

# **The Long-Term Soil Productivity Study (LTSP) in Great Lakes Aspen Ecosystems: findings from the first decade**

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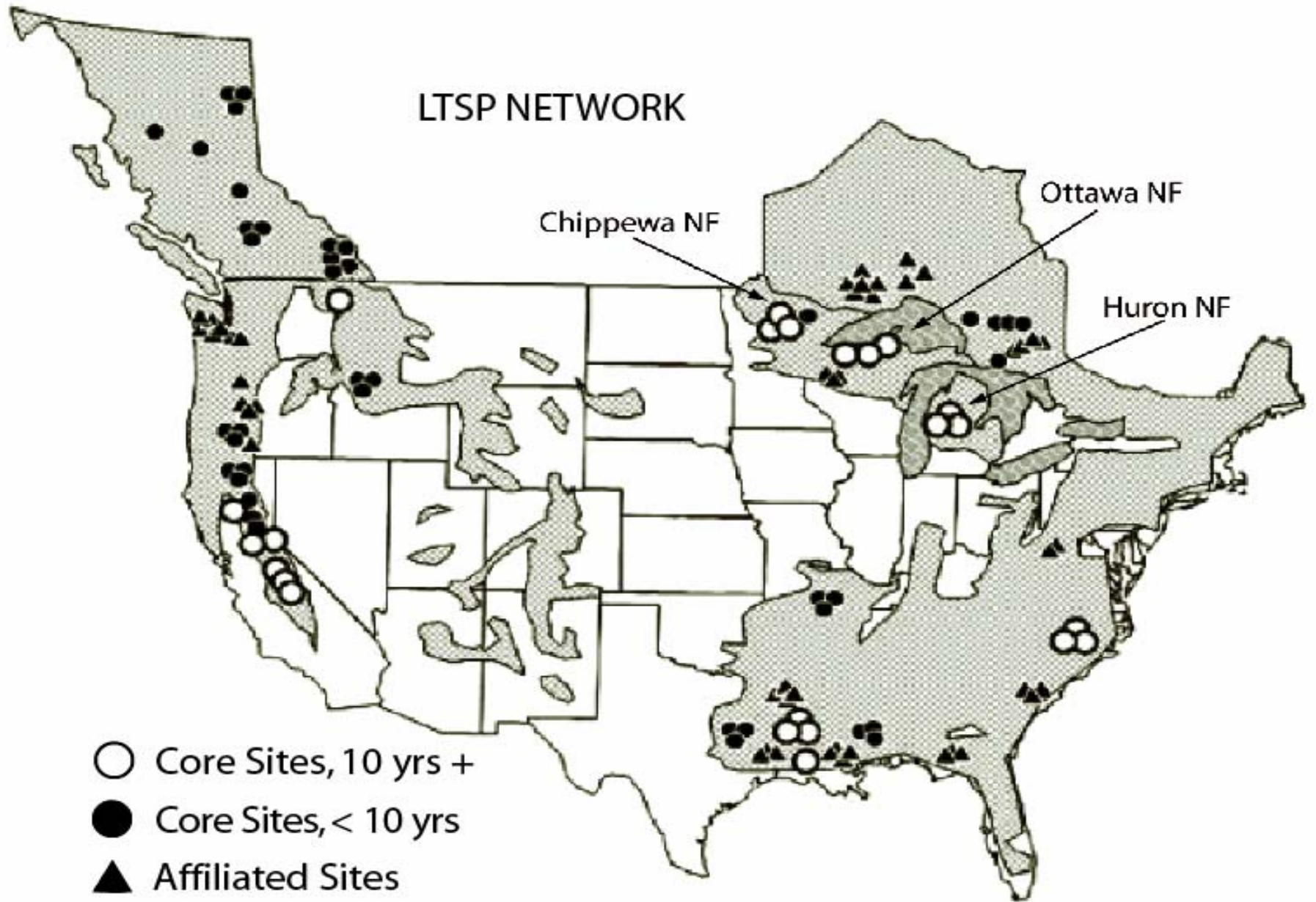
# Overview of LTSP National Study

- Discussions between NFS and FS Research soil scientists lead to the establishment of the North American Long-Term Soil Productivity Program in 1989.
- The issue: How to provide scientifically sound data for the forests to comply with the NFMA, which requires NF to monitor effects of their management activities to ensure that the long-term productivity of the land is not impaired.

# Overview of LTSP National Study

- An extensive review of the world's literature revealed that organic matter removal and/or soil compaction most affected site productivity.
- Today, the LTSP program is an international endeavor involving government, university and industry cooperators.

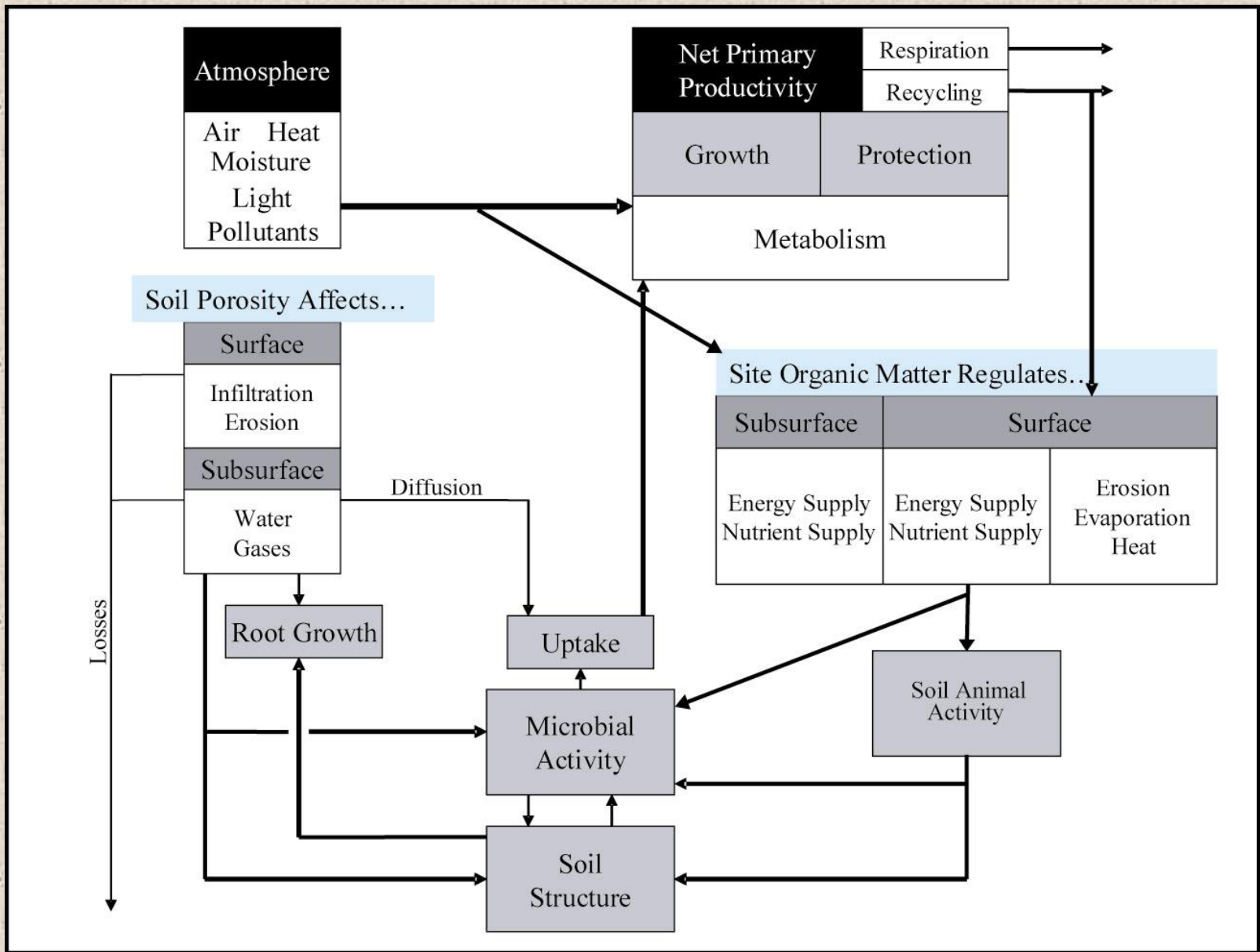
# LTSP NETWORK



# Overview of LTSP National Study

## Objectives:

- Determine how soil porosity and organic matter affect soil processes controlling forest productivity and sustainability
- Monitor changes in soil properties following soil compaction and OM Removal



Conceptual model suggesting influence of site organic matter and soil porosity on fundamental site processes that regulate primary productivity (after Powers et al. 2005).

# General Effects of Compaction on Soils

Compaction primarily affects soil macroporosity and can:

- decrease soil aeration
- alter the balance of  $O_2$  and  $CO_2$  in the soil profile and gas exchange w/ atmosphere
- influence the soil moisture holding capacity soils (decreases in most soils but can increase in some sands)

# General Effects of Organic Matter Removal on Soils

Loss of organic matter can alter:

- development of soil structural aggregates
- soil water holding capacity
- ion exchange and nutrient availability

# Overview of LTSP National Study

## LTSP Hypotheses and associated guidelines:

- **Pulse changes in site organic matter or soil porosity will not affect a site's long-term productivity.**
  - **Guideline: how much impact can occur before productivity is affected**
- **If impacts do occur, they are universal.**
  - **Guideline: what sites are most susceptible**
- **If impacts occur, they are irreversible.**
  - **Guideline: how can impacts be ameliorated**

# LTSP Great Lakes Aspen Study

- NCRS scientists and the R9 soil scientist and Silviculturist determined that aspen would be the target species.
- In 1990, the Lake States LTSP program in aspen ecosystems was approved by the Chippewa, Huron-Manistee, and Ottawa Forest Supervisors.

# LTSP Great Lakes Aspen Study

- The LTSP study in Great Lakes aspen is composed of 3 geographically separate installations, each site representing a distinctly different soil textural type.
- 1<sup>st</sup> installation: established in 1992 on a loamy clay located at the Ottawa NF.
- 2<sup>nd</sup> installation: established in 1993 on a loam soil located at the Chippewa NF.
- 3<sup>rd</sup> installation: established in 1994 on a sand soil at the Huron-Manistee NF.

# LTSP Great Lakes Aspen Study

- Determine soil physical and chemical responses to compaction and organic matter removal
- Determine total above ground plant biomass and aspen responses to compaction and organic matter removal
- Compare responses across a range of soils in the northern Lake States region

# Aspen Productivity Gradient

- High: Chippewa National Forest; 30 – 40 cm silt loam cap/till; 50-year Aspen SI ~ 75
- Med: Huron National Forest; deep, acid, outwash sands, SI ~ 65
- Low: Ottawa NF; deep, calcareous clay, moderately well-drained, SI ~ 55 - 60

# Treatments and Design

- Organic Matter Removal (OM) and Soil Compaction (C); in a completely randomized 3x3 factorial design.
- Organic Matter Removal:  $OM_0$  - Merchantable Bole Harvest (MBH);  $OM_1$  - Total Tree Harvest (TTH); and  $OM_3$  - Total Tree Harvest + Forest Floor (TTH+FFR).
- Compaction treatment to increase BD after harvest – targets:  $C_0$  – No compaction above that from initial winter harvest,  $C_1$  - Moderate and  $C_2$  - Heavy.

# Compaction and Organic Matter Removal Treatments

|       | $OM_0$                                  | $OM_1$                                  | $OM_2$   |
|-------|---|---|--|
| $C_0$ | (1)<br>MBH, No Additional<br>Compaction | (2)<br>TTH, No Additional<br>Compaction | (3)<br>TTH+FFR, No<br>Additional<br>Compaction |
| $C_1$ | (4)<br>MBH, Moderate<br>Compaction      | (5)<br>TTH, Moderate<br>Compaction      | (6)<br>TTH+FFR, Moderate<br>Compaction         |
| $C_2$ | (7)<br>MBH, Heavy<br>Compaction         | (8)<br>TTH, Heavy<br>Compaction         | (9)<br>TTH+FFR, Heavy<br>Compaction            |

MBH = Main Bole Harvest, TTH = Total Tree Harvest,

TTH+FFR = Total Tree Harvest plus Forest Floor Removal





# Measures

- Soil Bulk Density (soil cores)
- Soil Strength (penetrometer)
- Total soil carbon and nitrogen, pH
- Tree, shrub, herbaceous vegetation data
- measured preharvest, post-treatment (year 0), year 1, year 5, year 10
- idea is to continue to monitor every 5 years through one rotation

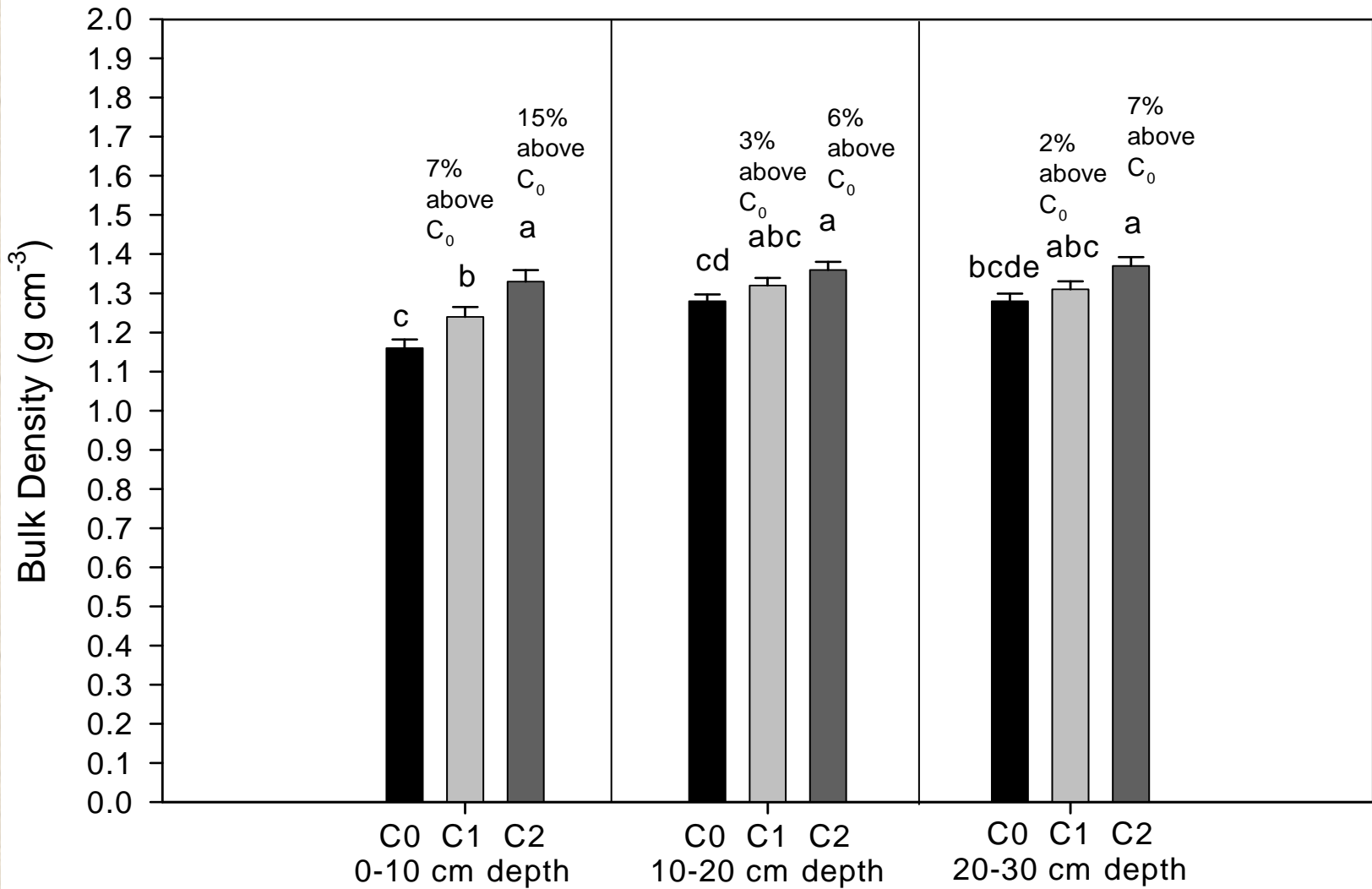
# Statistical Analysis

- Repeated Measures Analysis (SAS)
- Replications are considered random effects
- Least Squares Means comparisons ( $p = 0.05$ )

# Results

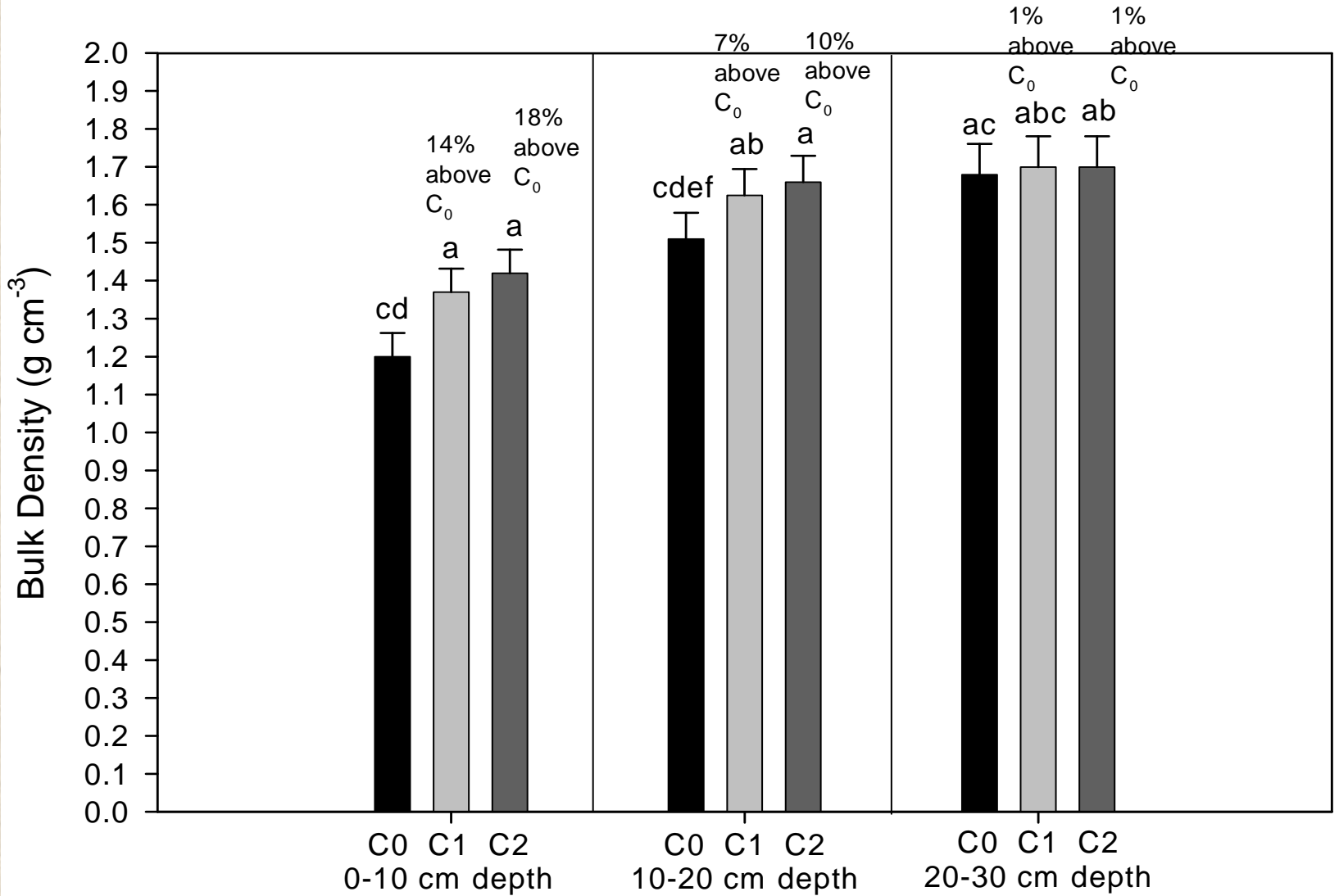
- No strong interactions detected between compaction and organic matter removal treatments
- Effects of organic matter removal and compaction on total carbon and nitrogen storage and effective cation exchange capacity were not significant at year 10 for all 3 soil types at any depth when compared to the main bole removal and no-compaction treatments.

# What overall degree of compaction was reached on the clay?



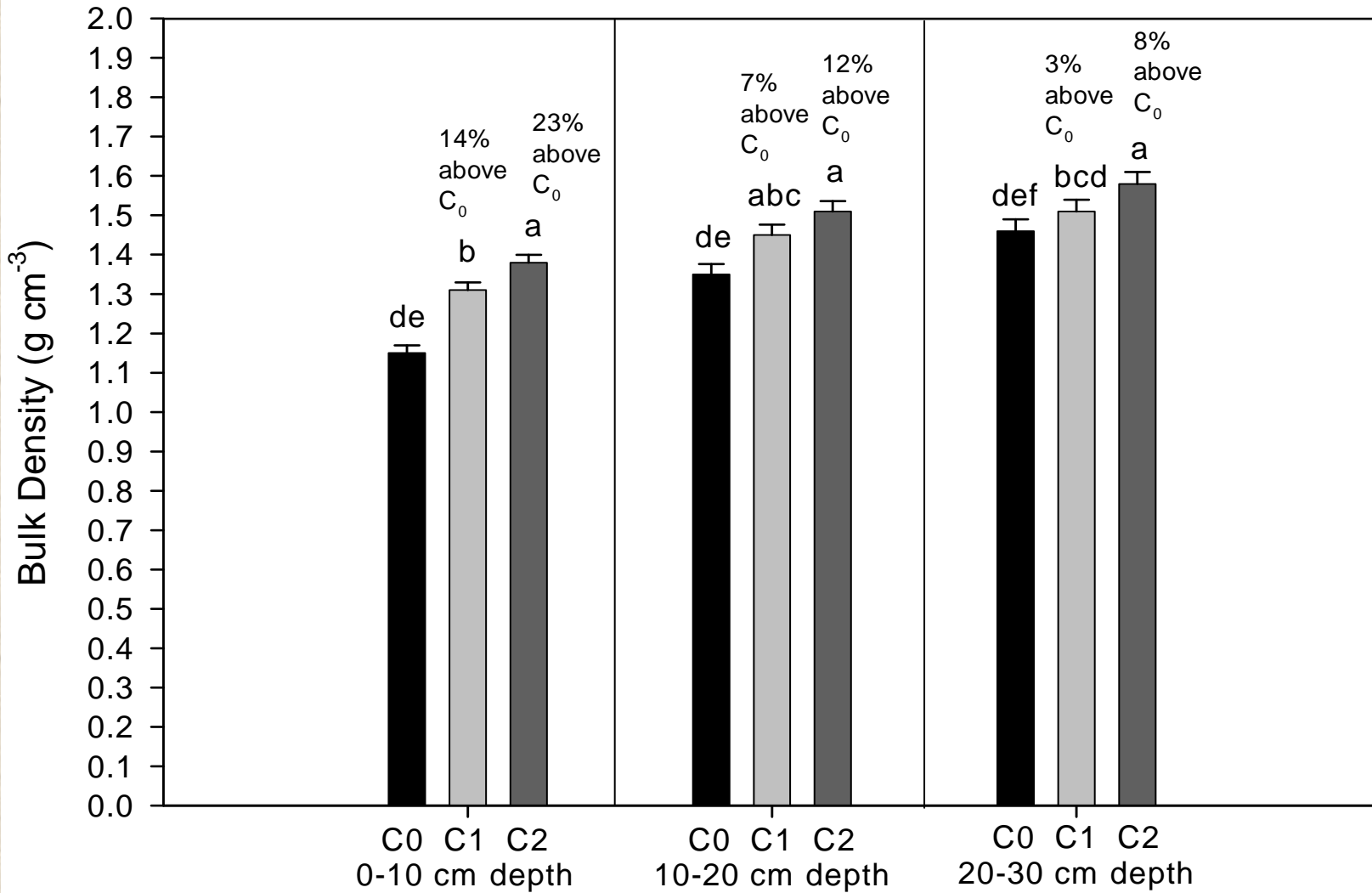
Compaction Treatments within Soil Depth Categories

# What overall degree of compaction was reached on the loam soil?

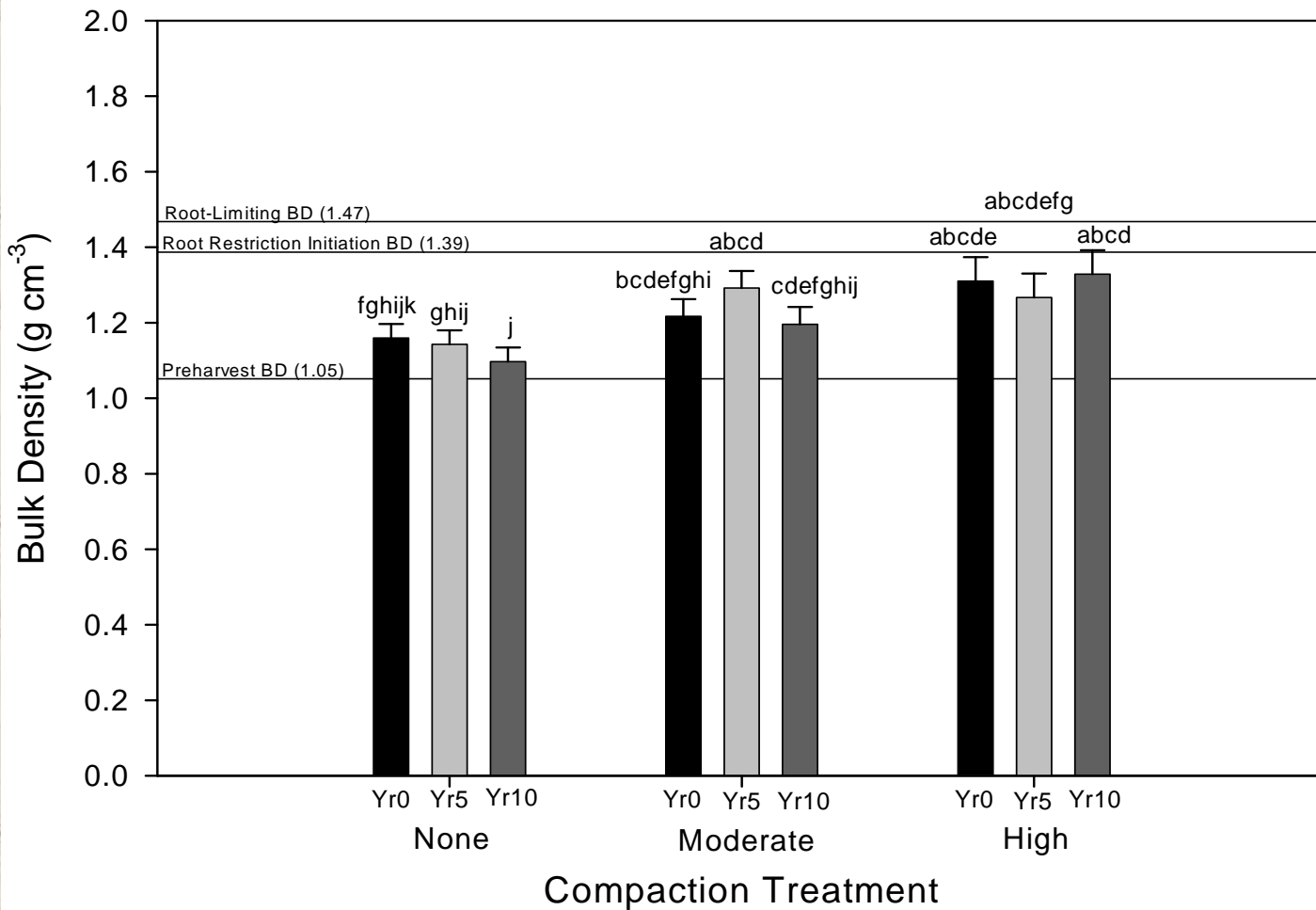


Compaction Treatments within Soil Depth Categories

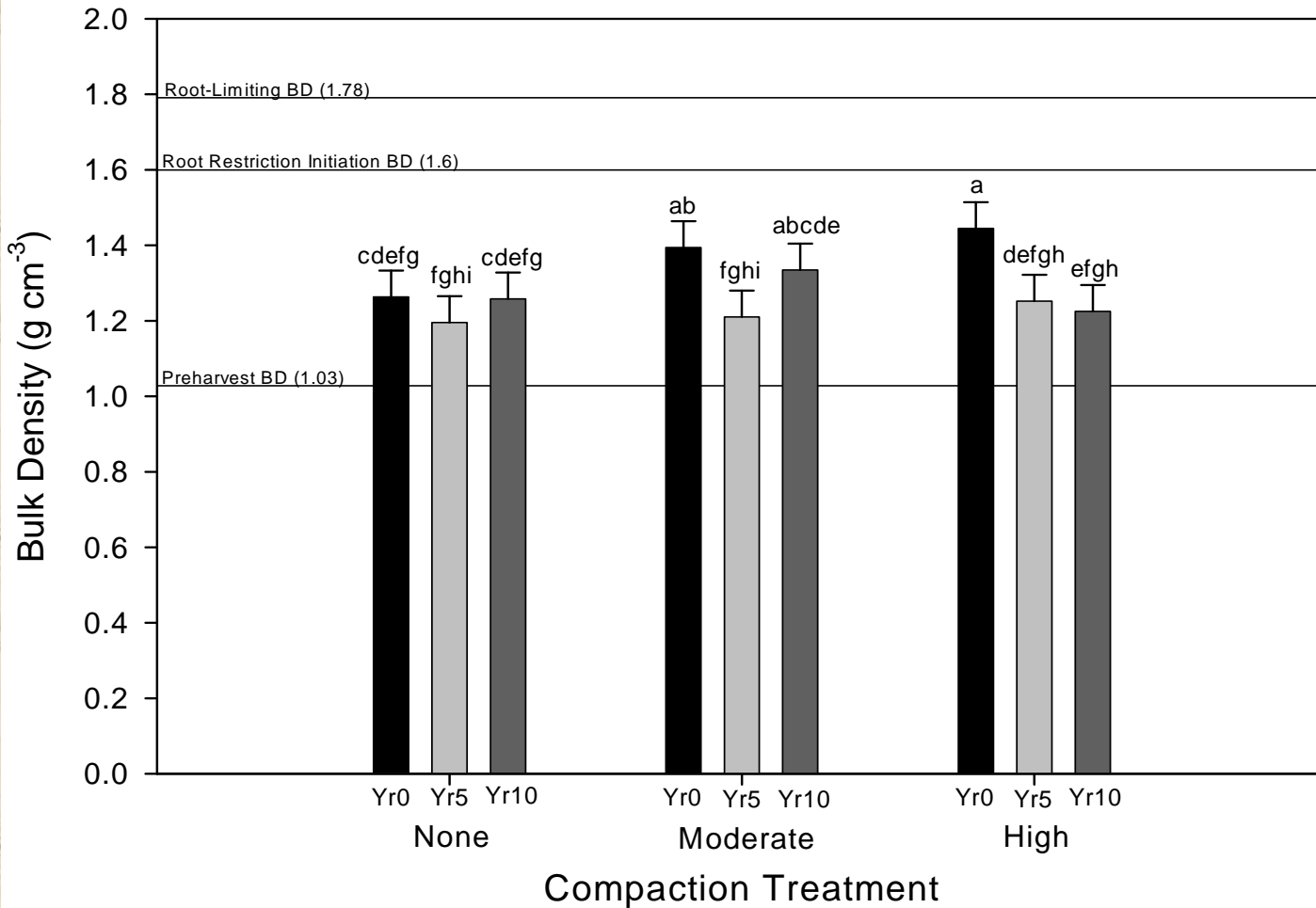
# What overall degree of compaction was reached on the sand soil?



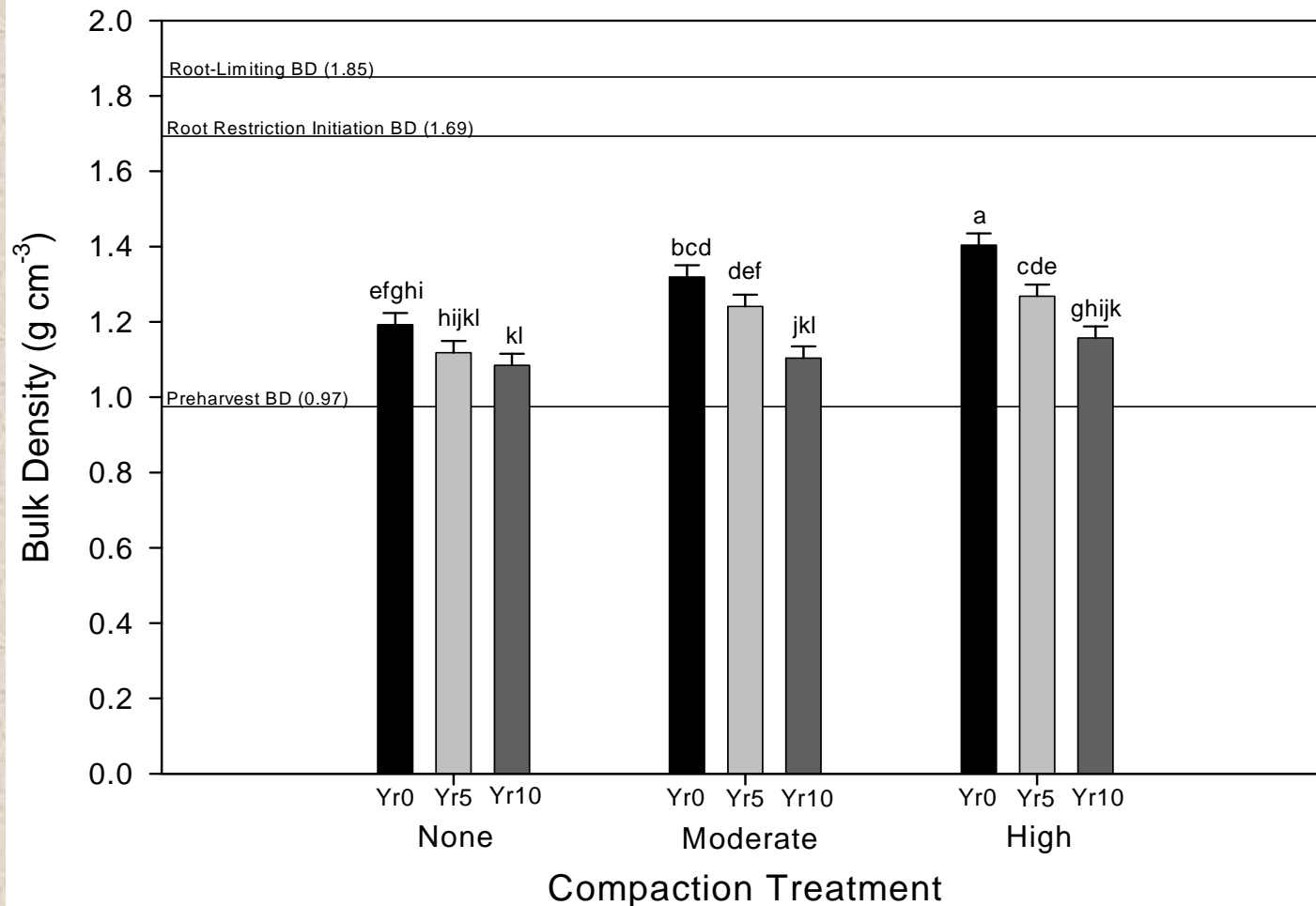
Compaction Treatments within Soil Depth Categories



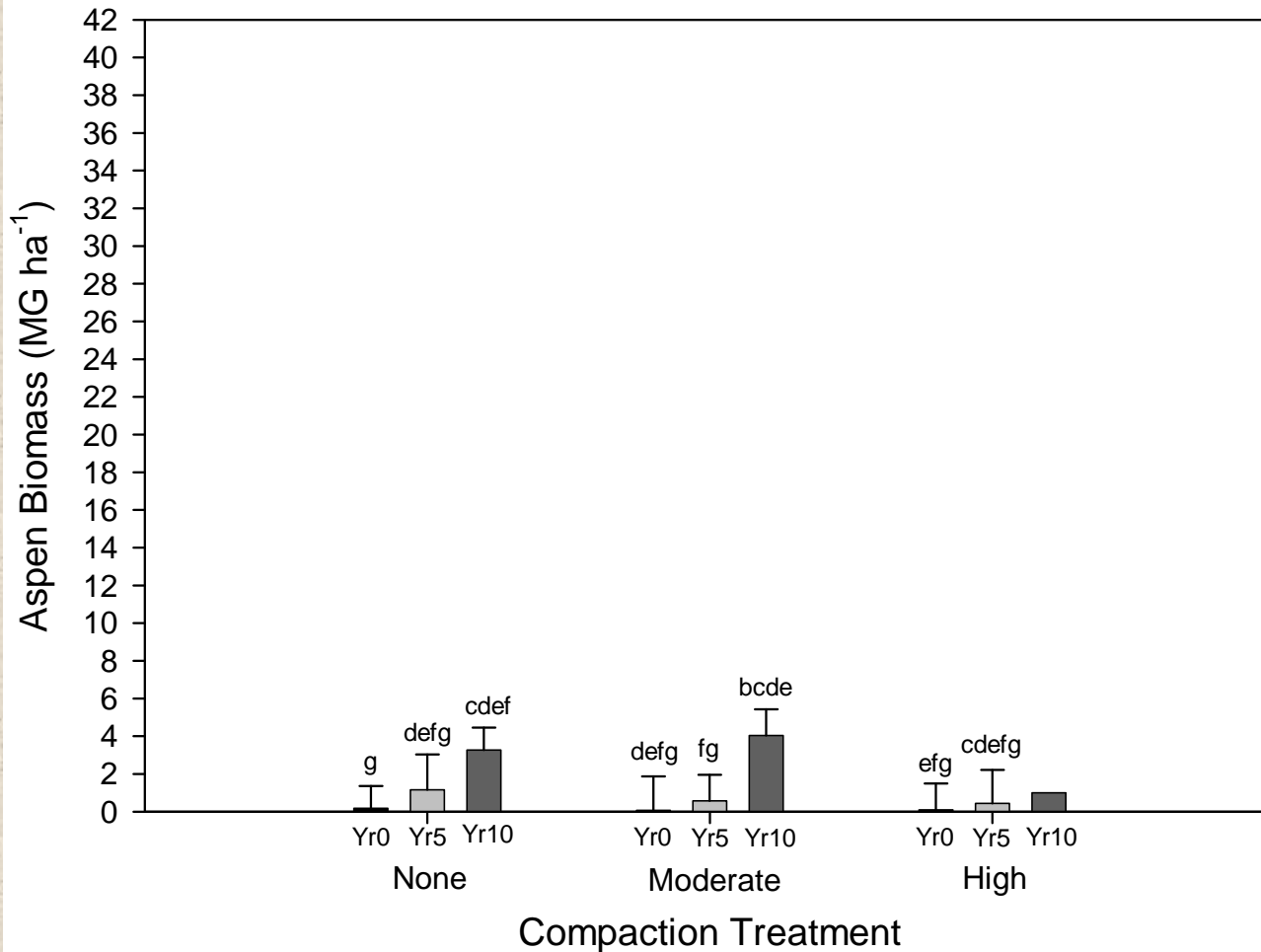
Effect of compaction treatments on 0-10 cm bulk density for the clay soil at Ottawa NF. Result: high compaction bulk density is still significantly greater than the no-compaction treatment after 10 years.



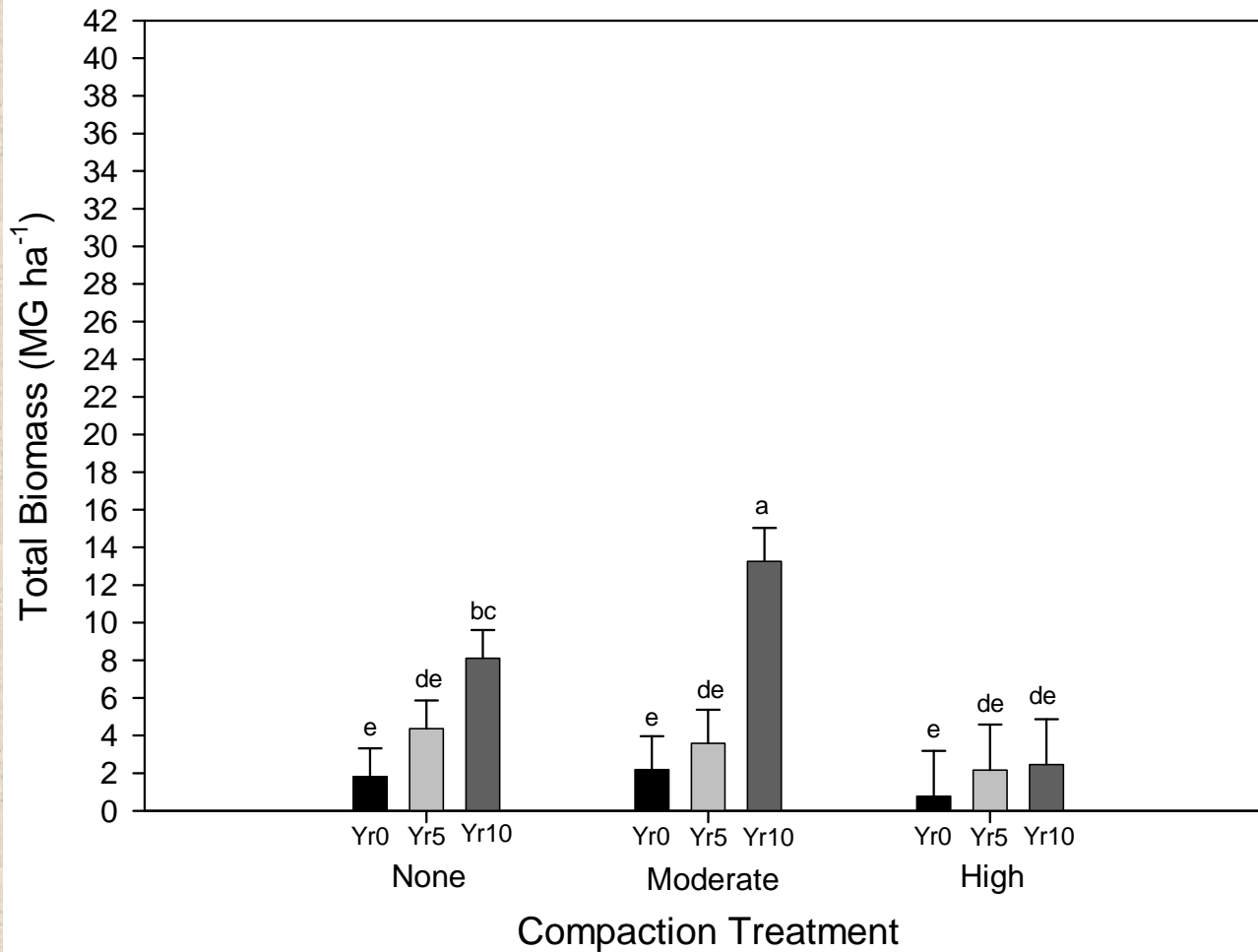
Effect of compaction treatments on 0-10 cm bulk density for the loam soil at Chippewa NF. Result: high compaction bulk density not significantly different from no-compaction treatment by year 10.



Effect of compaction treatments on 0-10 cm bulk density for the sand soil at Huron NF. Result: high compaction bulk density not significantly different from the no-compaction treatment by year 10.



Effects of compaction treatments on aboveground aspen biomass on the clay soil at Ottawa NF. Result: compaction had little effect on aspen biomass on the clay soil.



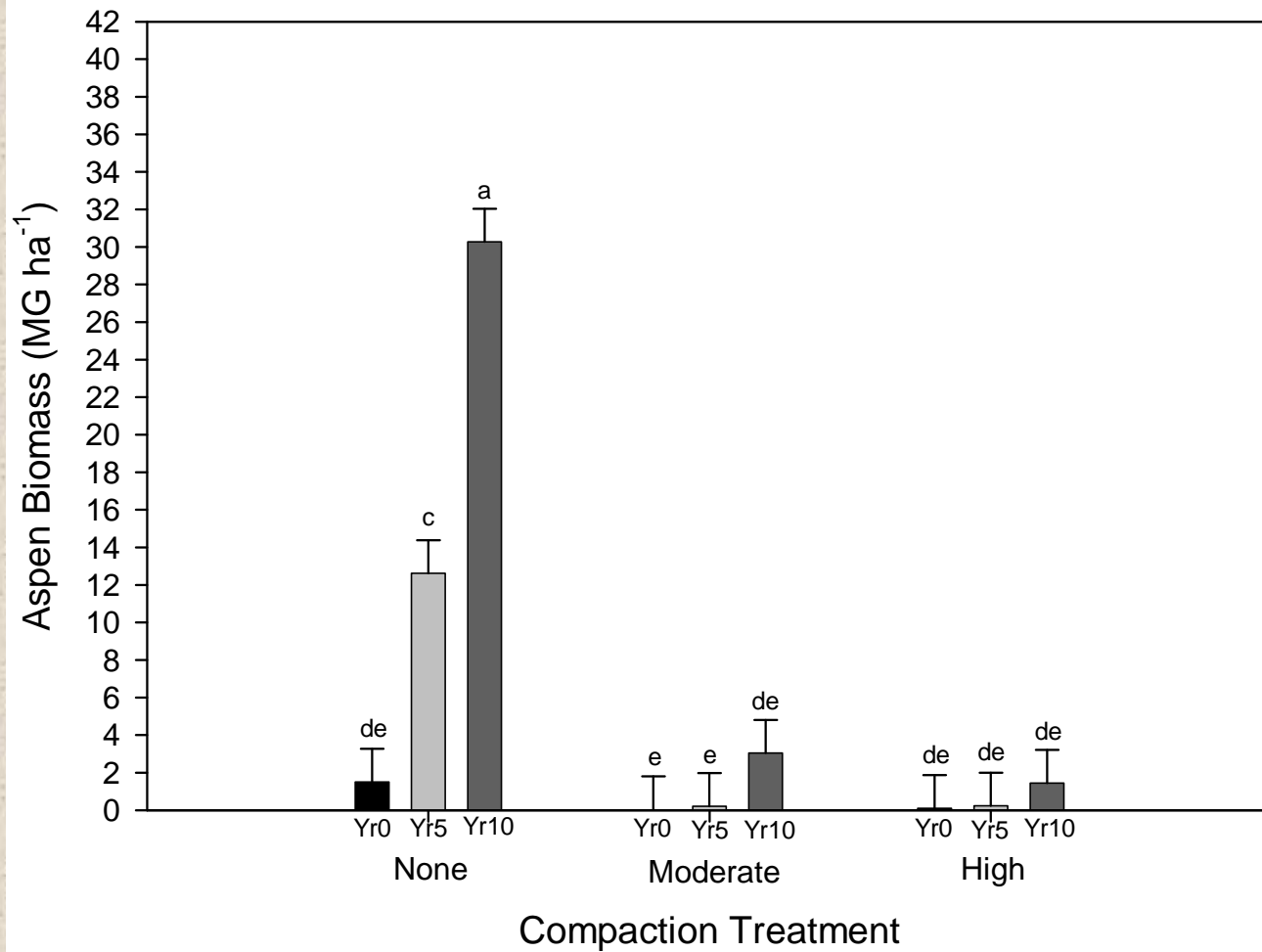
Effects of compaction treatments on aboveground total plant biomass on the clay soil at Ottawa NF. Result: moderate compaction significantly increase total biomass by year 10, while high compaction significantly decreased total biomass by year 10.



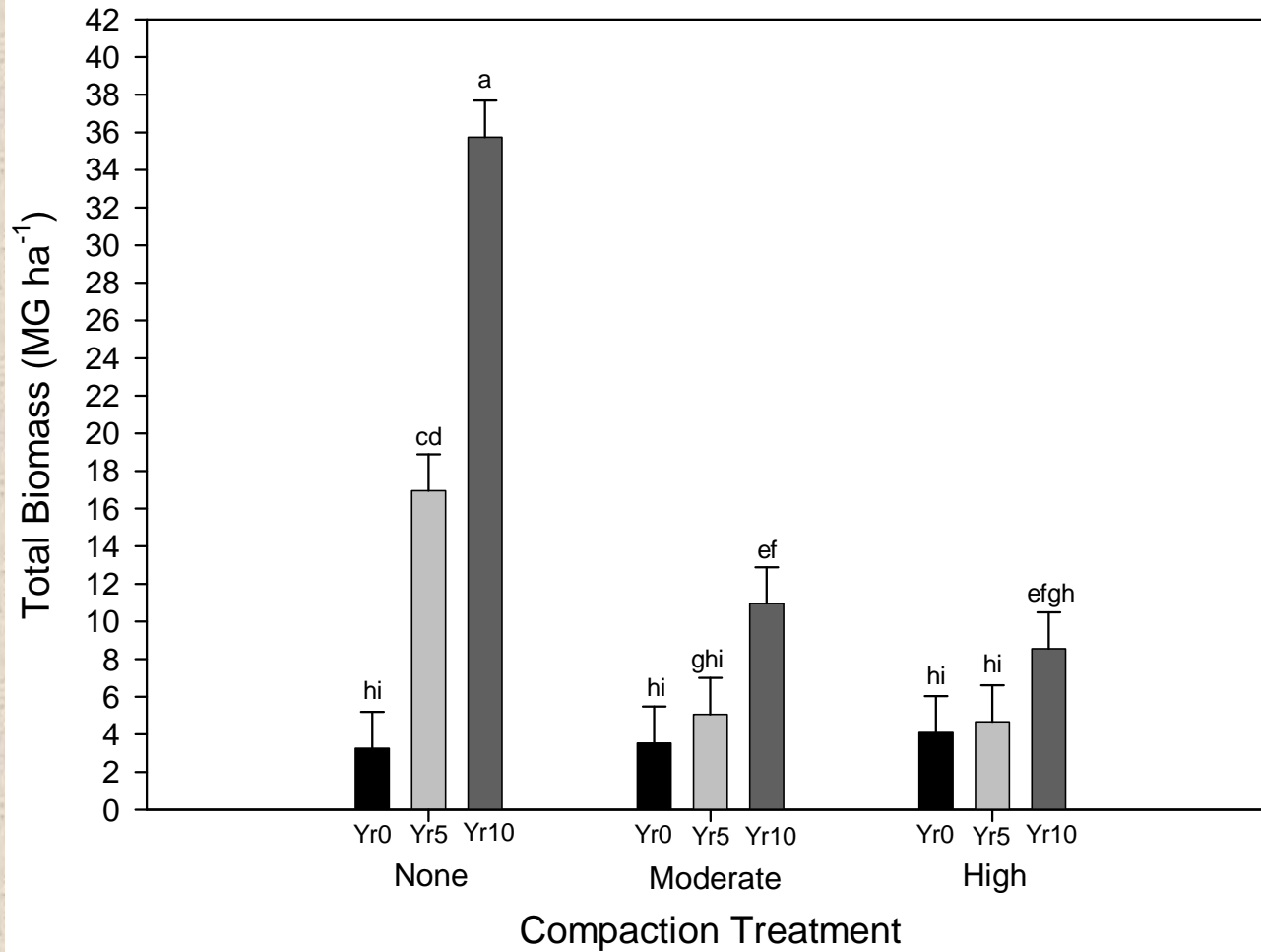
Ottawa NF (clay). No Comp, MBH



Ottawa NF (clay). High Comp, MBH



Effects of compaction treatments on aboveground aspen biomass on the loam soil at Chippewa NF. Result: both moderate and high compaction significantly reduced aspen biomass.



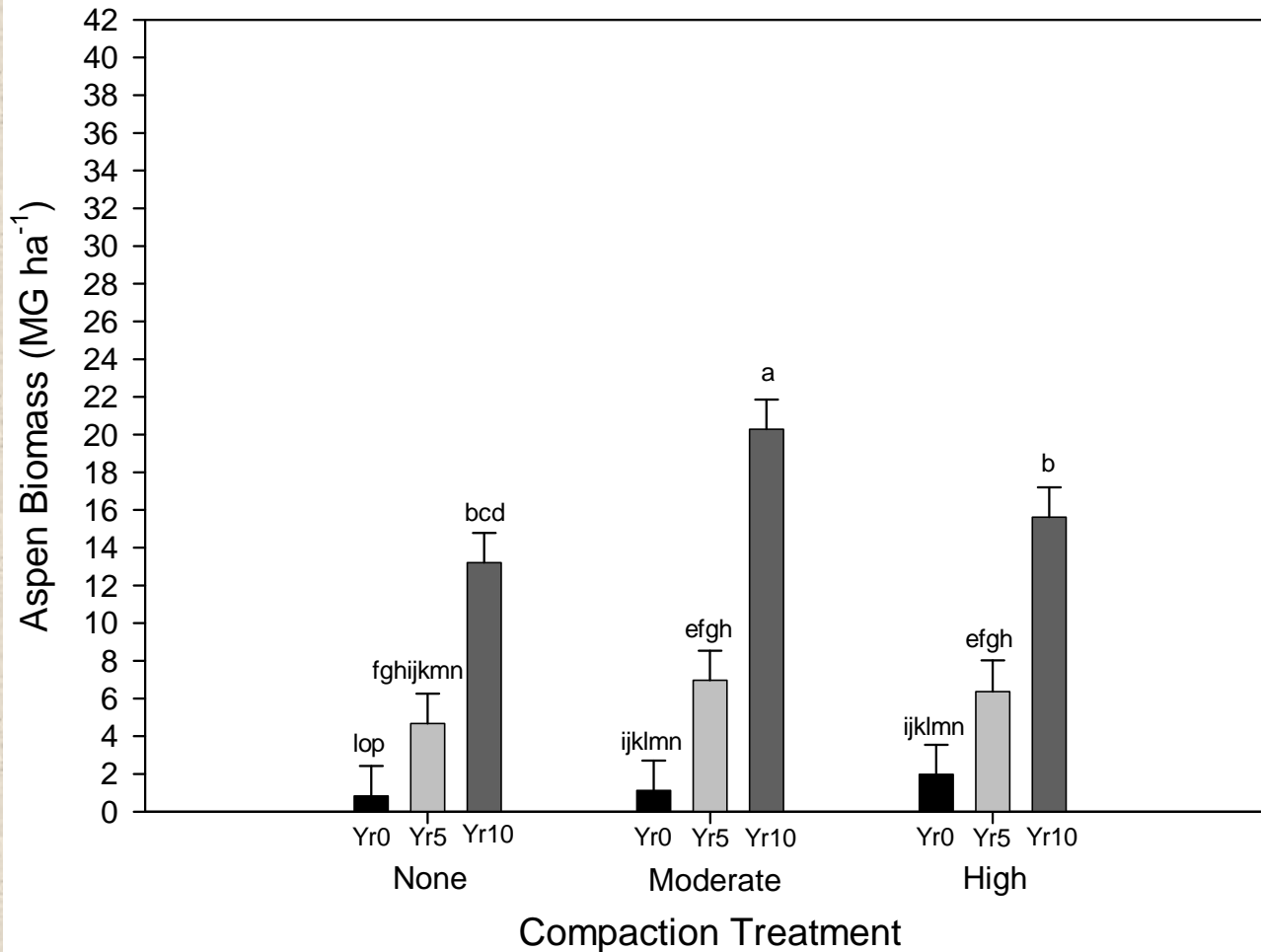
Effects of compaction treatments on aboveground total plant biomass on the loam soil at Chippewa NF. Result: both moderate and high compaction significantly reduced total biomass.



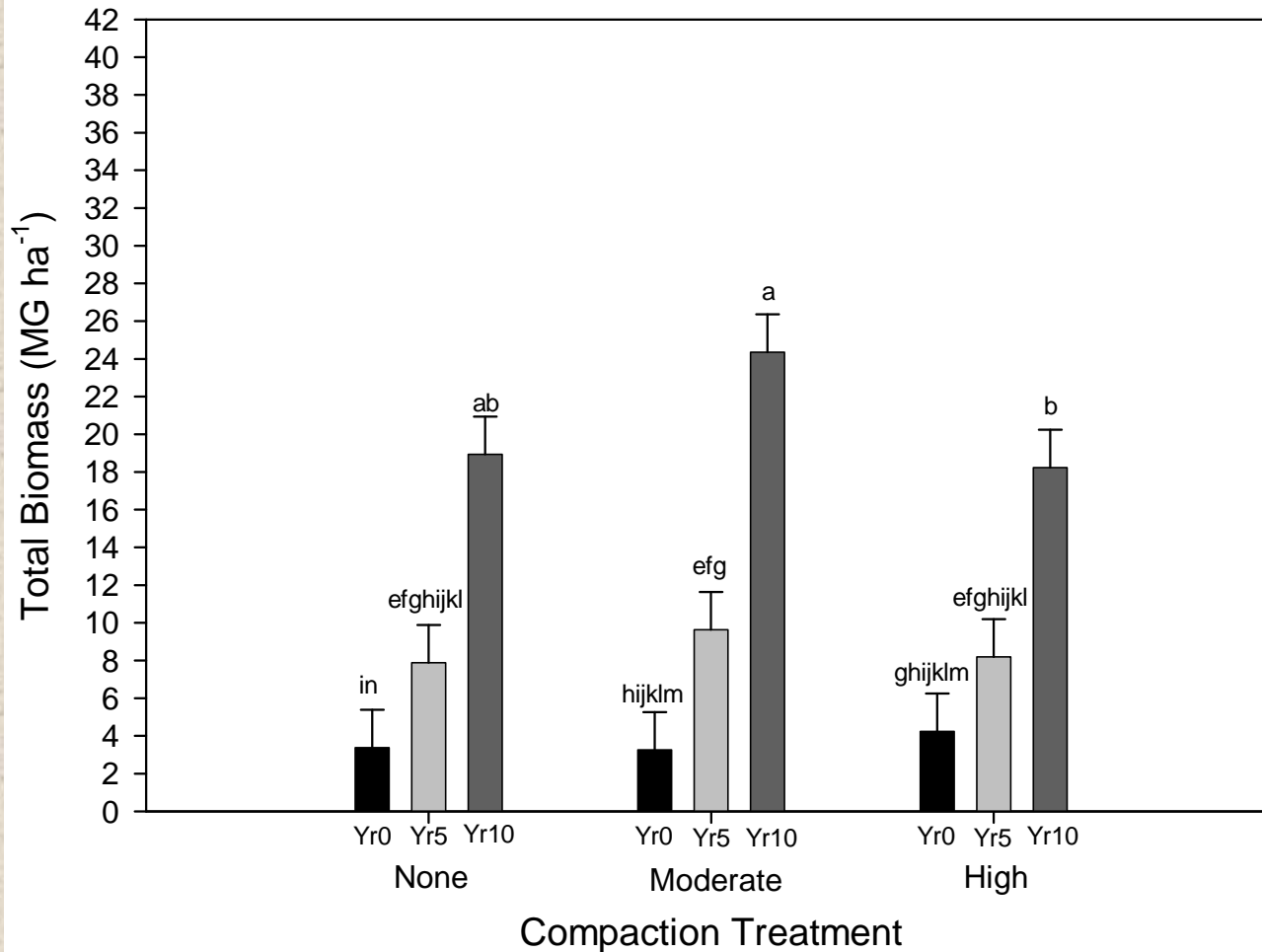
Chippewa NF (loam). No Comp, MBH



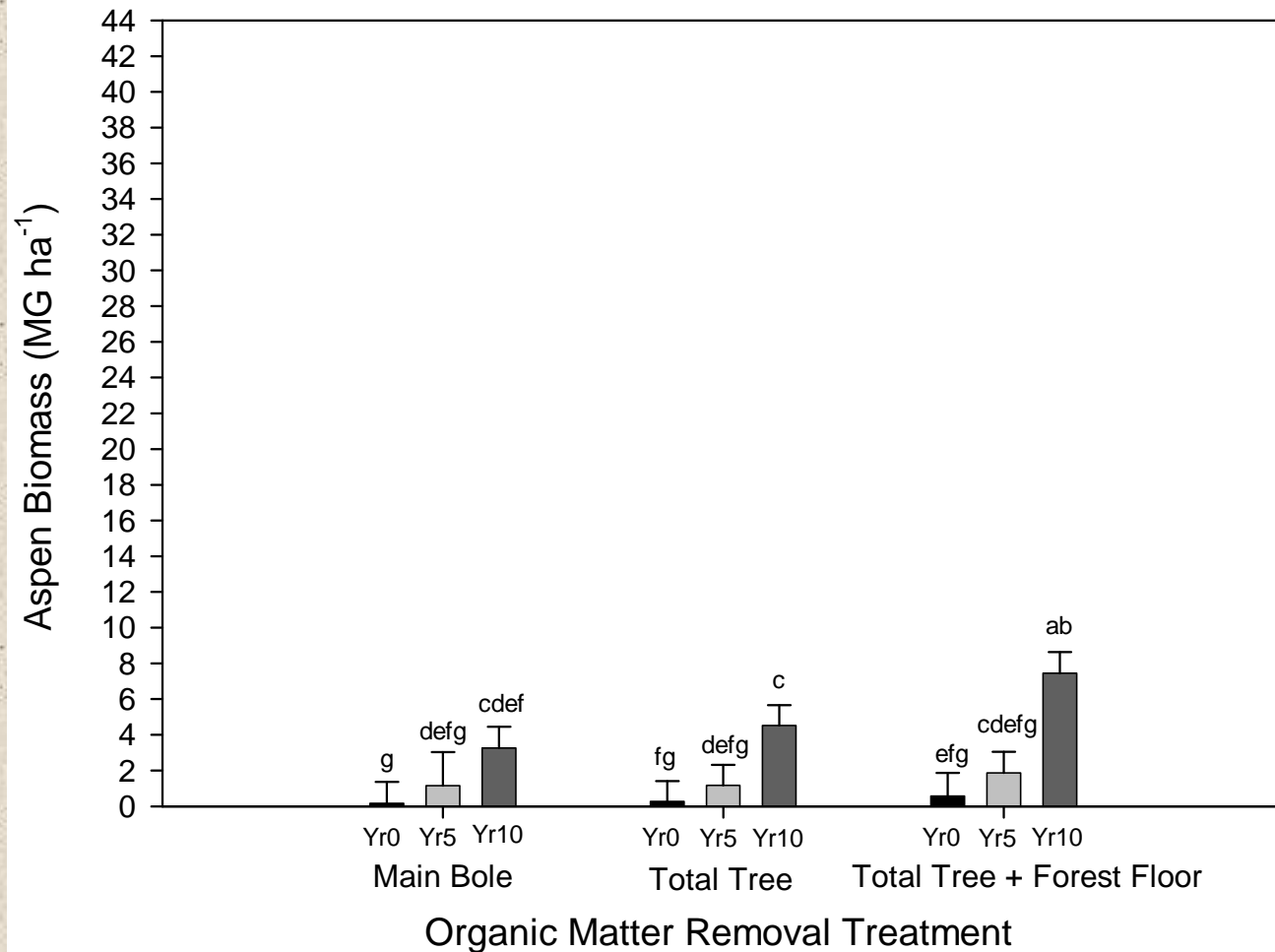
Chippewa NF (loam). High Comp, MBH



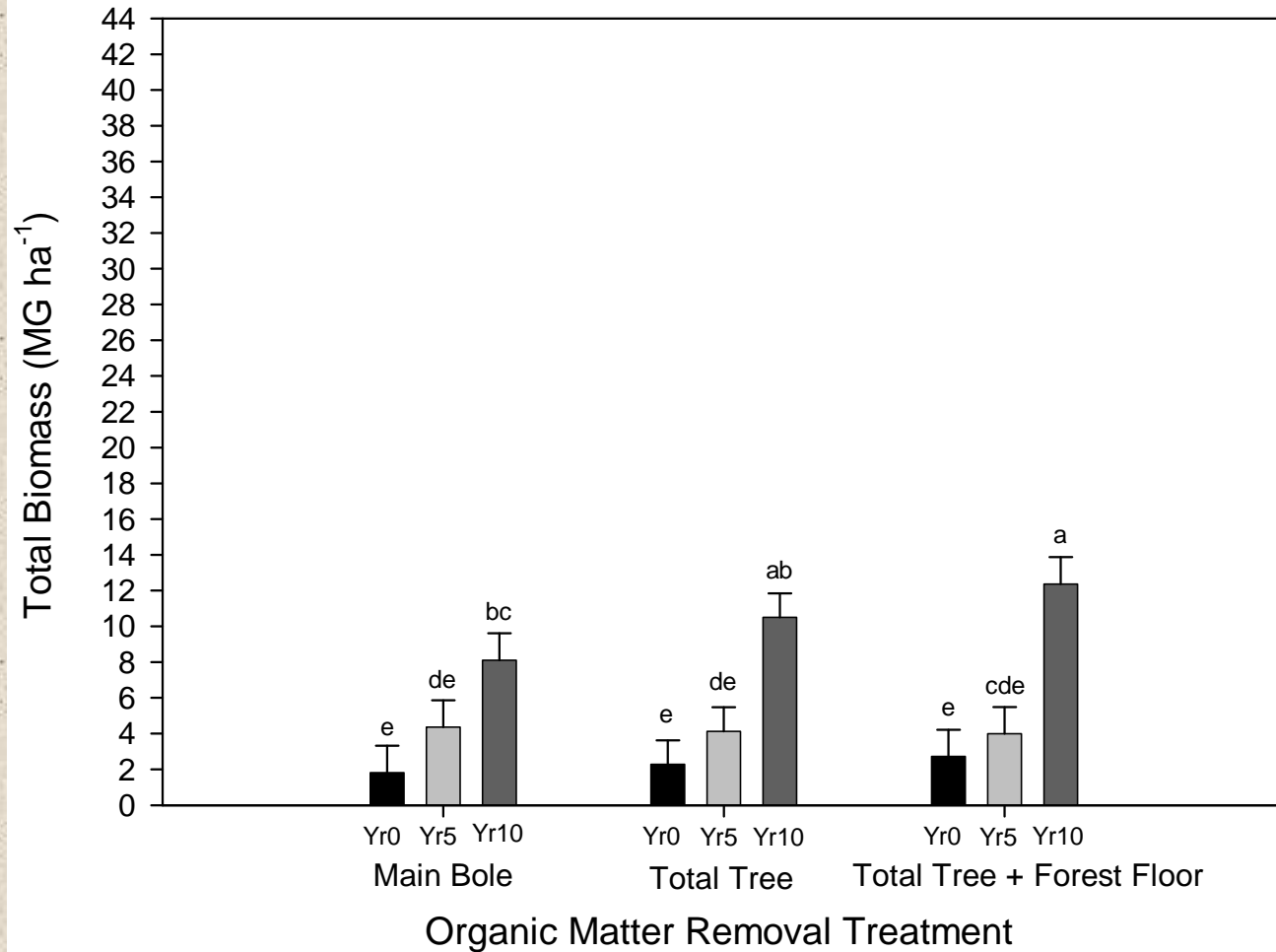
Effects of compaction treatments on aboveground aspen biomass on the sand soil at Huron NF. Result: moderate compaction significantly increased aspen biomass by year 10, while high compaction is not significantly different from the no-compaction treatment.



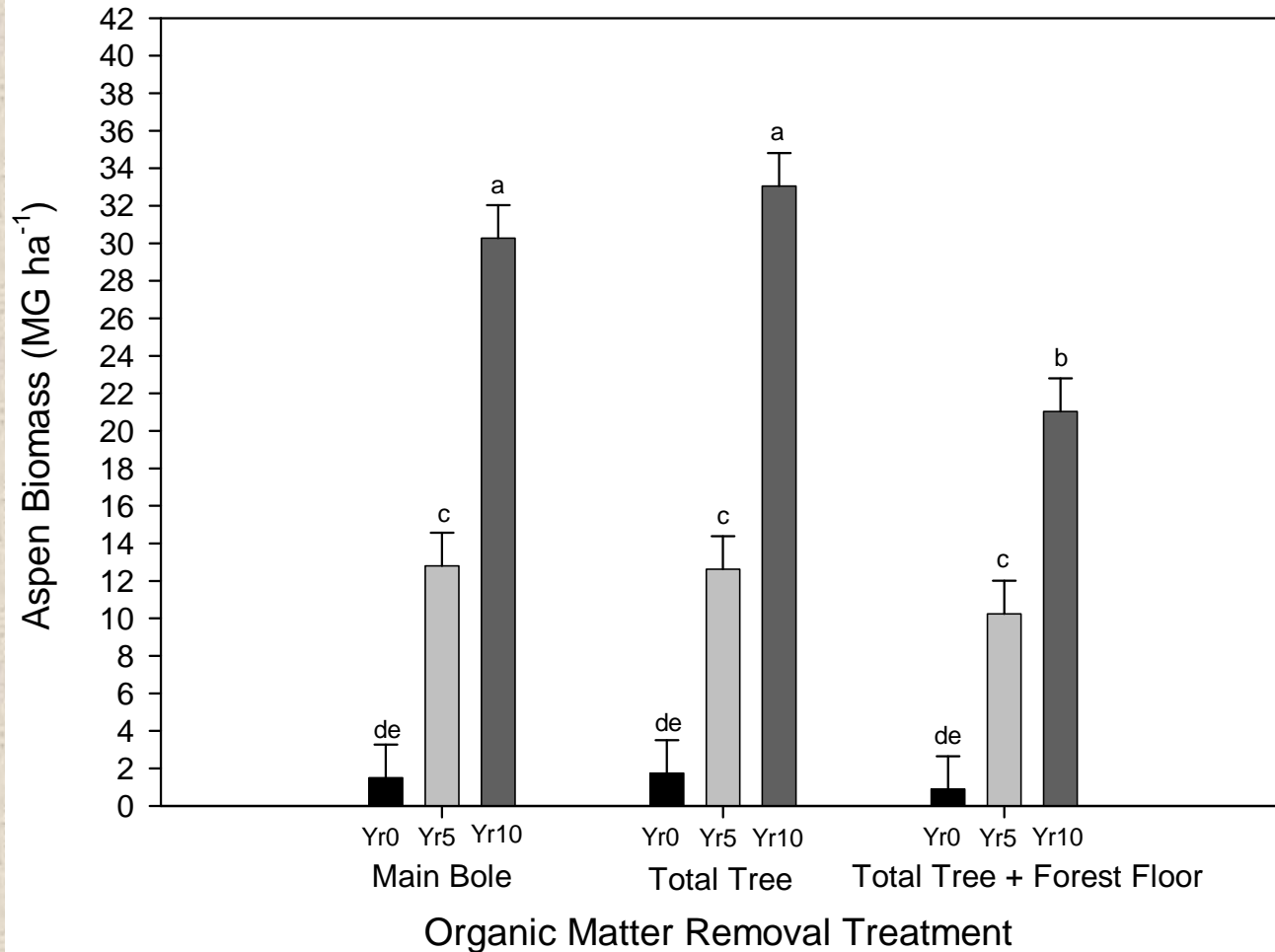
Effects of compaction treatments on aboveground total plant biomass on the sand soil at Huron NF. Result: both moderate and high compaction did not differ significantly from the no-compaction treatment by year 5 and 10.



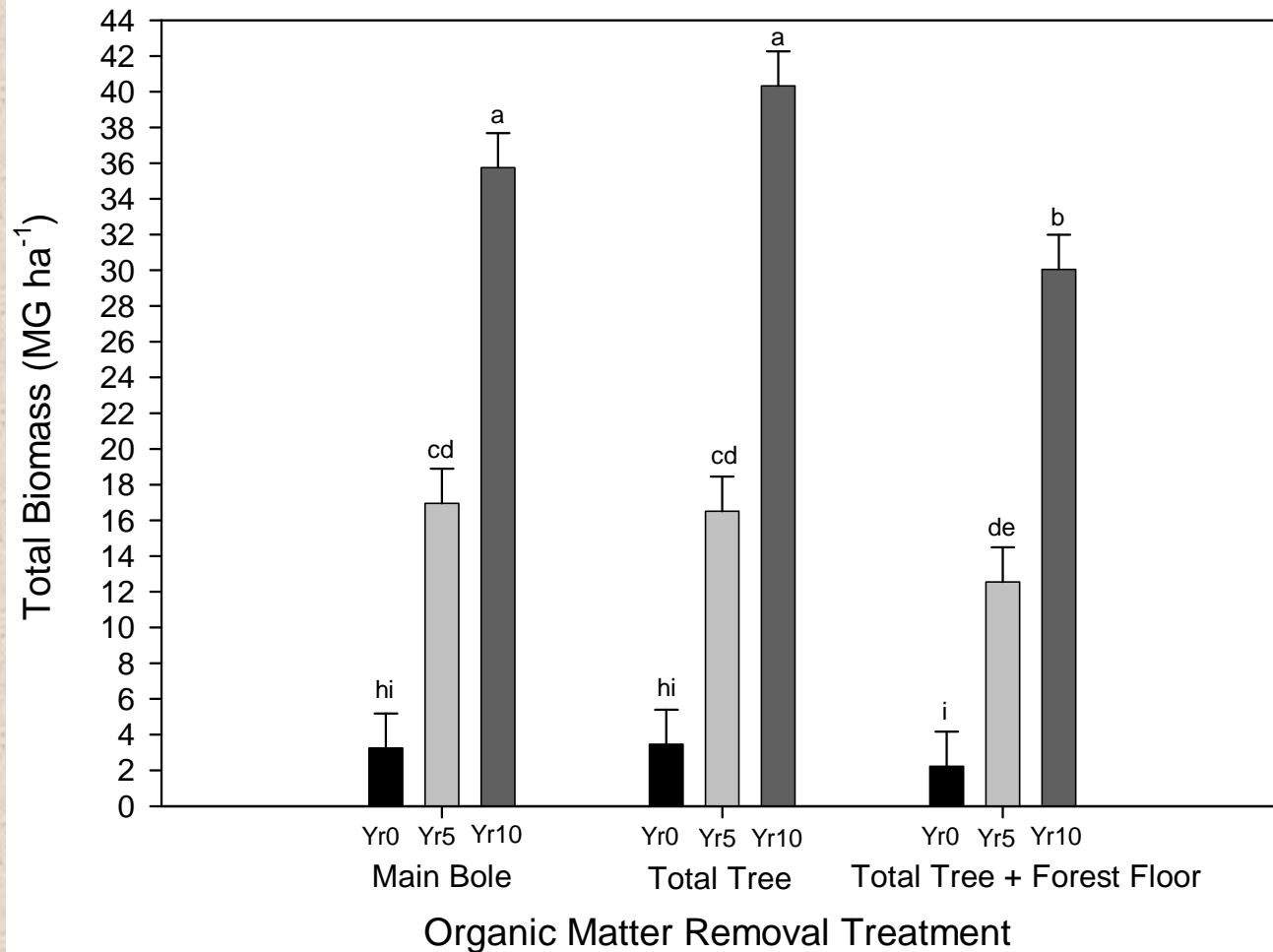
Effects of organic matter removal treatments on aboveground aspen biomass on the clay soil at Ottawa NF. Result: TTH+FFR resulted in a significant increase in aspen biomass by year 10.



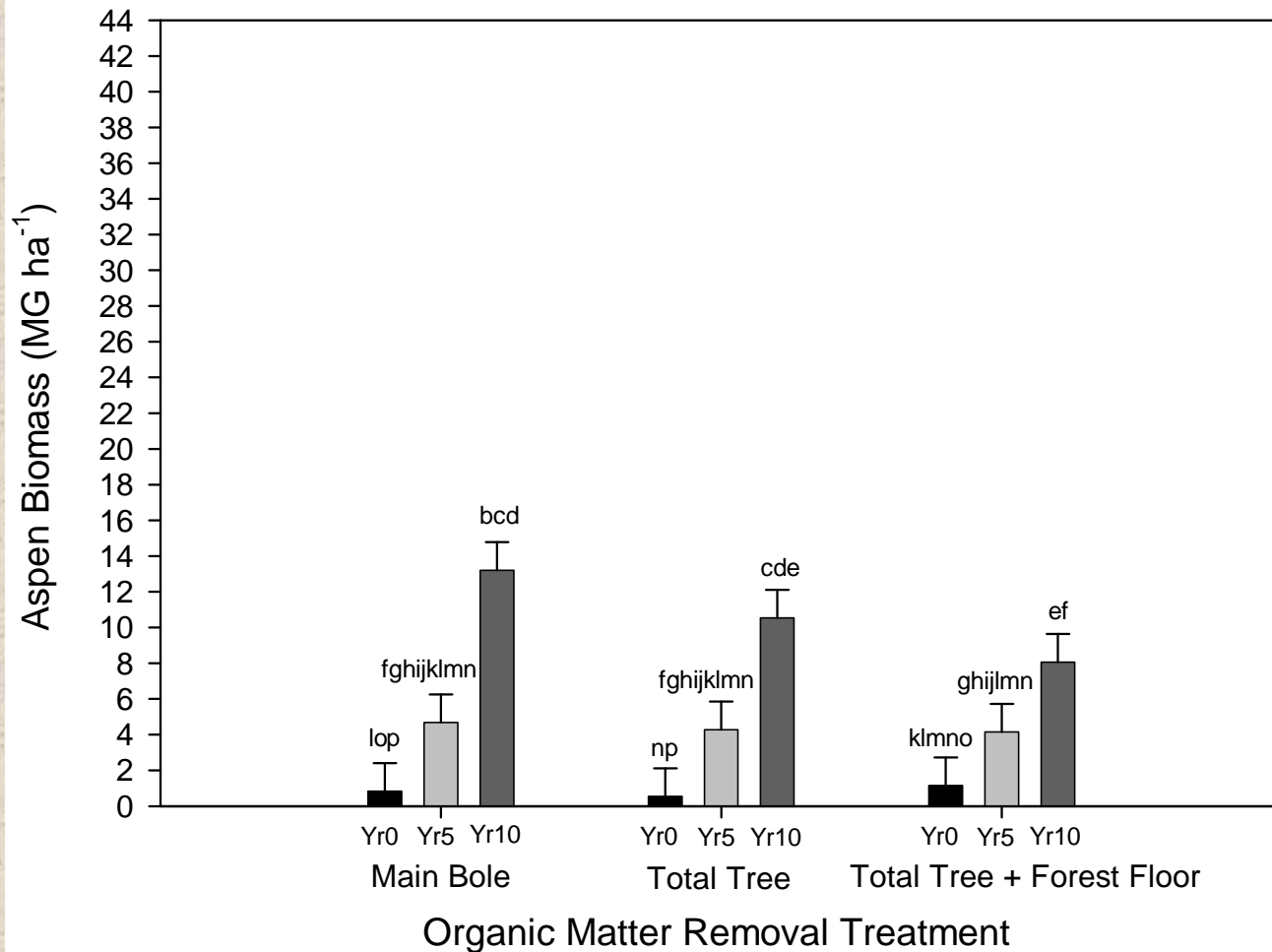
Effects of organic matter removal treatments on aboveground total plant biomass on the clay soil at Ottawa NF. Result: TTH+FFR resulted in a significant increase in total biomass by year 10.



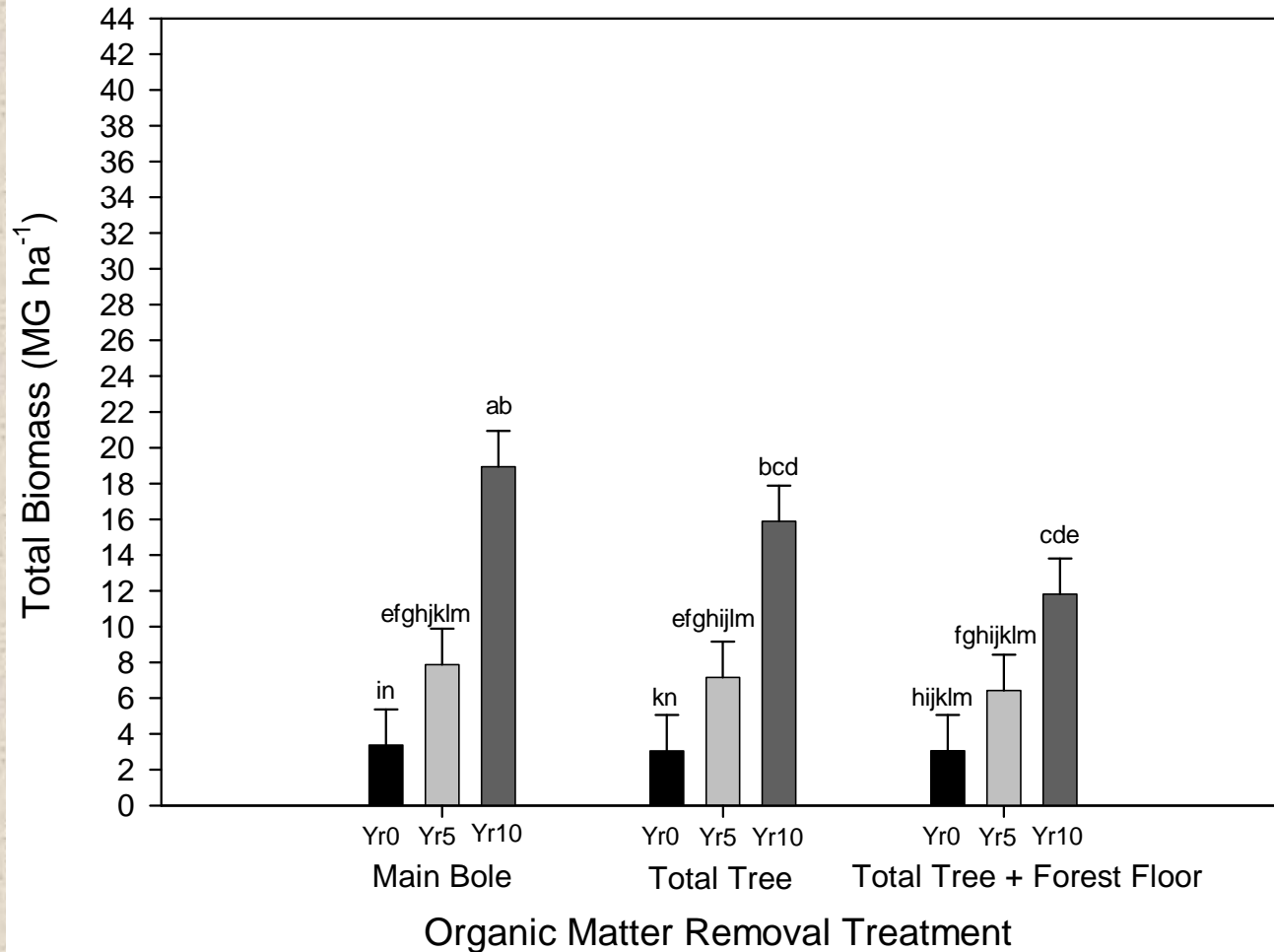
Effects of organic matter removal treatments on aboveground aspen biomass on the loam soil at Chippewa NF. Result: TTH+FFR resulted in a significant decrease in aspen biomass by year 10.



Effects of organic matter removal treatments on aboveground total plant biomass on the loam soil at Chippewa NF. Result: TTH+FFR resulted in a significant decrease in total biomass by year 10.



Effects of organic matter removal treatments on aboveground aspen biomass on the sand soil at Huron NF. Result: TTH+FFR resulted in a significant decrease in aspen biomass by year 10.



Effects of organic matter removal treatments on aboveground total plant biomass on the sand soil at Huron NF. Result: TTH+FFR resulted in a significant decrease in total biomass by year 10.

# DISCUSSION AND SUMMARY

- **COMPACTION EFFECTS**
  - Soil compaction treatments increased bulk density at our sites.
  - Soil bulk density generally increased with depth and intensity of compaction treatments.
  - For the moderate and high compaction treatments soil bulk density remained higher than the no-compaction treatment 10 years after treatment application.

# DISCUSSION AND SUMMARY

## COMPACTION EFFECTS

- Does the level of compaction attained in our study affect forest productivity 10 years after treatment?
  - Yes, the effects of which are not universal for the three soil types studied.
  - For the loam soil, total biomass and aspen biomass decreased significantly with increasing compaction levels.
  - By year 10, the effect of compaction on total biomass in the clay soil was that high compaction caused a significant decrease while moderate compaction caused a significant increase. While this trend is similar for aspen biomass on the clay soil, significant differences were not detected.
  - On the sand soil, the general trend was that both total biomass and aspen biomass increased with compaction; the greatest gain being with moderate compaction. However, only the increase in aspen biomass for moderate compaction at year 10 was significant.

# DISCUSSION AND SUMMARY

## EFFECTS OF ORGANIC MATTER REMOVAL

- Does the organic matter removal affect forest productivity in our study 10 years after treatment?
  - Yes, by year 10 significant effects were detected for biomass on all soil types for the TTH+FFR treatment.
  - For TTH+FFR both aspen and total biomass were significantly greater than MBH by year 10 on the clay soil.
  - Compared to MBH, both aspen and total biomass for TTH+FFR were significantly less by year 10 for both the loam and sand soils.

# CONCLUSIONS

- It is clear that aspen forest productivity is affected by impacts of compaction on soil physical attributes and the loss of organic matter from the site, and that these impacts vary by soil texture.
- Further monitoring and analyses are needed to determine the nature of these impacts through time. (extrapolation of current data to a full rotation should not be attempted).
- It is important to continue to monitor this study throughout a full rotation.
- Funding issues are ever-present it seems; sampling intervals could be altered from every 5 years to key times such as year 15 and year 25 (half rotation) with further adjustments to sampling made based on that information.

# ACKNOWLEDGEMENTS

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