and deforested areas, shallow groundwater areas, wetlands, urban areas, grazed areas, and cropland areas. Our set of signatures characterized soil moisture dynamics at three temporal scales: event, season, and a complete timeseries. Statistical assessment of extracted signatures showed that (1) event-based signatures can distinguish different dynamics for all the land-uses, (2) season-based signatures can distinguish different dynamics for some types of land-uses (deforested vs. forested, urban vs. greenspace, and cropped vs. grazed vs. grassland contrasts), (3) timeseries-based signatures can distinguish different dynamics for some types of land-uses (deforested vs. forested, urban vs. greenspace, shallow vs. deep groundwater, wetland vs. non-wetland, and cropped vs. grazed vs. grassland contrasts). Further, we compared signature-based process interpretations against literature knowledge; event-based and timeseries-based signatures generally matched well with previous process understandings from literature, but season-based signatures did not. This study will be a useful guideline for understanding how catchment-scale soil moisture dynamics in various land-uses can be described using a standardized set of hydrologically relevant metrics.

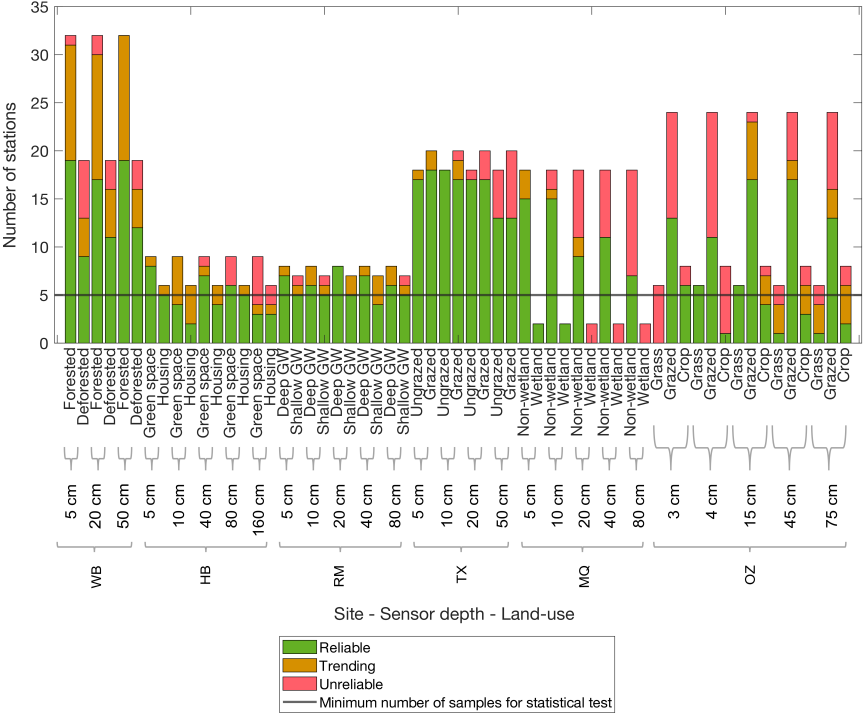
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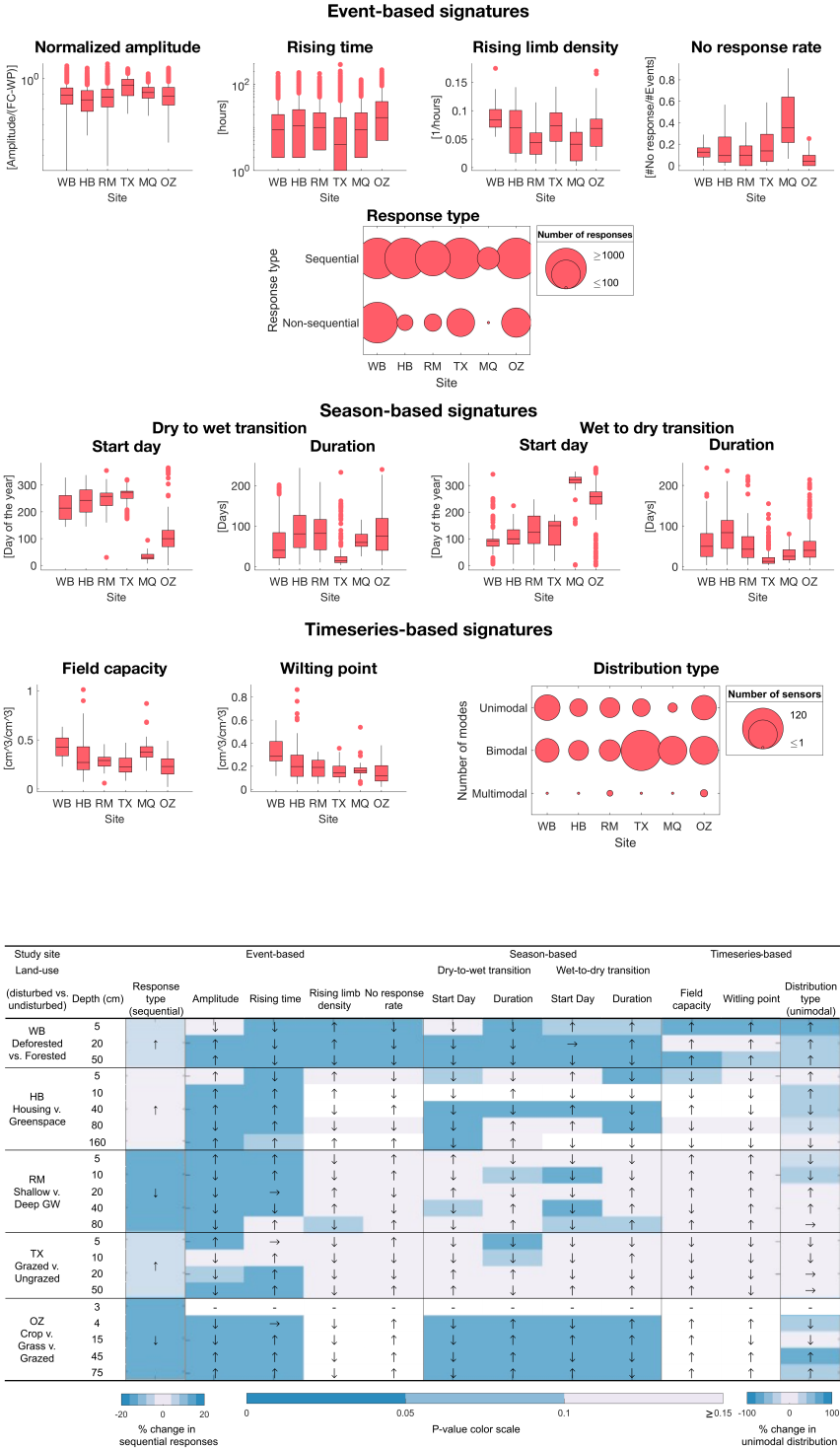
HYP-21-0457-R1\_Proof\_hi.pdf available at <https://authorea.com/users/421061/articles/527226-a-signature-based-approach-to-quantify-soil-moisture-dynamics-under-contrasting-land-uses>



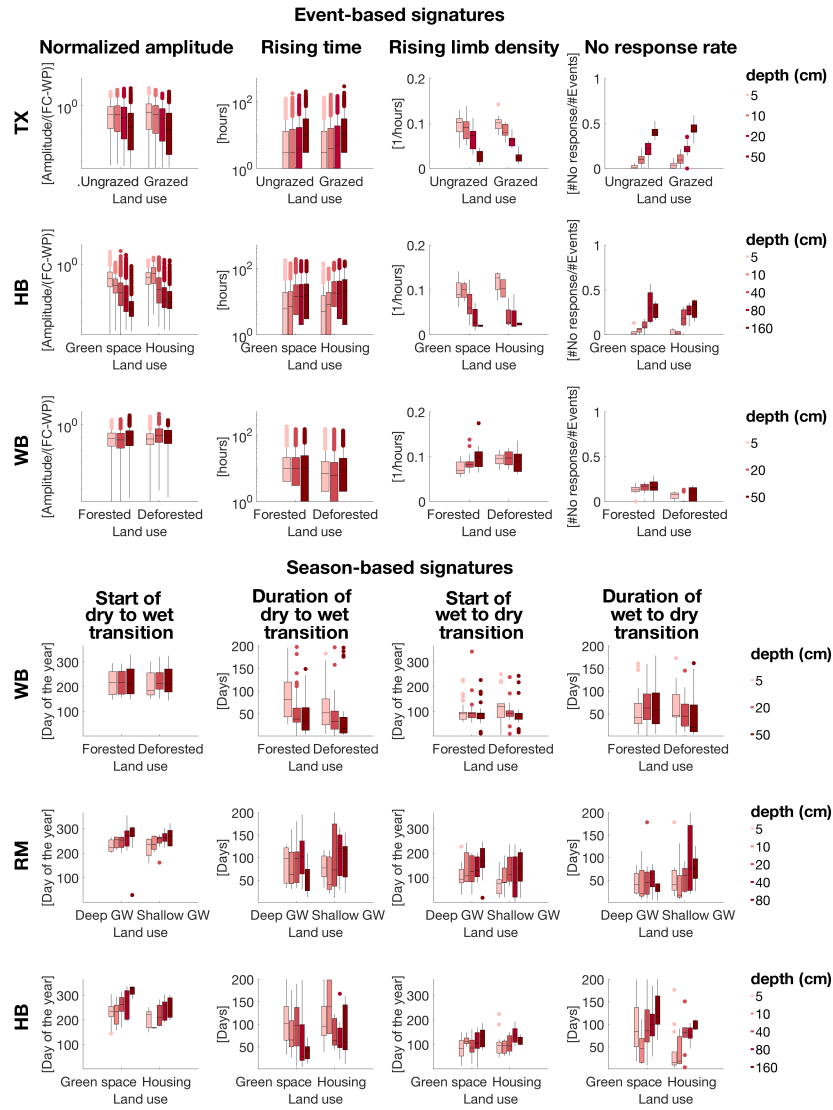
(b)

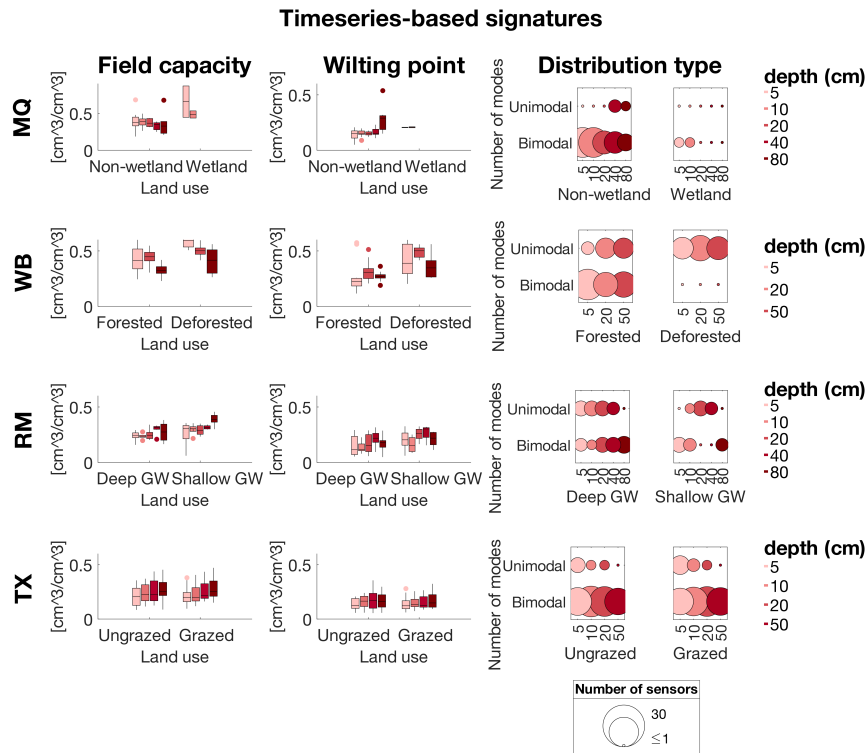
|          |           | Timescale   |  |   |
|----------|-----------|---|--|---|
|          |           | Event   | Season   | Complete timeseries   |
| Dynamics | Shape     | Rising limb density (Sawicz <i>et al.</i> , 2011)                     | -  | Distribution type (Branger & McMillan, 2019; Graham and Lin, 2012)                        |
|          | Timing    | Response type (Graham and Lin, 2012; Wiekenkamp <i>et al.</i> , 2016) | Transition date (Branger & McMillan, 2019)     | -   |
|          | Speed     | Rising time (Branger & McMillan 2019)                                 | Transition duration (Branger & McMillan, 2019) | -   |
|          | Magnitude | Normalized amplitude (Branger & McMillan, 2019)                       | -  | Field capacity<br>Wilting point (Branger & McMillan, 2019; Chandler <i>et al.</i> , 2017) |





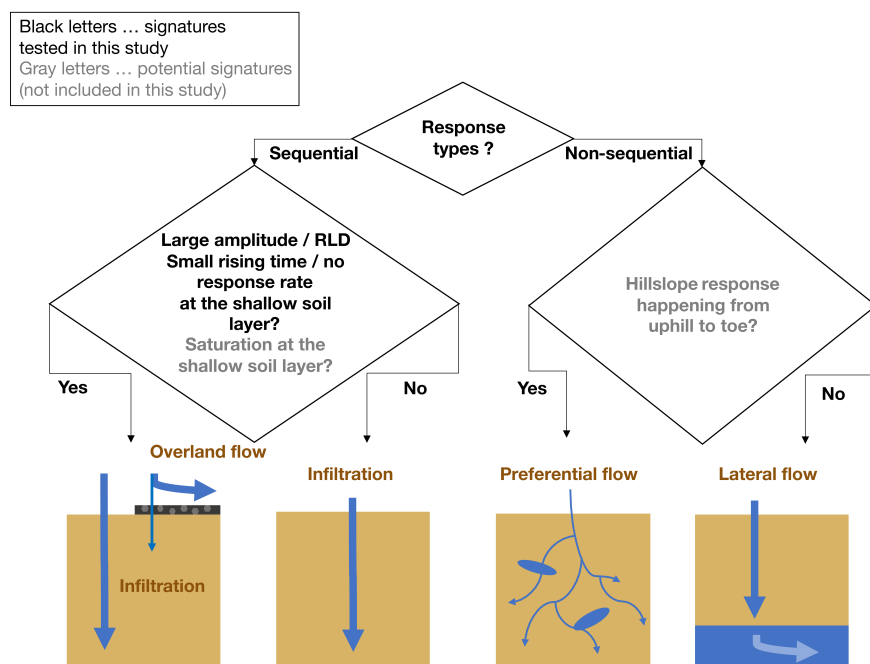






|  |  | Event-based  |                |                |                     |                  | Signatures  |          |                       |                | Timeseries-based  |               |                                   |
|--|--|--|----------------|----------------|---------------------|------------------|---|----------|-----------------------|----------------|---|---------------|-----------------------------------|
|  |  |  |                |                |                     |                  | Season-based  |          |                       |                |   |               |                                   |
|  |  | Response type (% of sequential)  | Amplitude      | Rising time    | Rising limb density | No-response rate | Dry-to-wet transition   |          | Wet-to-dry transition |                | Field capacity  | Wilting point | Distribution type (% of unimodal) |
|  |  |  |                |                |                     |                  | Start Day   | Duration | Start Day             | Duration       |   |               |                                   |
| Wüstenbach Deforested vs. Forested     | Expected process   | Sequential flow↑; no flow↓; storage flashiness↑ due to storage↑ (Wiekenkamp et al., 2016a & 2019)  |                |                |                     |                  | Earlier transition due to interception↓ & rain rate↑ & root depth↓ (Wiekenkamp et al., 2016b; Laio, 2002); closer to transition threshold due to storage↑ (Detty & McGuire, 2010)   |          |                       |                | Storage↑ due to transpiration↓ & interception↓ (Wiekenkamp et al., 2016a)   |               |                                   |
|  | Expected signature   | ↑  | ↑              | ↓              | ↑                   | ↓                | ↓   | ↓        | ↓                     | ↑              | ↑   | ↑             |                                   |
|  | Observed signature   | ↑  | ↑              | ↓              | shallow↑ deep↓      | ↓                | ↓   | →        | shallow↑ deep↓        | ↑              | ↑   | ↑             |                                   |
|  | Expected process   | Vertical infiltration -> overland flow due to surface sealing (Scalenghe & Ajmone-Marsan, 2009; Ziegler et al., 2001); storage flashiness↓ due to storage↓ |                |                |                     |                  | Delayed transition due to surface sealing & rain rate↓ (Laio, 2002); stagnant water & rapid drainage due to construction waste (Wiesner et al., 2016); less close to transition threshold due to storage↓ (Detty & McGuire, 2010) |          |                       |                | Storage↓ & GW table↓ due to infiltration↓ (Scalenghe & Ajmone-Marsan, 2009; Wiesner et al., 2016)   |               |                                   |
| Hamburg Housing vs. Urban              | Expected signature   | ↑  | shallow↓ deep↓ | shallow↓ deep↓ | shallow↓ deep↓      | shallow↓ deep↑   | ↑   | ↑        | ↑                     | ↓ or ↑         | ↓   | ↓             | deep↓                             |
|  | Observed signature   | ↑  | shallow↑ deep↑ | shallow↓ deep↑ | shallow↓ deep↓      | shallow↓ deep↑   | ↓   | →        | →                     | ↓              | ↓   | ↓             | shallow↑ deep↓                    |
|  | Expected process   | Vertical infiltration -> lateral flow; less variable soil moisture due to near-saturated soil (Soylu & Bras, 2021)   |                |                |                     |                  | Earlier transition due to shallow GW (Miguez-Macho & Fan, 2012); more close to transition threshold due to storage↑ (Detty & McGuire, 2010)   |          |                       |                | Storage↑ due to capillary rise (Benninga et al., 2018b; Soylu & Bras, 2020)   |               |                                   |
|  | Expected signature   | ↓  | ↓              | ↓              | →                   | →                | ↓   | ↓        | ↓                     | ↓              | ↑   | ↑             | ↑                                 |
| Raam Shallow vs. Deep groundwater (GW) | Observed signature   | ↓  | ↓              | ↑              | →                   | →                | →   | →        | ↓                     | →              | →   | →             | shallow↓ deep↑                    |
|  | Expected process   | Vertical infiltration -> overland flow due to compaction (Woodruff & Wilding, 2008; Alaoui et al., 2018; Ziegler et al., 2001)                             |                |                |                     |                  | Less close to transition threshold due to storage↓ (Detty & McGuire, 2010)  |          |                       |                | Storage↓ due to compaction (Bormann & Klaassen, 2008; Selassie & Ayanna, 2013)  |               |                                   |
|  | Expected signature   | ↑  | shallow↑ deep↓ | shallow↓ deep↑ | shallow↑ deep↓      | shallow↓ deep↑   | →   | ↑        | →                     | ↑              | ↓   | ↓             | ↓                                 |
|  | Observed signature   | ↑  | shallow↑ deep↓ | ↑              | →                   | →                | →   | ↓        | →                     | →              | →   | →             | →                                 |
| Texas Grazed vs. Ungrazed              | Expected processes   | Less variable soil moisture due to near-saturated soil (Soylu & Bras, 2021); less responses while frozen   |                |                |                     |                  | Seasonal transition timing of vegetation growth do not change (Dente et al., 2012); Freeze/thaw process takes longer and delayed due to heat capacity↑  |          |                       |                | Storage↑ due to soil organic matter (Dente et al., 2012; Hudson et al., 2014)   |               |                                   |
|  | Expected signature   | ↓  | ↓              | ↓              | ↓                   | ↑                | → or ↑  | → or ↑   | → or ↑                | → or ↑         | ↑   | ↑             | ↑                                 |
|  | Observed signature   | Not enough data  | →              | →              | ↓                   | ↑                | →   | →        | →                     | →              | ↑   | ↑             | ↑                                 |
|  | Expected process   | Vertical infiltration -> overland-flow due to compaction (Alaoui et al., 2018; Ziegler et al., 2001); storage flashiness↑ due to storage↑                  |                |                |                     |                  | More close to transition threshold due to storage↑ (Detty & McGuire, 2010); extended wet period due to irrigation (Smith et al., 2012)  |          |                       |                | Storage↓ due to compaction (Bormann & Klaassen, 2008; Selassie & Ayanna, 2013); Storage↑ due to irrigation (Smith et al., 2012; Lawston et al., 2017) |               |                                   |
| Oznet Crop vs. Grazed vs. Grass        | Expected signature   | ↑  | shallow↓ deep↓ | shallow↓ deep↑ | shallow↑ deep↓      | shallow↓ deep↑   | ↓   | ↓        | ↑                     | ↓              | ↓ or ↑  | ↓ or ↑        | ↓ or ↑                            |
|  | Observed signature   | ↓  | shallow↓ deep↑ | ↑              | ↓                   | ↑                | ↓   | ↑        | mixed ↑ & ↓           | shallow↑ deep↓ | ↑   | ↑             | shallow↓ deep↑                    |
|  | Observed signature matches with literature interpretation        |  |                |                |                     |                  |   |          |                       |                |   |               |                                   |
|  | Observed signature does not match with literature interpretation |  |                |                |                     |                  |   |          |                       |                |   |               |                                   |

Observed signature matches with literature interpretation      Observed signature does not match with literature interpretation



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tab1\_studysites.docx available at <https://authorea.com/users/421061/articles/527226-a-signature-based-approach-to-quantify-soil-moisture-dynamics-under-contrasting-land-uses>