Impacts of soil/crop management systems on arid land soil quality.

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INTRODUCTION

The sustainable use of soil resources depends on soil characteristics, land use climate, hydrology, etc. [1].

There is a need to develop soil quality (SQ) assessment tools for different regions and various performance [2]. While some soil quality assessment tools have been developed across the U.S.A, these tools need refinement to be applicable to agroecosystems and climatic zones [3]. One of the ways to finetune SQ assessment tools is to evaluate potential soil quality indicators for their ability to distinguish between soil and crop management differences in agroecosystems [4].

Most of the SQ assessment studies have focused on surface soil (0 - 0.15 m), while few have investigated subsoil impacts on the overall soil quality. However, the health of the subsoil will ultimately affect the performance of the overall soil, to deliver different ecosystem services [5]. While information abounds on potential soil quality indicators for humid regions of the United States, there is a research gap on suitable indicators for arid and semi-arid systems [6].

OBJECTIVES

- To assess the impacts of soil and crop management practices on selected soil quality indicators in arid agroecosystem.
- To assess the performance of soil quality indicators in the surface soil and subsoil as a function of management systems.

MATERIALS AND METHODS

Study Location

- New Mexico State University Agricultural Science Center at Los Lunas, NM (Latitude 34˚46'00.34"N, Longitude 106˚45'31.95"W, and 1478 m elevation) [Plate 1].

Treatments

- **All the fields sampled have been under the same management practice for at least 5 years**
- Four management practices in a **clay loam** (Typic Torrifluvents) with three replicate fields
  i. Conventionally tilled land with varied annual crops (CTCL).
  ii. Alfalfa field (ALF)
  iii. Peach orchard with clover understory (POC).
  iv. Permanent grass field of tall fescue (TFG).
- Two management practices in a **sandy loam** (Typic Torripsamments) with three replicate fields
  i. Conventionally tilled soil with varied annual crops (CTSD).
  ii. Young cottonwood tree orchard (CWO).

Sampling

- 10 random soil subsamples (0 - 0.15 m) and (0.15 - 0.30 m) collected per experimental unit to form a composite for each depth and were air dried and analyzed for multiple soil physical and chemical properties [7], while soils for biological soil quality indicators were collected at (0 - 0.05 m) and (0.05 - 0.15 m) soil depths. Phospholipid Fatty Acid method was used for soil microbial analysis.

Statistical analysis

- Data were analyzed as a completely randomized design with treatment factor management systems and repeated measures (two soil depths). A model accounting for a compound symmetric covariance structure between depths was fitted using SAS PROC MIXED version (SAS Institute Inc., 2002). Within each depth, means were separated using the LSD ($P \leq 0.05$).

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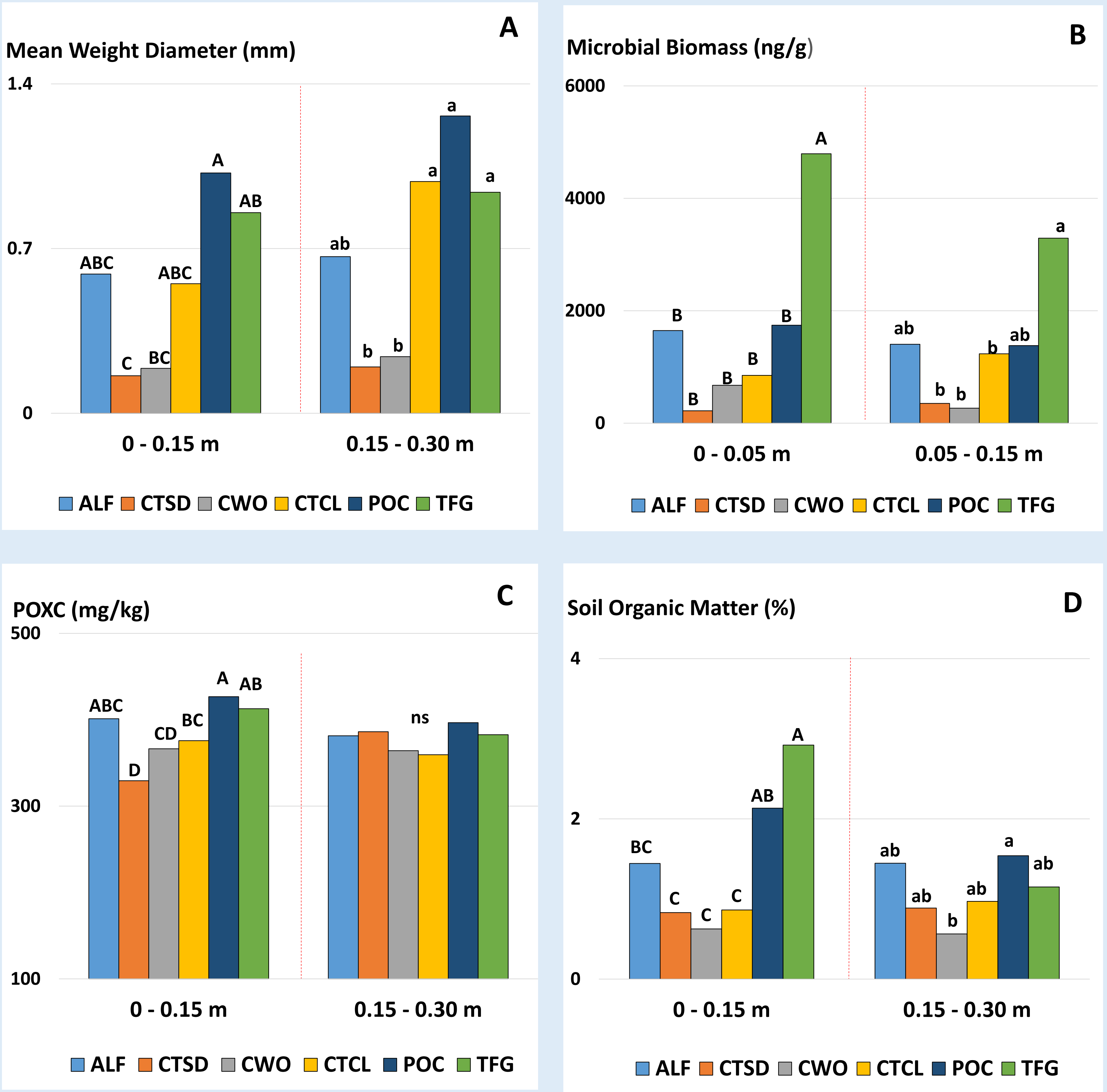

Figure 1. Mean weight diameter of dry aggregates (A), total microbial biomass (B), permanganate oxidizable carbon [POXC],(C) and soil organic matter (D) measured in different soil/crop management systems.

Table 1. Analysis of variance results and means values and separation of selected soil quality indicators.

Soil Measurements	Soil Depth (m)	ALF	CTSD	CWO	CTCL	POC	TFG
Dry aggregates 2–4mm (%)	0-0.15	18.0ab	1.0b	2.0b	15ab	35a	28a
Dry aggregates <0.25mm (%)	0-0.15	31b	59a	50a	24b	24b	21b
Wet aggregates stability (%)	0-0.15	64ab	55b	68ab	60ab	65ab	77a
Available Water Content (m/m)	0-0.15	0.36ab	0.34b	0.33b	0.31b	0.35ab	0.43a
Penetration Resistance (kPa)	0-0.10	2931a	2062ab	606c	657c	2439a	1324bc
Nitrate nitrogen (mg/kg)	0-0.15	16ab	4.0c	1.0c	7.0bc	21a	3.0c
Electrical conductivity (dS/m)	0-0.15	0.76ab	0.57ab	0.34b	0.46ab	0.87a	0.80ab
pH	0 - 0.15	7.6ab	7.8a	7.7a	7.7a	7.6ab	7.4b
Bacteria (%)	0-0.05	53a	38bc	34c	53a	55a	50ab
Total Fungi (%)	0-0.05	7.0ab	5.0b	4.0b	10ab	8.0ab	12a
Microbial Diversity Index	0-0.05	1.32ab	1.2b	1.3ab	1.36ab	1.34ab	1.5a
Aggregates 2–4mm (%)	0.15-0.30	21ab	2.0b	3.0b	33a	41a	32a
Aggregates <0.25mm (%)	0.15-0.30	31bc	51a	37ab	18c	23bc	22bc
Wet aggregates stability (%)	0.15-0.30	60	57	66	59	69	69
Available Water Content (m/m)	0.15-0.30	0.37	0.35	0.33	0.38	0.34	0.36
Penetration Resistance (kPa)	0.10-0.20	5088a	3921ab	2125bc	1681c	2471bc	1506c
Nitrate nitrogen (mg/kg)	0.15-0.30	16a	3.0bc	2.0c	15ab	20a	3.0bc
Electrical conductivity (dS/m)	0.15-0.30	0.87abc	0.55bc	0.48c	1.11a	1.00ab	0.50c
pH	0.15-0.30	7.6ab	7.6abc	7.7a	7.5abc	7.4c	7.4bc
Bacteria (%)	0.05 - 0.15	56a	38bc	32c	48ab	52a	46ab
Total Fungi (%)	0.05 - 0.15	7.0ab	2.0b	2.0b	7.0ab	5.0ab	11a
Microbial Diversity Index	0.05 - 0.15	1.33ab	1.2b	1.2b	1.35ab	1.26ab	1.52a

a, b, c, d: means within a row followed by the same letter are not significantly different , ns: not significant.

RESULTS

- Management effect was significant for all the soil measurements in the surface soil (Figure 1 & Table 1).
- Management effect was significant for most of the soil quality indicators measured in the subsoil (0.15-0.30 m), except for the available water capacity, wet aggregate stability and permanganate oxidizable carbon (Figure 1 & Table 1). Soil biological indicators measured at both depths of sampling (0-0.05 m & 0.05-0.15 m) were significantly impacted by management practices (Figure 1 & Table 1).
- Tall fescue grass fields (TFG) had significantly higher microbial biomass and microbial diversity index at 0-0.05 m, higher soil organic matter, higher mean weight diameter (MWD) of dry aggregates, higher wet aggregate stability and higher available water capacity at 0-0.15 m compared to other management practices (Figure 1 & Table 1).
- Conventionally tilled field (CTSL) and the cottonwood orchard (CWO) in the sandy loam soils generally had less favorable soil quality indicators with lower organic matter, MWD, wet aggregate stability, POXC and lower microbial biomass compared to the management systems in clay loam soils (Figure 1 & Table 1).

CONCLUSION

- Soil and crop management systems significantly influenced soil quality indicators both in the surface soil (0-0.15 m) and the subsoil (0.15-0.30 m). Although more soil quality indicators showed significant differences in the surface soil, there were still many indicators showing significant impacts of management in the subsoil. This indicates that deeper soil layers may need to be considered for development of soil quality assessment.
- More favorable soil measurements occurred under long term and less disturbed agricultural management practices such as tall fescue grass fields and peach orchard with clover understory.
- Management practices in the sandy loam soils had less favorable soil quality indicator measurements compared to the management practices in clay loam, highlighting the importance of soil texture in soil quality assessment.
- This study shows that several measurements are available that could potentially track directional changes in soil quality in arid regions for example, MWD of dry aggregates, POXC, SOM and total microbial biomass; more regionally based studies are needed to further streamline these measurements for effective soil quality assessment.

Plate 1. New Mexico State University Agricultural Science Center at Los Lunas.

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