The Impact of the 2019 El Nino on Soil Moisture in Nong Khuay village, Xieng Nguen district, Luangprabang province: Effects of Ground Cover

Yingshan Lau*[1] and Siphanh Daovongdeuan[2]

Department of Geography, Faculty of Arts & Social Sciences, National University of Singapore, Singapore

[1]Correspondence:
Yingshan Lau, Department of Geography, Faculty of Arts & Social Sciences, National University of Singapore, Singapore, Tel: +6597728645, E-mail: lau_ying_shan@u.nus.edu

[2] Department of Plant Science, Faculty of Agriculture and Forest resource, Souphanouvong University, Lao PDR

Article Info:
Submitted: Aug 05, 2021
Revised: Oct 15, 2021
Accepted: Nov 05, 2021

Abstract

Soil moisture is essential for agriculture, and is retained to different degrees through different soil management practices. This study describes the effects of ground cover on soil moisture at different sites - a vegetable garden, a regenerating bush fallow, a swidden rice field, a dry paddy rice field and a forest - in an upland village in Xieng Nguen district, Luangprabang province. Soil samples up to 1m deep were collected from each site over a 3-month period from end-November 2019 to end-February 2020. They were analysed for soil moisture, pH and soil texture using, respectively, the gravimetric method, a pH meter and the manipulative test. Our findings suggest that, while the presence of ground cover helps to reduce the loss of soil moisture, the ground cover's thickness and density should be considered. Shade, soil texture and subsurface hydrology could also affect soil moisture. The impact of the 2019 weak El Nino was such that four of the five sites experienced at least a 0.1 decrease in soil moisture over the study period.

Keywords: *Soil moisture; Soil management; El Nino; Poupeung mountain range; Kuang Si watershed area*

1. Introduction

From 1980-2015, El Nino events have been associated with 30% less rain in the Lao PDR (Sutton et al, 2019). In 2019, there was a weak El Nino event coupled with a positive Indian Ocean Dipole (Wang and Cai, 2020). In Xieng Nguen district, Luangprabang province, the rain first arrived in July 2019 and ended in late-October 2019. This paper describes the effects of different soil management practices on soil moisture during the 2019 El Nino in an upland village which mostly relies on semi-subsistence agriculture. Nong Khuay village is part of the Huoay Khod cluster in Xieng Nguen district, Luangprabang province. Situated about 800mASL in the Poupeung mountain range, it forms part of the Kuang Si watershed area (CHESH-Lao, 2018). The area's geology is karstic, with limestone mountains, sinkholes and an estavelle, referred to as the 'Buffalo Pond', from where the village derived its name.

Like other upland villages in Laos where swidden agriculture is discouraged (Badendoch, 1999), Nong Khuay villagers are moving towards intensifying agriculture. Hence, there are different ways of land management. We focus on five sites with different land management practices: (1) a vegetable garden, (2) a bush fallow, (3) a swidden dry rice field, (4) a dry paddy rice field, and (5) a forest. With the hypothesis 'Having ground cover helps to conserve soil moisture', we compare the reduction of soil moisture over a 3-month period between (a) sites with ground cover (Sites 2, 3 and 5) and (b) sites without ground cover (Sites 1 and 4). This study contributes to the small but important pool of research on the impact of El Nino / La Nina events on Lao PDR (Sutton et al, 2019), by documenting the impact of dry spells on agricultural soil and the effects of ground cover to mitigate it.

2. Materials and methods

To investigate the hypothesis 'Having ground cover helps to conserve soil moisture', we compared how soil moisture changed from November 2019 to end-February 2020 between various existing soil management practices. This 3-month period commenced after the end of Luangprabang's rainy season and ended in the middle of the dry season. The soil management practices compared were at five different sampling sites (Figure 1):

1. a vegetable garden,
2. a regenerating bush fallow (ປ່າເລົ່າ),
3. a swidden rice field (ໄຮ່),
4. a dry paddy rice field, and
5. a forest.

These sites were chosen to be around the same area so that the underlying geology would be the same. Each site represents a type of soil management practice (Table 1). Sites 2, 3 and 5 are categorised as having ground cover; Sites 1 and 4 are categorised as without ground cover. Site 1, the vegetable garden, had been machine-ploughed to about 20cm deep before this season's planting. The soil surface was bare with only some weeds. Site 2, the regenerating bush fallow, was about 2 years old and was previously used to plant dry rice as part of swidden cultivation. It had not been tilled, and the soil surface was covered with dried leaf litter and bushes. Site 3, the swidden rice field, was previously fallow for 4-5 years before 2019's rice-planting season. It had not been tilled, and there were some weeds and dried rice straw left on the soil as ground cover. Site 4, the dry paddy rice field, had been machine-ploughed to about 50cm deep in the past 2-3 years. The landowners would like it to be a wet paddy rice field, but there was insufficient rain and they lacked funds for irrigation. The soil surface was bare, with only a few weeds growing in between the sparse dried rice stalks. Site 5, the forest, was protected since the 1980s. Villagers would enter only to pick up dead branches for firewood. There were dried leaves and some small plants as ground cover amongst the trees.

A Villager Research Team comprising four youth from the village (two Khmu women and two Hmong men) was set up to understand the land use history of each site and to help with the soil sampling. We used a soil augur to collect soil samples up to 1m deep, with each sample representing a depth of 10cm or 20cm. The soil samples were collected from each site on 23-24 November 2019, 11-12 January 2020 and 29 February-1 March 2020. We made sure that the sampling at each site was at the same time of the day, e.g. Sites 1, 3 and 5 in the morning and Sites 2 and 4 in the afternoon. The samples were stored in Ziploc bags and brought to the soil laboratory of the Northern Agriculture & Forestry College (NAFC) for soil moisture analysis, within 1.5 weeks of sampling. Using the gravimetric method (KBS, 2019; Madhav, undated), a 100g subsample was weighed and placed in an oven at 60°C until constant mass was reached, typically after two nights. The oven-dried subsample was then weighed again. The gravimetric soil moisture, Θ_m, of each sample was calculated by:

$$\Theta_{m(\text{site, sample depth, sampling timepoint})} = \frac{(\text{final mass of soil and beaker} - \text{mass of beaker})}{(\text{initial mass of soil and beaker} - \text{mass of beaker})}$$

The manipulative test was used, in which a handful of soil was wet and shaped, was used to analyse soil texture. The extent to which the ball of soil could be shaped without cracking or falling apart indicated the soil texture class (FAO, 2016). The analysis was conducted in the village's meeting house with the Villager Research Team and other villagers, or in the NAFC laboratory within 1.5 weeks after sampling. Where possible, two people did the manipulative test concurrently for each sample so that the result could be cross-checked.

In addition, soil pH was analysed to understand the general soil condition. This was done on the soil samples of 0-10cm depth, 40-50cm depth and 80-90cm depth collected from the 5 sites on 23-24 November 2019 and 29 February-1 March 2020. Within 1.5 weeks after sampling, a subsample of 40g of soil was mixed with 40ml of pure water and filtered, and the filtrate's pH was tested using the Horiba pocket pH meter.

3. Results

3.1 Soil pH

At all 5 sites, soil pH ranged from 7 - 8.5 (Table 2). This was consistent with the presence of many limestone/karst mountains in Nong Khuay village. The lower pH at the 0-10cm soil surface layer could be due to decomposition of organic matter at the soil surface. In general, there is not much difference between sites, showing that geology plays a bigger role in determining soil mineral availability for plants.

3.2 Gravimetric soil moisture and soil texture

Tables 3 and 4 respectively show how soil moisture and soil texture vary with depth and over time for the five sites.

3.2.1 Sites with ground cover

At Site 2, soil moisture was almost similar in end-November 2019 and mid-January, with soil moisture of the 0-10cm depth at around 18%-19% and both increasing to 22%-23% at the 90-100cm depth. However, in end-February, soil moisture decreased to 15% at the 0-10cm depth of soil. Soil moisture increased with depth, reaching ≈21% at the 90-100cm depth. This suggests that although evaporation occurred from the soil surface, the deeper layers of soil did not lose moisture as quickly. Generally, soil texture is loamy at the surface, more clayish at the 10-60cm depth, and then subsequently loamy after 60cm depth.

At Site 3, soil moisture in the 0-10cm layer of soil was ≈13% both in end-November 2019 and mid-January 2020. This decreased to ≈8% in end-February 2020. However, while soil moisture decreased to ≈10-12% at 30cm-80cm depth for the end-November 2019 sample, it increased to peak at ≈17% at 50-60cm depth for the mid-January 2020 sample. This suggests that, between end-November 2019 and mid-January 2020, moisture was added into the soil. This could be due to moisture from rice straw that were left on the ground after the rice harvest, which then gradually leached into the deeper layers of the soil. Nonetheless, this moisture was lost by end-February 2020. Soil moisture was ≈13-14% at 90-100cm depth in end-November 2019, mid-January 2020 and end-February 2020, suggesting that this deep layer of soil was able to retain moisture over time. Generally, soil texture ranged from heavy loam to clay.

At Site 5, soil moisture was the highest at the soil surface layer of 0-10cm depth, at ≈24% in end-November 2019, 23% in mid-January 2020 and 19% in end-February 2020. For all three sampling timepoints, soil moisture decreased slightly with increasing depth, with soil moisture across almost the entire 1m-soil profile being the lowest in end-February 2020. These suggest that soil moisture was increasingly lost over time. Generally, soil texture was between heavy loam to light clay.

3.2.2 Sites without ground cover

At Site 1, soil moisture decreased over time, with the greatest decrease in soil moisture happening during the period between mid-January and end-February 2020, from ≈12% to 9% at the 0-10cm layer. At all three sampling timepoints, it was observed that soil moisture increased with depth. In end-November 2019 and mid-January 2020, soil moisture plateaued at around 20% at around 50-70cm depth; however, for end-February 2020, soil moisture remained below 15% up to 90cm depth in soil. These suggest that evaporation was occurring from the soil surface, and over time, the deeper layers of soil lost moisture as the top layers became drier. Generally, soil texture is loamy sand to loam at the surface 0-10cm layer, and heavy loam to clay in the deeper layers.

At Site 4, soil moisture at the surface was already low at $\Theta_{m(\text{Site 4, 0-10cm, end-Nov 2019})} \approx 9\%$, and then $\Theta_{m(\text{Site 4, 80-90cm, mid-Jan 2020 and end-Feb 2020})} \approx 11\%$. For both the end-November 2019 and mid-January 2020 samples, the soil moisture did not change much with depth except for peaking at ≈16-17% at the 50-60cm depth of soil. At the 90-100cm depth of soil, soil moisture was ≈12% for both samples. The observed peak in soil moisture at the 50-60cm depth of soil could be due to soil texture. Soil texture is observed to be generally heavy loam to clay, with a sandy layer is at the 30-50cm depth of soil, suggesting that the sandy layer drains moisture but the clayish layer below the sand retains moisture. For the end-February 2020 sample, soil moisture generally increased with depth from $\Theta_{m(\text{Site 4, 0-10cm, end-Feb 2020})} \approx 11\%$ to $\Theta_{m(\text{Site 4, 90-100cm, end-Feb 2020})} \approx 19\%$ at the 90-100cm layer. Soil texture for the end-February 2020 sample was generally light clay to clay.

3.2.3 Overall change

Figure 2 shows the proportional change in soil moisture against the final soil moisture, averaged over the 0-100cm soil depth, over the 3-month period. The final soil moisture for Sites 2 and 5 were around 18-19%, with a decrease of 0.10 to 0.15. The final soil moisture for Site 3 was ≈10%, with a decrease of about 0.16. In comparison, the final soil moisture for Site 1 was ≈13% and had decreased by about 0.26. This suggests that the soil management practices at Site 1 were the least effective in retaining soil moisture. Interestingly, although Site 4 was similar to Site 1 in that it had no ground cover, soil moisture had actually increased by 0.13 to ≈14%. It is noted, from Table 3, that the increase in the averaged soil moisture is attributed to the deeper layers of soil, e.g. $\Theta_{m(\text{Site 4, 80-90cm, end-Feb 2020})} \approx 17\%$ and $\Theta_{m(\text{Site 4, 90-100cm, end-Feb 2020})} \approx 20\%$.

4. Discussion

In terms of the hypothesis of "Having ground cover conserves soil moisture more than not having ground cover", our comparison revealed that although Sites 2, 3 and 5 are categorised as having both ground cover, Site 2 and Site 5 share similar soil moisture characteristics than Site 3. For example, at both Sites 2 and 5, soil moisture ranged from 15-25%, and at each respective soil depth, did not differ much between each of the three sampling timepoints. This is likely because the soil at Sites 2 and 5 are shaded by bushes or trees. In contrast, the final soil moisture for the 0-70cm layer of soil at Site 3 was below 10%. This is considered even dryer than Site 1, where the final soil moisture was below 10% only for the 0-10cm layer of soil. Site 3's soil moisture profile for the mid-January 2020 time point had a peak at around 40-60cm depth, which is likely due to moisture from the decaying rice straw leaching into the ground. These above observations suggest that, in addition to ground cover, shade/tree cover plays a role in preventing evaporation from soil, and the thickness and density of ground cover makes a difference in soil moisture retention.

Site 3 is a swidden upland rice field, and the soil management practices there is typical of most rice-farming in Laos. The observation that soil moisture levels at Site 3 is low is therefore significant, because it suggests that, although upland rice cultivation is a traditional practice (Casella et al, 2013), it might not be effective in withstanding the effects of climate change such as the prolonged dry spell during the 2019 El Nino. More research needs to be done to validate this new hypothesis.

Comparing Site 1 and Site 3, although the overall soil moisture of Site 1 (≈13%) was higher than Site 3 (≈10%), Site 1 lost 0.26 of its soil moisture over the 3-month period, whereas Site 3 lost 0.16 of its soil moisture. Given that Site 1 is similar to Site 3 in that both do not have shade, this suggests that ground cover is nonetheless important in helping to conserve soil moisture during dry periods. The large proportion by which soil moisture at Site 1 decreased is concerning.

For Site 4, although it did not have any ground cover, soil moisture increased over time.

This is due to soil moisture increasing in the deeper layers of soil, e.g. deeper than 30cm and especially at 80-100cm. This shows that the hypothesis that 'Having ground cover helps to conserve soil moisture' does not completely hold. Besides ground cover, there could be other factors affecting soil moisture at Site 4. In terms of soil texture, Site 4 is predominantly clay with a sandy layer at around 40-50cm depth. This sandy layer is not as visible in the end-February 2020 sample, suggesting either a change in soil texture over time (e.g. clay particles migrating into the sandy layer) or that there was variation in the sub-surface soil texture in the sampling location. It is also noted that Site 4 is between a hillslope with bush fallow and a stream, suggesting that there could also be groundwater movements which is retained by the sub-surface clayish soil. This was unlike Site 3, where the soil texture was also generally clay but which was located on a small hillcrest. With the promotion of paddy rice farming as an alternative to shifting cultivation (Nyianu, 2020), understanding the role of sub-surface hydrology could help inform farmers about where to locate their rice paddy fields.

This study, however, is limited because the soil moisture data only relies on the result of only one subsample, instead of the average of a 5-6 subsamples. This was due to limitations in the laboratory. With the limited number of glass beakers, we needed about four nights to finish the procedure for one subsample of all soil samples. Hence, having more replicates would mean that the samples would be stored in the Ziploc bags for a longer period of time, which would also undermine the reliability of the data (for example, it was observed that there was condensate forming on the inside of some bags). Where necessary, duplicates were conducted for a few samples. This study would also have been further enhanced if the soil moisture data collected was volumetric instead of gravimetric, as we would then be able to combine the volumetric data with the soil texture data to deduce whether there was plant-available water for each sample.

Finally, soil health is determined by a matrix of factors. In addition to soil moisture and pH, other factors include: the soil organic matter, soil mineral content, susceptibility to erosion, etc. (FAO, 2019; Mauseth, 2017). For a more complete assessment of agricultural resilience, these other factors also need to be studied.

5. Conclusion

The hypothesis that 'Having ground cover helps to conserve soil moisture' holds to a certain extent. Compared to a similar site without any ground cover, the presence of ground cover does help to reduce the loss of soil moisture. However, the understanding of ground cover needs to be deconstructed, as the density and thickness of the ground cover are also important considerations. In addition, there could be other factors influencing soil moisture, such as: shade, soil texture and subsurface hydrology. This study has documented the impact of the 2019 weak El Nino on gravimetric soil moisture at five sites of different soil management practices in a case study village in Luangprabang province, over a 3-month period of end-November 2019 to end-February 2020. Four of the five sites experienced at least a 0.1 decrease in soil moisture. Significantly, one of the sites, a swidden rice field, experienced relatively low soil moisture of less than 10% for 0-70cm soil depth at the end of the study period. Double-cropping would unlikely be possible for this site, and the restoration of soil moisture would depend on the return of the rain, which is becoming increasingly unpredictable due to climate change. Our observation at this site preliminarily suggests that upland dry rice cultivation in Laos might not be sustainable in the face of climate change, and more research should be done to investigate this.

6. Conflict of Interest

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

7. Acknowledgements

Many thanks to the National Geographic Society Early Career Grant in Singapore for supporting my research in 2019 in NongKhuay village, Xiengngern district, Luangprabang province, Lao PDR.

8. References

Badendoch, N. (1999). Watershed management and upland development in Lao PDR: a synthesis of policy issues. World Resources Institute.

Castella, J.C., Lestrelin, G., Hett, C., Bourgoin, J., Fitriana, Y.R., Heinimann, A. and Pfund, J.L. (2013). Effects of landscape segregation on livelihood vulnerability: moving from extensive shifting cultivation to rotational agriculture and natural forests in northern Laos, Human Ecology.

CHESH-Lao. (2018). Report on the work of land allocation for 7 villages in the KuangSi watershed area, the committee in-charge of land and forest allocation in KuangSi watershed area, Luang Prabang province, Lao PDR.

FAO. (2016). Soil Texture, Food and Agriculture Organisation.

FAO. (2019). Soil Erosion: the greatest challenge for sustainable soil management. Food and Agriculture Organisation, Rome, Italy.

KBS. (2019). Gravimetric Soil Moisture, Protocols, Kellogg Biological Station Long-term Ecological Research, Michigan State University.

Madhav, M. (undated). Determination of Moisture Content, Geotechnical Laboratory Experiments, Indian Institute of Technology.

Mauseth, J.D. (2017). Soils and Mineral Nutrition, An introduction to plant biology, the sixth edition. Jones & Barlett Learning, USA.

Nyianu, L. (2020). How can paddy rice farmers adapt to climate change? A case study of Climate-Smart Agriculture (CSA) in Luang Prabang province, Laos. School of Geography, Environment and Earth Sciences, Victoria University of Wellington, New Zealand.

Sutton, W.R., Srivastava, J.P., Rosegrant, M., Koo, J., Robertson, R. (2019). Striking a Balance: Managing El Niño and La Niña in Lao PDR's Agriculture. World Bank, Washington, DC.

Wang, G. and Cai, W. (2020). Two-year consecutive concurrences of positive Indian Ocean Dipole and Central Pacific El Niño preconditioned the 2019/2020 Australian "black summer" bushfires. Geoscience Letters.

Table 1: Sampling sites, the corresponding soil management practice, whether they have ground cover.

Site	Land cover/land management practice	Has ground cover?
1	Vegetable garden - machine ploughed to about 20cm deep	No
2	Regenerating bush fallow - about 2 years old	Yes (dried leaves and some small plants)
3	Swidden rice field - previously fallow for 4-5 years	Yes (weeds are left on the ground during weeding; dried rice straw after rice harvesting)

4	Dry paddy rice field - machine -ploughed to about 50cm deep	No
5	Forest - protected since the 1980s	Yes (dried leaves and some small plants)

Table 2: Average soil pH for the 5 site

Site	Average soil pH					
	23-24 November 2019			**29 February-1 March 2020**		
	0-10cm depth	40-50cm depth	80-90cm depth	0-10cm depth	40-50cm depth	80-90cm depth
1	7.4	8.1	8.4	7.3	7.4	7.8
2	7.2	8.0	8.1	7.3	7.5	7.9
3	7.6	7.5	7.3	7.2	7.6	7.7
4	7.5	8.0	7.9	7.9	8.0	8.1
5	7.6	7.5	7.7	7.7	7.6	7.5

Figure 1: Locations of the sampling sites.

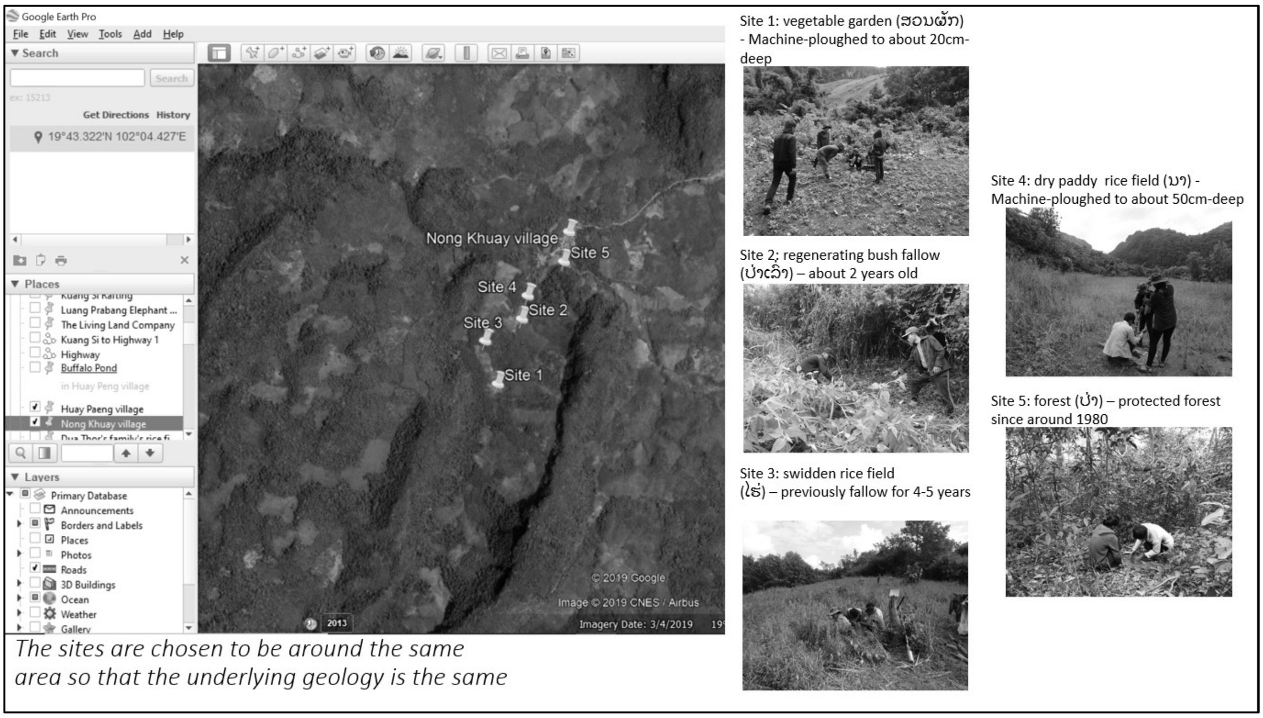

Figure 2: Graph of change in soil moisture (averaged over 0-100 soil depth) over the 3-month study period versus final soil moisture in end-February 2020.

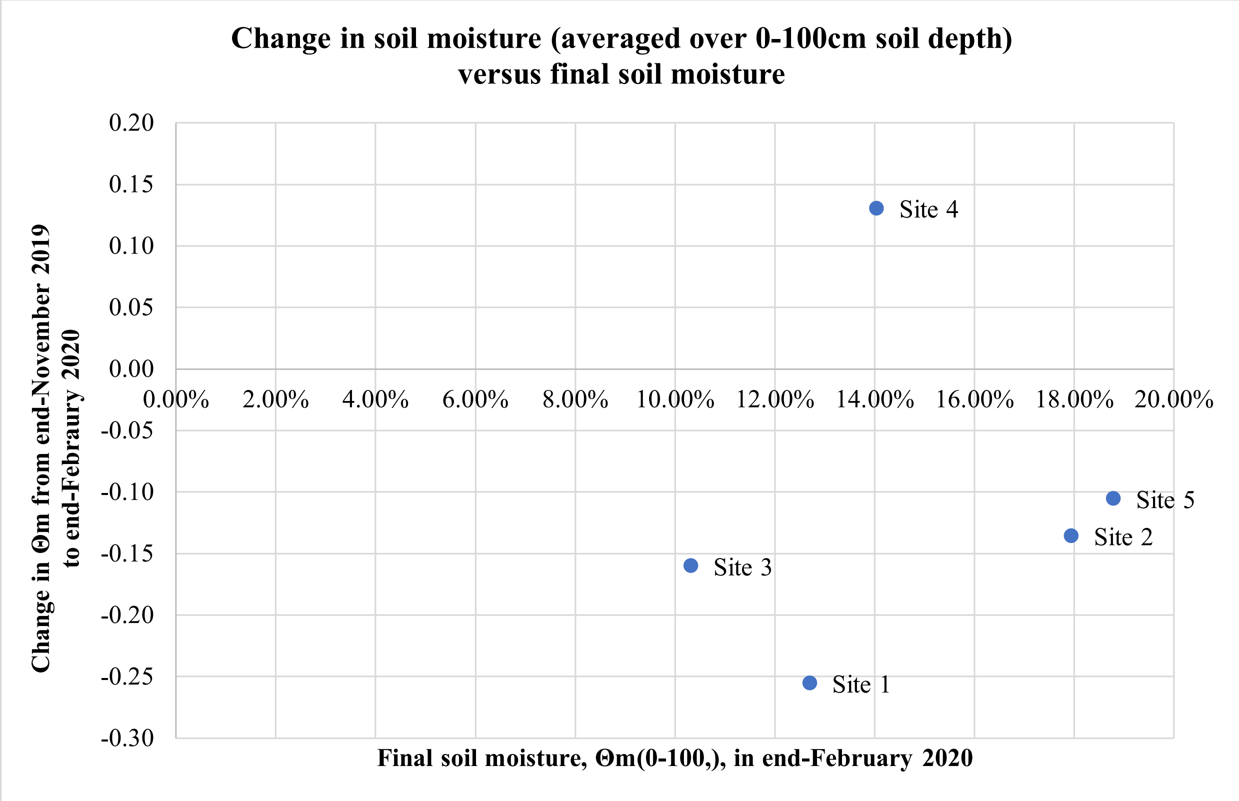

Table 3: Gravimetric soil moisture in 100 cm depth of soil

Soil depth (cm)	Gravimetric soil moisture, Θ_m (%)														
	Site 1			Site 2			Site 3			Site 4			Site 5		
	23-24 Nov 2019	11-12 Jan 2020	29 Feb - 1 Mar 2020	23-24 Nov 2019	11-12 Jan 2020	29 Feb - 1 Mar 2020	23-24 Nov 2019	11-12 Jan 2020	29 Feb - 1 Mar 2020	23-24 Nov 2019	11-12 Jan 2020	29 Feb - 1 Mar 2020	23-24 Nov 2019	11-12 Jan 2020	29 Feb - 1 Mar 2020
0-10	14.06	12.07	9.19	18.62	18.14	14.95	12.72	12.93	8.15	8.81	11.09	10.56	24.03	22.69	18.58
10-20	15.80	15.03	11.61	18.62	18.52	14.98	12.61	14.05	8.59	12.60	12.72	10.89	23.37	22.14	19.73
20-30	15.80	13.69	10.99	19.02	17.48	15.80	13.10	14.68	9.85	9.88	13.31	13.01	20.97	21.38	20.30
30-40	12.97	13.97	11.78	19.65	18.80	16.11	10.62	15.58	9.60	10.86	11.49	15.34	22.99	22.49	21.20
40-50	15.82	13.37	12.94	20.79	21.30	17.45	11.66	16.28	9.54	11.36	9.61	14.20	22.65	21.95	19.00
50-60	20.03	15.76	13.74	21.26	20.94	18.05	11.11	16.76	9.78	17.37	15.91	15.84	21.40	22.11	16.74
60-70	18.09	19.55	13.18	22.10	21.80	19.60	11.64	15.35	9.97	17.37	12.01	12.82	17.61	21.29	20.55
70-80	18.09	17.45	13.39	22.66	22.24	20.49	11.76	15.38	11.68	15.13	13.07	11.90	16.64	22.90	15.45
80-90	19.68	18.62	14.31	21.89	21.73	21.23	13.58	13.75	12.69	13.61	11.48	16.64	22.35	20.03	18.45
90-100	21.14	20.56	15.91	22.28	22.90	20.82	14.32	12.95	13.41	12.04	11.75	19.29	20.33	17.92	17.92
0-100 (averaged)	17.15	16.01	12.70	20.69	20.38	17.95	12.31	14.77	10.33	12.90	12.24	14.05	21.23	21.49	18.79

Table 4: Soil texture in 100cm depth of soil

Soil depth (cm)	Soil texture														
	Site 1			Site 2			Site 3			Site 4			Site 5		
	23-24 Nov 2019	11-12 Jan 2020	29 Feb - 1 Mar 2020	23-24 Nov 2019	11-12 Jan 2020	29 Feb - 1 Mar 2020	23-24 Nov 2019	11-12 Jan 2020	29 Feb - 1 Mar 2020	23-24 Nov 2019	11-12 Jan 2020	29 Feb - 1 Mar 2020	23-24 Nov 2019	11-12 Jan 2020	29 Feb - 1 Mar 2020
0-10	Loamy sand (sandy loam)	Sandy loam	Loam	Loam (heavy loam / light clay)	Heavy loam (light clay)	Loam	Clay	Light clay (clay)	Light clay (clay)	Light clay	Light clay (clay)	Light clay (clay)	Loam (heavy loam)	Loam	Heavy loam
10-20	Loam	Light clay (clay)	Light clay (clay)		Light clay	Light clay	Light clay	Light clay (clay)	Clay	Clay	Light clay	Clay	Loam (heavy loam)	Heavy loam	Heavy loam

20-30		Light clay	Light clay (clay)	Light clay	Clay	Light clay (clay)	Light clay	Light clay (clay)	Clay	Clay	Light clay (clay)	Heavy loam (light clay)	Loam (heavy loam)	Loam (heavy loam)	Heavy loam
30-40	Heavy loam (loam)	Heavy loam	Light clay (clay)	Heavy loam	Light clay (clay)	Light clay (clay)	Light clay	Light clay	Clay	Sand	Light clay (clay)	Light clay	Loam	Loam	Heavy loam (light clay)
40-50	Clay	Light clay	Heavy loam	Heavy loam	Light clay (clay)	Loam	Heavy loam (light clay)	Light clay	Clay	Sand	Sandy loam	Light clay	Loam	Loam	Heavy loam (light clay)
50-60	Light clay (clay)	Light clay	Loam (heavy loam)	Light clay	Light clay (clay)	Loam	Heavy loam (light clay)	Heavy loam	Light clay	Light clay	Clay	Clay (light clay-clay)	Heavy loam	Loam	Light clay (clay)
60-70	Light clay (clay)	Clay	Heavy loam (light clay)	Sandy loam	Loam	Loam	Light clay	Light clay	Clay		Light clay (heavy loam)	Clay	Heavy loam (light clay)	Loam	Heavy loam (loam-heavy loam)
70-80		Clay	Light clay (clay)	Sandy loam (loamy sand)	Loam	Sandy loam (loam)	Heavy loam (light clay)	Light clay	Clay	Light clay (clay)	Heavy loam	Light clay (clay)	Loam (heavy loam)	Loam	Loam
80-90	Clay (light clay)	Light clay (clay)	Light clay (clay)	Loamy sand (sandy loam)	Heavy loam	Loam	Heavy loam (light clay)	Light clay (clay)	Clay	Clay (light clay)	Heavy loam	Clay	Loam	Loam (heavy loam)	Loam (heavy loam)
90-100	Clay (light clay)	Heavy loam (light clay)	Light clay (clay)	Loamy sand	Loam	Loam	Heavy loam (light clay)	Light clay (clay)	Clay	Heavy loam (light clay)	Light clay	Clay	Loam	Loam (heavy loam)	Heavy loam (light clay)