Can Soil Health Rehabilitation be Maintained after Re-Introduction of Low-Input Row Cropping Systems?

Jon Cotton (Jon.Cotton@ARS.USDA.GOV) and Veronica Acosta-Martinez (Veronica.Acosta-Martinez@ARS.USDA.GOV), USDA-ARS Cropping Systems Research Lab, Lubbock TX

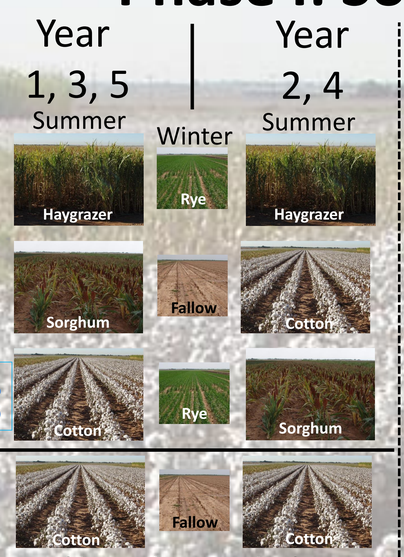
The Texas High Plains, which produces ~30% of U.S. cotton (*Gossypium hirsutum* L.), is facing challenges to sustaining agriculture common to many semiarid regions:

1) Changing climatic conditions with more frequent and intense drought and heat waves (Acosta-Martinez et al., 2014).
2) Less available irrigation water due to the depletion of the Ogallala aquifer.
3) Soil health/erosion issues caused by 50+ years of low residue continual cotton row cropping that depleted soil organic matter (SOM<1%) in the sandy soils of this region (Allen *et al.*, 2008).

- Profitability and adaptability make cotton essential to this region, so integrating practices to improve soil health will be important to sustaining viable agricultural production.
- To study improving soil health, we conducted a two-phase dryland study on a representative sandy loam soil (16.4% clay, 67.6% sand, 0.65 g kg^{-1} OM) using rotations with haygrazer (Hay-*Sorghum bicolor* (L.) Moensch), grain sorghum (Srg-*Sorghum bicolor)* and/or rye (*Secale cereale*) winter cover crops. Cotton lint and sorghum grain were harvested while all Hay residue was incorporated.
- We evaluated soil health (0-5cm) parameters including soil organic matter (SOM), six enzyme activities involved in C, N, P and S cycling, and soil microbial community size and composition.

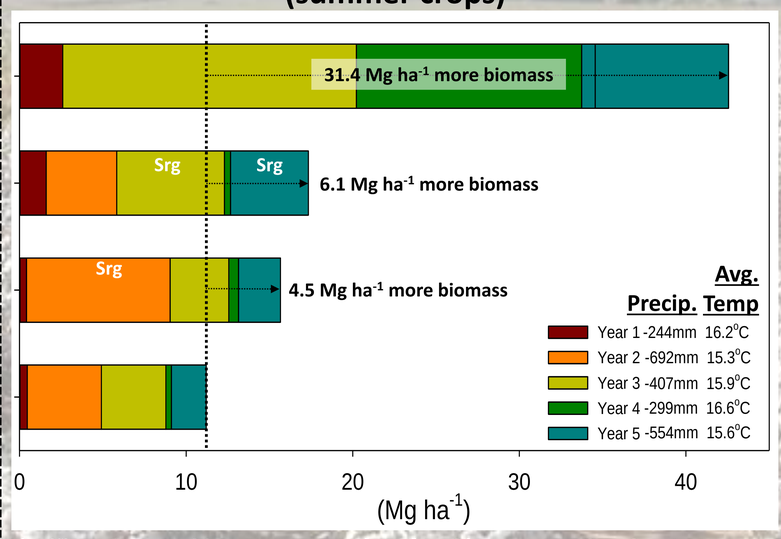
Phase I: Soil Health Rehabilitation via Higher Biomass Cropping Systems

Cropping System



- Systems designed to increase biomass incorporation by utilizing crops with maximum biomass production (hay), rotating grain sorghum with cotton, and/or using winter cover crops under conventional tillage (CT) and no tillage (NT)
- Cont. Ctn was sampled in nearby plots for relative comparison and was not a part of the experimental design.

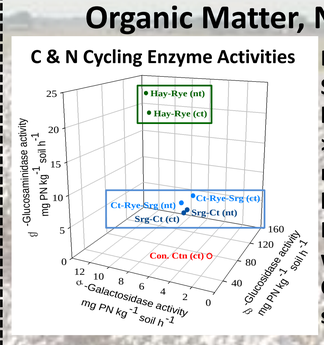
Above Ground Biomass Production (summer crops)



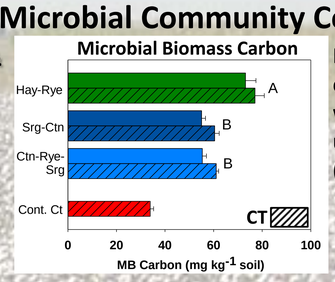
Significantly more biomass was produced and incorporated under Hay-Rye than other systems, but all systems produced more biomass than Cont. Ctn. Tillage had no effect and data presented was averaged across CT and NT.

Soil Health After Phase I

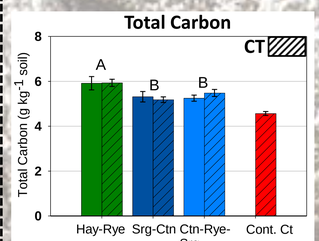
Organic Matter, Nutrient Cycling, Microbial Community Composition



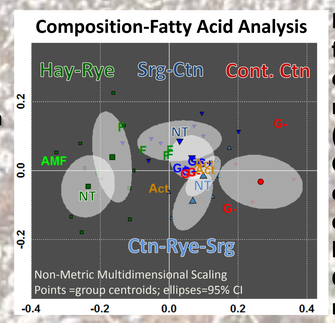
EAs involved in C, N, P & S cycling were 66-159% higher where Hay-Rye >Srg-Ctn=Ctn-Rye-Srg, reflecting the increased biomass incorporation. However, all systems were higher than Cont. Ctn (P & S EAs not shown).



Microbial biomass carbon and nitrogen were 38-69% higher under Hay-Rye (nitrogen not shown).



Total C under Hay-Rye was 13-17% higher than the other systems after 5 years. Total C also significantly increased, but Total N did not (not shown).



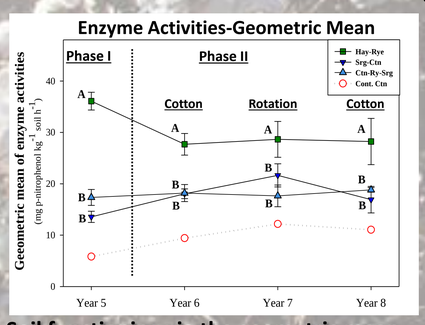
Hay-Rye had higher fungal indicators, especially arbuscular mycorrhizal fungi (AMF). Srg-Ctn and Ctn-Rye-Srg were composed of a combination of bacteria and fungi, and Cont. Ctn had relatively more Gram- bacteria.

Phase I Summary:

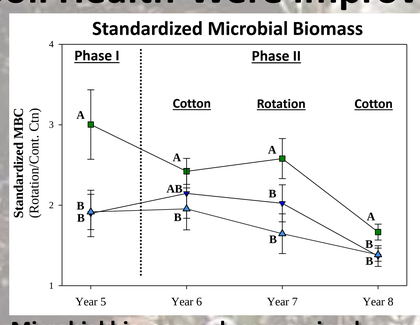
- By incorporating more biomass from haygrazer, annual rotation with sorghum, and/or rye winter cover crops, after five years these systems had improved soil health indicators compared to the typical practice in the THP of monoculture cotton. This was seen in increases in soil microbial biomass (e.g., saprophytic and AMF fungi), enzyme activities involved in nutrient cycling and soil carbon.
- However, of continuing interest was if these improvements in soil health indicators could be maintained when returning cropping to more typical, low input practices after our initial research was concluded.

Phase II: Return to Row Cropping-Is Soil Health Maintained and are Yields Improved?

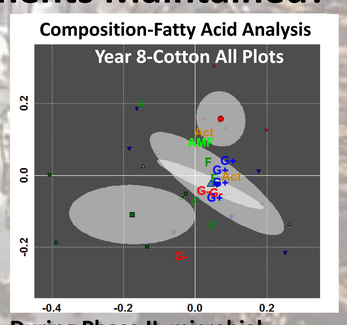
Soil Health-Were Improvements Maintained?



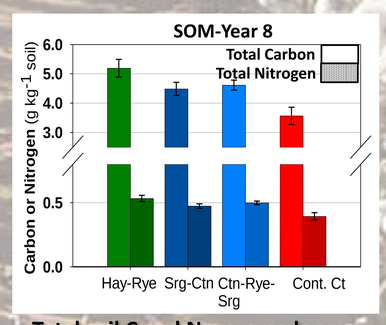
Soil functioning via the geometric mean of all EAs was higher under Hay-Rye than the other systems during all sample times, though the difference was less during Phase II compared to Phase I. There was a significant decreased for Hay-Rye after the first year of Phase II.



Microbial biomass values remained relatively stable throughout Phase II (not shown). However, when standardized by the values of Cont. Ctn to account for annual variation (often due to precip.), biomass trended lower during Phase II, especially for Hay-Rye.

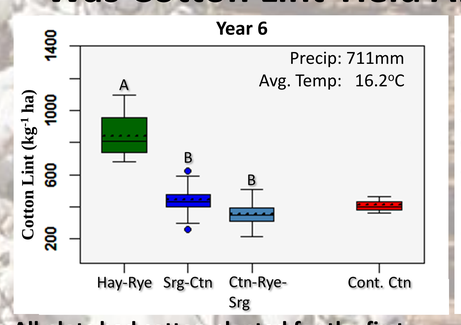


During Phase II, microbial communities were similarly different to the end of Phase I. However, Hay-Rye was less associated with fungi (e.g., AMF) during each successive year, with no strong trends for microbial groups found in Year 8.

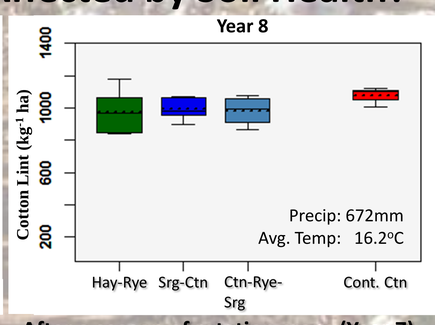


Total soil C and N were no longer significantly higher in Hay-Rye, though all systems were still higher than Cont. Ctn (13-42%). No difference was found due to tillage.

Was Cotton Lint Yield Affected by Soil Health?



All plots had cotton planted for the first year of Phase II. Improved soil health in Hay-Rye lead to 107-150% higher cotton yields, though they were significantly reduced due to early season hail damage. No difference was found due to tillage.



After a season of rotation crops (Year 7), cotton was planted in all plots during the final year of the study. In a high precip. year (42% above average), good yields for dryland occurred, with no difference between systems or Cont. Ctn.

Conclusions

- Soil health indicators were significantly was improved after 5 years of higher biomass input cropping systems compared to continual cotton. Tillage had no effect during this time period.
- Higher cotton frequency during Phase II had negative effects on certain soil health indicators, especially for Hay-Rye: decreases in enzyme activities, lower microbial biomass and less association with AMF.
- However, soil health was still improved in all systems relative to Cont. Ctn, though less so at the end of Phase II compared to Phase I.
- Increased soil health indicators were associated to increased cotton lint yield in 1 of the 2 years this was measured across all plots.
- Higher biomass cropping systems followed by increasing cotton frequency did show improved soil health in sandy, low SOM soils in the semiarid Texas High Plains, though the duration of these improvements needs further study. Due to the record drought of 2011-2013 (Year 9+), this dryland study could not be continued as no crops were established during this time.

References:

- Acosta-Martínez V, Moore-Kucera J, Cotton J, et al., 2014. Soil enzyme activities during the Texas record drought/heat wave and implications to biogeochemical cycling and organic matter dynamics. Appl. Soil Ecol. 75,:43–51.
- Acosta-Martínez V, Lascano R, Calderón F, et al., 2011. Dryland cropping systems influence the microbial biomass and enzyme activities in a semiarid sandy soil. Biol. Fertil. Soils 47, 655–667.
- Allen VG, Brown CP, Segarra E, et al., 2008. In search of sustainable agricultural systems for the Llano Estacado of the U.S. Southern High Plains. Agric Ecosyst Environ 124:3–12