SOIL CARBON STOCK RESPONSE TO SUBSURFACE DRAINAGE IN THE NORTH WILLAMETTE VALLEY

L.C. Breza, J.M. Moore, A.A. Tomasek, and K.M. Trippe

Introduction

Subsurface drainage, or tile drainage, is a water management tool that Willamette Valley farmers use to mitigate high water tables in their fields. Although some cool-season grasses can tolerate wet soil, many other grasses grown for seed cannot. Thus, wet soils can compromise yields and limit crop choice. Subsurface drainage allows farmers to plant a wider variety of crops, extends the growing season, and provides earlier and more reliable equipment access to historically wet fields.

Because tile drainage plays such an important role in land management, nearly 30% of cropland in the Willamette Valley has subsurface drainage, and growers regularly install new tile lines in previously untiled fields. Tile installations may target especially wet areas or span the entirety of a field, depending on the soil type and topography. Additionally, farmers may install tile drainage in fields with steeper slopes to help minimize erosion via surface runoff.

High soil heterogeneity and rolling topography across the northern Willamette Valley generally result in farmers utilizing subsurface drainage both for mitigating high water tables and for minimizing surface runoff. Furthermore, the northern Willamette Valley landscape often has poorly draining soils adjacent to moderately or well-draining soils within a single field. Thus, a field with subsurface drainage can contain soils of varying drainage classes, soil texture, and soil carbon (C) concentrations.

Many of the soil series located in the northern Willamette Valley have cumulative soil organic carbon (SOC) ranging from about 1 to 5% in the 0–60 cm depth, with an average SOC content of approximately 3% (soil survey staff). Generally, the greater the SOC content in agricultural land, the more productive it is, and preserving SOC has become increasingly important. For example, preventing C loss and building SOC via management are major focuses of the recent United States Department of Agriculture (USDA) Climate Smart initiative. This initiative has encouraged the incentivization and monetization of “carbon farming” by agricultural production companies. Therefore, understanding how different management practices, such as tile drainage, influence soil C stocks has implications for Willamette Valley farmers, as well as farmers outside the region.

Our research aimed to understand the response of soil C to subsurface drainage in Willamette Valley soils. There are three possible soil C outcomes resulting from drainage. Drainage may decrease soil C due to increased aeration, microbial activity, and mineralization of existing soil C. In contrast, lower water tables may lead to increased root biomass and microbial biomass deeper in the soil profile, increasing soil C. Alternatively, there could be no change detected in response to drainage.

Here we report results from the continuation of a 2-year study initiated in 2022 that investigates the response of soil C to subsurface drainage. The 2022 study focused on poorly drained soils in the south Willamette Valley, while the present study targeted moderately well-drained soils in the north Willamette Valley.

Materials and Methods

Soil collection and analysis

Soils were collected in April and May 2023 from 14 grass seed production fields near Monmouth, OR. We targeted moderately well drained soils, which included Woodburn (fine-silty, mixed, superactive, mesic Aquultic Argixerolls), Carlton (fine-silty, mixed, superactive, mesic Aquultic Haploxerolls), and Coburg (fine, mixed, superactive, mesic Oxyaquic Argixerolls) soil series. Map units containing one of the target soil types were identified in each field. Soil properties are shown in Table 1.

Field treatments included newly tiled (fewer than 5 years since tile drain installation, n = 4), old tile (more than 15 years since tile drain installation, n = 5), and untiled (no history of tile drainage, n = 5). The fields selected for this study have a history of grass seed crops. At the time of sampling, four fields were planted with tall fescue [*Schedonorus arundinaceus* (Schreb.) Dumort.], four with perennial ryegrass (*Lolium perenne* L.), one with meadowfoam (*Limnanthes alba* Hartweg ex. Benth), one with red clover (*Trifolium pratense* L.), and two fields were left fallow.

Table 1. Average clay, silt, and sand percentage and the texture class of each target soil series at 0–15, 15–30, and 30–60 cm.

Soil depth	Component	Carlton	Coburg	Woodburn
0–15 cm	Clay (%)	25.6	32.1	26.0
	Silt (%)	51.0	55.2	65.8
	Sand (%)	23.4	12.6	8.2
	Texture	Silt loam	Silty clay loam	Silt loam
15–30 cm	Clay (%)	26.5	33.5	27.7
	Silt (%)	50.0	54.9	64.8
	Sand (%)	23.5	11.6	7.5
	Texture	Silt loam/loam	Silty clay loam	Silty clay loam
30–60 cm	Clay (%)	28.7	34.7	29.7
	Silt (%)	44.8	52.3	62.8
	Sand (%)	26.5	13.1	7.5
	Texture	Clay loam	Silty clay loam	Silty clay loam

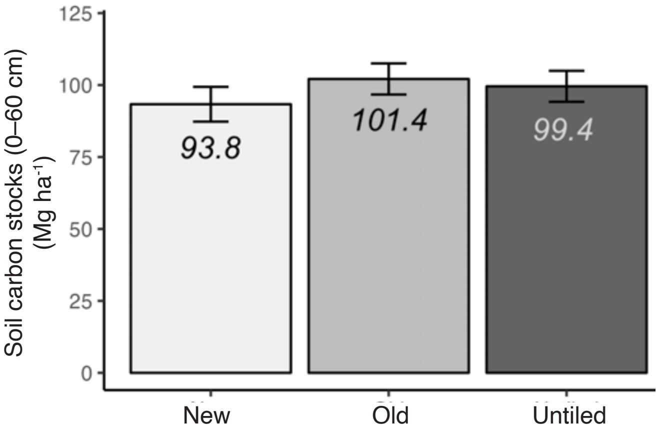

Figure 1. Cumulative soil C was not different between tile drainage treatments ($P = 0.344$). Bars represent standard error around the mean.

Nine cores were collected in each field within each sampling zone. Samples were collected to 1 m deep with an ATV-mounted hydraulic soil probe (Giddings Machine Company, Inc.), and plastic liners were used within a stainless steel soil probe (4.25 cm diameter) to extract intact soil cores. Cores were processed upon collection and segmented at standard soil depths of 0–15 cm, 15–30 cm, and 30–60 cm. Bagged soil was transported on ice packs and stored at 4°C.

Each sample was air dried, finely ground, and analyzed for total C and nitrogen (N) (LECO CN828). Prior to grinding, all vegetation was removed manually with tweezers. A texture analysis was performed on each sample by wet sieving air-dried soil of less than 2 mm and separating the resulting sample into two size fractions: greater than 53µm and less than 53µm. The larger size fraction was oven dried at 60°C, and the dry mass comprised the sand fraction. The smaller size fraction was analyzed for silt and clay composition by completing a particle size analysis via laser diffraction (Mastersizer 2000).

Statistical analysis

Mixed-effects models were used to analyze the response of soil C stocks to drainage treatments and incorporated clay content as a covariate to account for the potential influence of clay on C stocks. To analyze differences in soil C stocks across different soil types, similarly structured mixed-effects models were used. Similar statistical analyses were performed on total soil N. Soil N values were log+1 transformed to ensure the data fit the model's assumptions. All statistics were performed in the open-source computing software R.

Results and Discussion

There were no statistically significant differences in cumulative soil C among the three tile drainage treatments (Figure 1, $P = 0.344$), and clay was a predictor of soil C ($P < 0.0001$, data not shown). Although not statistically significant, there was a trend of slightly higher C stocks in old and untiled fields compared to newly tiled fields. This trend could indicate an initial loss of soil C after subsurface installation in new tile fields, followed by a recovery of soil C in old tile fields as the system stabilizes over time. However, increased replication of field treatments is needed to verify this trend. Cumulative N was not different between tile drainage treatments ($P = 0.183$), and clay was a significant predictor of soil N ($P < 0.001$, data not shown).

In our 2022 survey of C stocks in the southern Willamette Valley, which targeted the Dayton series, a poorly drained soil, similar results were found in that there were no differences among the drainage treatments (Breza et al., 2023). Similarly, in 2023, we found no difference in cumulative C stocks in moderately well-drained soils in the north valley. These findings suggest that subsurface drainage has no effect on soil C stocks even across different soil series with differing drainage properties. These results align with a recent study conducted in a primarily corn-soy system that found minimal tile drainage effect on soil C stocks at multiple sampling depths (Saha et al., 2024).

It is well understood that soil type and texture strongly influence soil C concentrations. Soil series was a moderate predictor of soil C stocks within the sampling zone (Figure 2, *P* = 0.056), with Coburg having the greatest cumulative soil C content. Coburg soils also had the greatest clay content (Table 1). These results suggest that soil C content in Willamette Valley grass seed fields is largely driven by soil texture and landscape geomorphology and that subsurface drainage may have little impact on total C stocks over the long term. This finding prompts the question of whether certain soil types are more susceptible to C accumulation or loss via subsurface drainage.

While soil type and texture impact soil C content, other agricultural management practices combined with subsurface drainage can potentially alter soil C. For example, tile-drained fields under no-tillage can alter soil physical properties and improve SOC stocks (Kumar et al., 2014), while tilled fields with subsurface drainage can promote dissolved organic C loss via water discharge (Manninen et al., 2018). However, Saha et al. (2024) found no interaction between tile drainage and tillage, crop rotation complexity, or cover crops. As such, the interaction between other management forms and tile drainage is likely system and soil dependent.

Conclusions

In summary, no differences in soil C stocks were detected in fields with new, old, or no tile drainage. However, soil type and texture influenced soil C regardless of drainage treatment. These findings are favorable for Willamette Valley growers because they indicate that subsurface drainage likely has little to no effect on soil C stocks over the long term. Nonetheless, potential interactions between different management practices (e.g., tillage, crop rotation history) and subsurface drainage remain understudied, and understanding these nuances will be important for providing farmers with best practice recommendations.

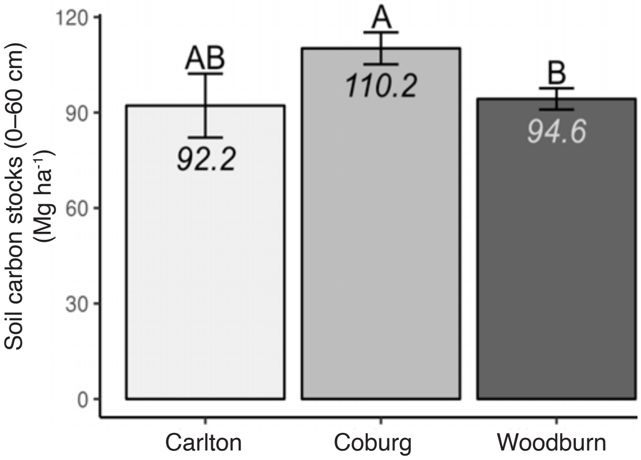

Figure 2. Cumulative soil carbon within each sampled soil series. Bars represent standard error of the mean; pairwise differences used significance level of alpha = 0.06.

A continuation of this work will use an equivalent soil mass approach to normalize C stocks on a mass per unit area basis to account for changes in bulk density throughout the soil profile (Wendt and Hauser, 2013). The next step in this work will investigate different C pools and where soil C accumulates within the soil to better understand how subsurface drainage impacts C cycling under shorter time frames.

References

Breza, L.C., J.M. Moore, A.A. Tomasek, K.M. Trippe. 2023. The effect of subsurface drainage in grass seed fields on soil carbon stocks. In N.P. Anderson, C.A. Mallory-Smith, D.L. Walenta, and J.F. Spring (eds.). *2022 Seed Production Research Report*. Oregon State University, Ext/CrS 168.

Kumar, S., T. Nakajima, E.G. Mbonimpa, et al. 2014. Long-term tillage and drainage influences on soil organic carbon dynamics, aggregate stability and corn yield. Soil Sci. and Plant Nut. 60:108–118.

Manninen, N., H. Soinne, R. Lemola, et al. 2018. Effects of agricultural land use on dissolved organic carbon and nitrogen in surface runoff and subsurface drainage. Sci. of the Total Environ. 618:1519–1528.

Saha, A.K., J.T. McMaine, T. Trooien, et al. 2024. Impact of no-till, crop rotation, cover crop, and drainage on soil physical and hydraulic properties. Soil Sci. Soc. of Amer. J. 00:1–19.

Wendt, J.W. and S. Hauser. 2013. An equivalent soil mass procedure for monitoring soil organic carbon in multiple soil layers. Eur. J. of Soil Sci. 64:58–65.

Acknowledgments

We thank the cooperating growers for their guidance and for allowing us to survey and sample their fields. We thank A. Gallagher for assisting with soil identification and classification. We also appreciate A. Anders, R. Baschieri, C. Kucera, K. Kucera, C. Lessey, V. Manning, K. Meyer, A. Ramirez, M. Roberto, J. Sakamoto, R. Stonebink, and G. Vasquez for their assistance in the lab and field. This work was funded by USDA-ARS project 2072-12620-001, OSU Agricultural Research Foundation, and the Oregon Seed Council.