TECHNICAL BULLETIN

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Decompaction and Compost Provide Improvements in Soil Health During Early Residential Development

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OVERVIEW: Decompaction and Compost Addition Have Clear Soil Health Benefits

Land development can have long-lasting effects on soil ecosystem services that include rainfall infiltration, turf and tree growth, and carbon sequestration. A multi-stakeholder partnership that consisted of the Iowa Stormwater Education Partnership (ISWEP), Southgate Development in Iowa City, and Iowa State University's Agronomy and Horticultural Departments studied residential development effects on soil health and effectiveness of rehabilitation.

The impact of five soil restoration practices on urban soils was studied in a development setting (Figure 1). Four of the five included combinations of decompaction and addition of an organic amendment, the remaining was a control. These treatments tested some the of soil quality restoration practices in the Iowa Stormwater Management Manual (ISWMM) after soil disturbance of mass and fine grading simulating subdivision development. Treatments included: a) the control which was business-as-usual treatment with compacted subsoil and 4" of topsoil, b) mechanically decompacted subsoil and 4" loosened topsoil [MD10], c) mechanically decompacted subsoil with 4" of green manure (tillage radish) amended loosened topsoil [BD10], d) mechanically decompacted subsoil with 1" of loosened topsoil mixed with 1" compost [CST5], and e) mechanically decompacted subsoil mixed with 1" compost and 1" loosened topsoil [CS15] (Figure 3). After turfgrass was established in all plots, compaction (bulk density), other physical parameters, and infiltration rates were measured, microbial biomass, and microbial activity were assessed via decomposition.

Strong effects of mechanical decompaction of subsoil were observed, which increased infiltration rate by over 2000% and time-to-runoff by 463% on average, providing strong evidence that deep ripping subsoils and placement of decompacted topsoil improves water infiltration and reduces runoff from residential lawns. Also, adding compost increased soil organic matter by 79% and some plant-available nutrients by over 60% compared to unamended soils. Biological decompaction after mass grading with tillage radish had little effect, likely due to the short growth period and degree of compaction. There were very few effects of post fine grading restoration treatments on soil microbial biomass and other biological soil health indicators. The rehabilitation practices, subsoil decompaction and compost addition had clear benefits to early physical and chemical soil health. Both of these practices are recommended to land developers for improving soil ecosystem services in the short-term, and perhaps even long-term, after urban land development projects.

Plot preparation for different soil restoration methods used for the study.

Ripper head skid loader used for mechanical decompaction of soils.

Infiltration rate and time of concentration monitoring using Cornell sprinkle infiltrometers.

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RESEARCH PROCESS

Research Site

The study took place near Iowa City, IA in a mixed-use commercial and farming area. Prior to the experiment, the field was left fallow for several decades with fill material brought in over several years, vegetation was mostly bromegrass (*Bromus spp.*). The soils were mainly silt loam. The trial was a non-randomized, blocked design experiment in a 1.38 acre field (Figure 1). The study was conducted September 2019-November 2021.

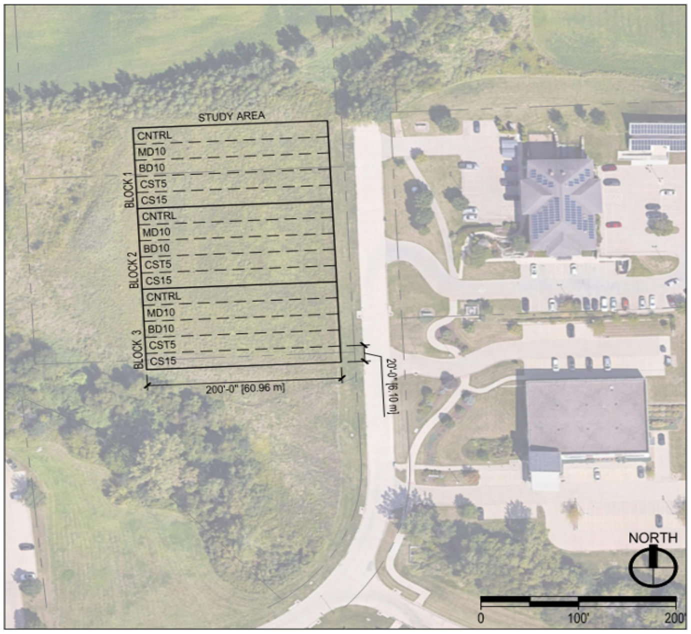

Figure 1. Study plot layout.

Mass Grading Phase

Typical mass grading practices were simulated on 1.85 acres on September 2019 (Step 1 – Mass Grading, Figure 2). Topsoil was stripped and stockpiled onsite using a 750k bulldozer. A six-wheel 140H AWD grader was used to simulate soil compaction during the mass grading and utility phases. Four inches of topsoil was placed on top of these soils using the same bulldozer. Plots were laid out and seeded with cereal rye (*Secale cereale*) and mulched with straw. The BD10 plots (Figure 3) were also initially seeded with tillage radish (*Raphanus sativus*) on September 2019 at a rate of 3 pounds/acre in addition to the cereal rye and straw.

Poor germination of tillage radish occurred the following spring of 2020, perhaps because of cereal rye allelopathy, so those BD10 plots were reseeded with tillage radishes on September 2020 at the same rate and added annual ryegrass (*Lolium multiflorum*) at a rate of 10 pounds/acre. There was successful germination of tillage radish in the spring of 2021.

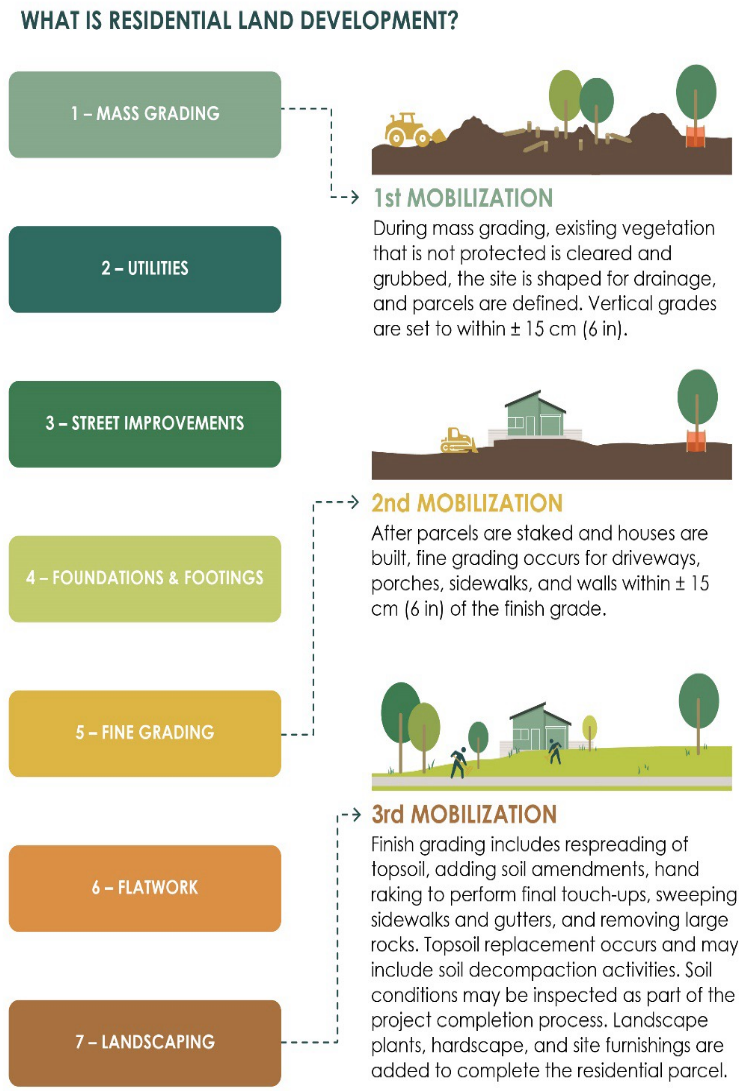

Figure 2. The process of site grading from mass grading to final landscaping. There are seven steps with three mobilization phases with mass-grading being the largest soil disturbance. Regarding the treatments in this study (Figure 3), the tillage radishes were planted prior to Step 5, all other treatments were implemented between Step 5 and Step 6.

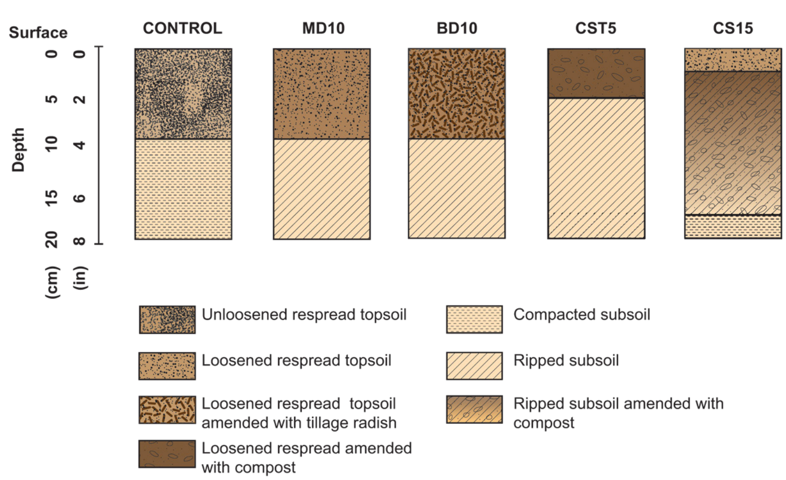

Figure 3. Soil restoration treatments used in the study.

Fine Grading SQR Phase

Five treatments were replicated, sequentially in three blocks with 200’ × 20’ plots (Figures 1 and 3). Development Steps 2, 3, and 4 were not simulated in this experiment because they deal with infrastructure installation (which we did not do at plot scale). Methods 5 and 6 in the Iowa Stormwater Management Manual (Chapter 5, Section 6) were evaluated in addition to other practices.

In May 2021, simulating the fine grading activities of Step 5 (Figure 2), topsoil was pushed to the end of the field and the subsoil in all plots were equally compacted with typical grading equipment. The earth moving during this fine grading was conducted with a bulldozer and a six-wheel, AWD grader. For subsoil decompaction, a compact track skid loader was used equipped with a 6.25’ wide CL Fab XR Ripper with 1.5’ depth capability. For the decompacted treatments, which includes all but the Control treatment, a first pass was ripped to 4” followed by a second and third pass to 6”.

Figure 4. Grader used to simulate soil compaction.

A day later, the fine grading was finished (Step 5), 1” of yard waste compost was added to the CST5 and CS15 treatments. The primary difference between the two compost treatments was how it was mixed and applied to the soil. With the CST5 treatment, the compost was mixed with 1” of topsoil and added on top of decompacted subsoil; whereas with the CS15 treatment, the compost was mixed with the subsoil and then 1” of loosened topsoil was added. Steps 6 and 7 were not simulated in this experiment. Soil testing occurred after this time.

Field & Lab Soil Health Analyses

- Bulk density (compaction), pore space, and water-filled pore space (WFPS)
- Infiltration rates and time-to-runoff
- Microbial biomass and salt-extractable organic carbon (C) and nitrogen (N)
- Phosphorus (STP) and potassium (STK)
- Soil organic matter (SOM) and pH
- Biological activity using green and rooibos teas.

Effects of Decompaction on Soil Health

- Decompaction increased infiltration rates by over 2000% and time-to-runoff by 463% on average compared to the control (Figure 5).
- Substantial improvements in water intake from the physical soil rehabilitation treatments aligns with the goals of, and guidance for, land developers offered by the Iowa Stormwater Management Manual.
- Compared to other studies on urban soils, bulk density, pore space, and infiltration measurements are within the norm for the treatments.
- The mechanical decompaction had mixed effects on bulk density (compaction) and pore space (Figure 6). This could be due to the dynamic nature of soil bulk density, rapid settling of decompacted soils and measurement noise using this imprecise method.
- Using the tillage radish for biological decompaction did not have a strong effect on infiltration in this study. This contrasts with multi-year agricultural studies that show tillage radish can decrease bulk density and improve infiltration rates. This could be due to length of time for full development and decomposition and degree of soil compaction. It may also be unreasonable to expect significant improvement in infiltration from tillage radish from only one year.
- Decompaction treatments had little effect on soil chemical or biological properties at either depth. Adding compost, however, did have positive impacts on these soil properties.

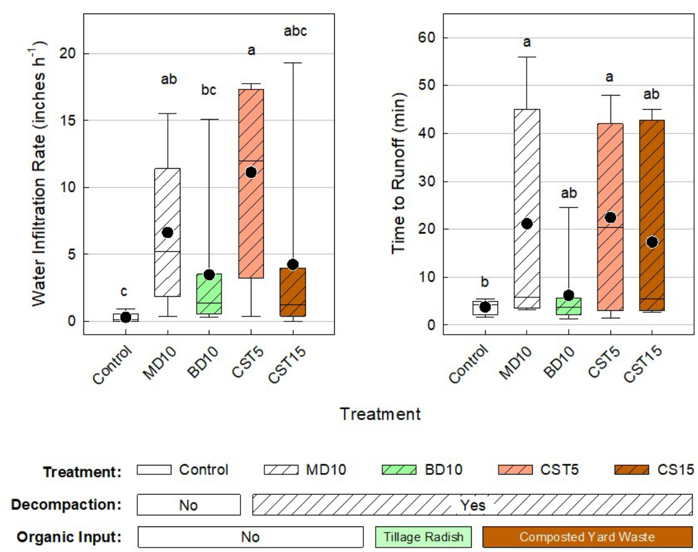

Figure 5. Infiltration rate and time-to-runoff shown from spring to autumn. Boxplots (n = 12) show total variation with 10th percentile (lower whisker), 25th percentile (lower box shoulder), median (horizontal line in box), mean (large black dot), 75th percentile (upper box shoulder), 90th percentile (upper whisker). Treatment differences are indicated by lowercase letters.

RESULTS: Effects of Compost and Tillage on Soil Health

•Compost inputs may have longer-term effects on providing nutrients (i.e. reduction of fertilizer inputs), improved soil water holding capacity, and enhanced soil biota habitat. This study is probably the only one that used yard waste compost and tillage radish as organic amendments

•Like many other studies, Soil organic matter (SOM) was greater in the upper 0-6” (2 to 7%) compared to 6-12” (1.5 to 2.5%) (Figure 7). Adding compost and tillage radish tended to increase indicators of chemical and biological soil health but had little effect on soil physical parameters.

•The compost had stronger effects than tillage radish, especially for the top 0-6” of soil. This is likely due to the short length of time for radish growth and decomposition and soil compaction after mass grading. There may be a range of moderate soil densities where biological tillage is feasible and where densities are great, mechanical tillage is needed. The compost was added and mixed with topsoil (Figure 3), thus the positive effects are mostly concentrated in 0-6” soil depth increment (Figure 7).

•On average, compost increased SOM by 43%, but only in the top 6” of the soil profile (Figure 7). Adding compost in general tends to have positive effects on SOM and soil organic carbon.

•Phosphorus (STP) significantly increased by 79% and STK by 60% compared to no compost treatment (MD10). Unlike SOM, however, the effect on these macronutrients persisted to 6-12” depth, albeit of a lesser magnitude (Figure 7). Soil nitrate, and ammonium, N remained low in our soils (< 1.05 ppm).

•While the compost tended to increase soil microbial biomass, activity via tea decomposition, and substrates available to microbes (e.g., SEOC, SEON); only a few of these soil properties were significantly different compared to the no amendment treatments (Figure 8). Compost increased SEOC by 220% compared to no amendment at all (i.e., Control & MD10, (Figure 3). Greater soil SEOC concentrations are considered to be better for soil health because of the connection to microbial activity and may even help contribute to lower nutrient (especially N) loss. Other studies have shown that organic inputs significantly increase microbial biomass and activity, this study showed only SEOC increases likely related to C:N ratios.

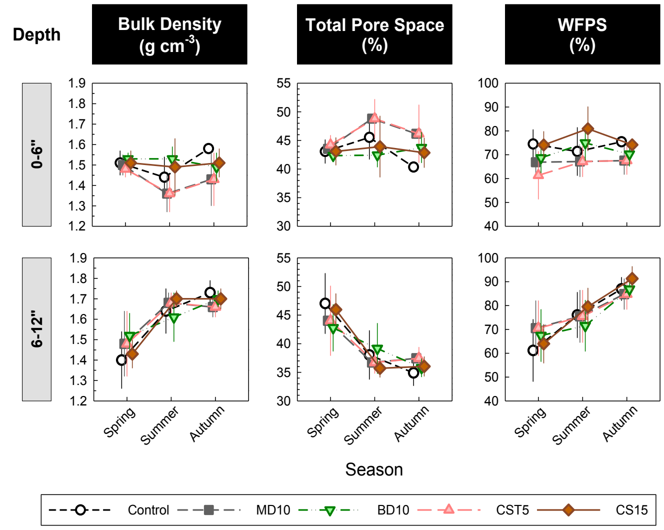

Figure 6. Physical soil properties: BD = bulk density, TPS = total pore space, WFPS = water-filled pore space. Data points are means with standard errors (n = 3).

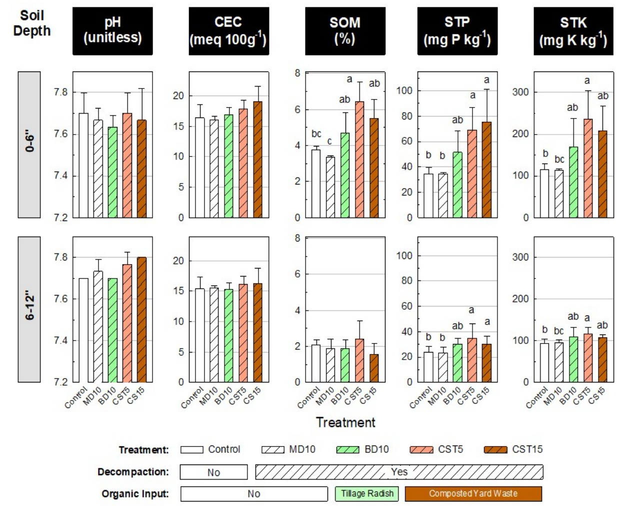

Figure 7. Chemical soil health measurements: CEC = cation exchange capacity, SOM = soil organic matter, STP = soil test phosphorus (Melich-III), STK = soil test potassium (Melich-III). Data are means with standard errors (n = 3) and significant treatment differences are indicated by lowercase letters.

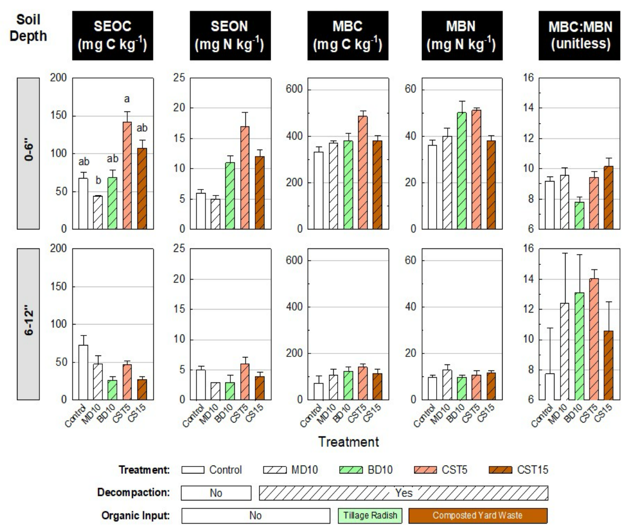

Figure 8. Biological soil health measurements: SEOC = salt-extractable organic carbon (C), SEON = salt-extractable organic nitrogen (N), MBC = microbial biomass C, MBN = microbial biomass N, MBC:MBN = microbial biomass C-to-N ratio. Data are means with standard errors (n = 3) and treatment differences shown with lowercase letters.