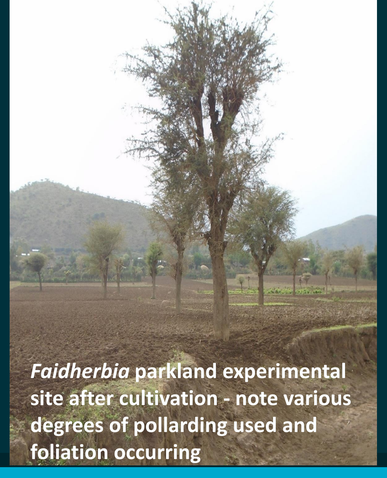

Faidherbia parkland experimental site after cultivation - note various degrees of pollarding used and foliation occurring

Carbon Enrichment Not Fully Explained by Tree Litter or Animal Manure Inputs in a Simulated Faidherbia-Maize Parkland

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Maize growing under trees and crop-only areas at the flowering stage of the 2015 low-rainfall season

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Background

- *Faidherbia albida* is an N-fixing tree native to many countries across a wide range of semi-arid, sub-Saharan Africa, including Ethiopia.
- Several researchers have recorded higher concentrations of C under tree canopies than in adjacent crop-only areas, and speculated about the role of tree litter inputs and indirect mechanisms.
- Natural regeneration of Faidherbia can also be favoured on pre-existing fertile microsites, e.g. generated by termites.

Objectives

- Using long-term process-based simulations for a Faidherbia-maize parkland system, determine if high rates of tree above-ground litter and cattle manure inputs could account for observed higher concentrations of soil C under trees compared to adjacent crop-only areas.

Methods

- Soil C was measured in 2015, and maize yield in 2015 and 2016 in fertilised sub-plots (see Dilla et al. 2018, and Dilla et al. 2019).
- Simulations commencing in 1967 were conducted with the APSIM Agroforestry model (www.apsim.info; Smethurst et al. 2017).
- Initial soil C concentrations were tuned to achieve a good fit of soil C and maize grain yield in the crop-only treatment (20-24 m away) after 48 years of simulation (Fig. 1a).
- Factorial combinations of zero (0 t ha^{-1}) or high annual additions of tree litter (15 t ha^{-1}) and manure (34.5 t ha^{-1}) were simulated.

Results and Discussion

- Commonly used low rates of fertiliser led to low crop yields and continual decline in soil C concentrations (Fig. 1a).
- Constant or increasing concentrations of soil C could only be simulated if high rates of fertiliser were used, which is atypical for small-holder farmers in the region.

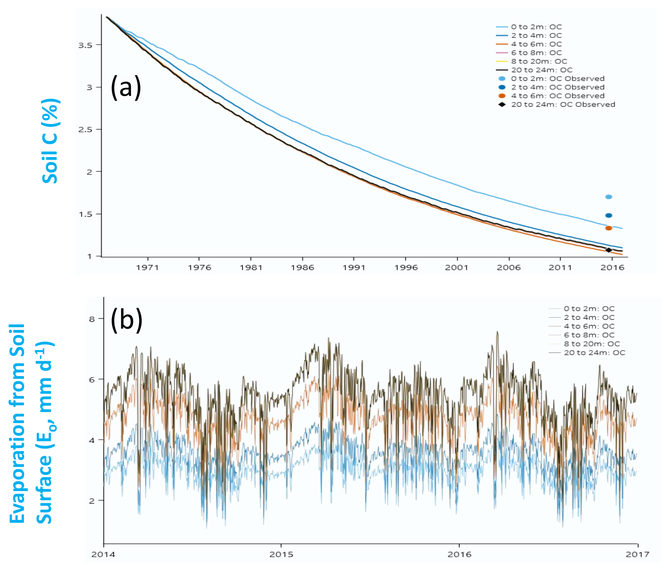

Fig. 1. (a) The extent of simulated C concentration decline during the simulation was affected by zone (0-6 m zones under trees, 20-24 m zone crop-only; symbols = observations). (b) Simulated evaporation from the soil surface was lower under trees (final 3 years shown).

- Reduced evaporation under trees was simulated (Fig. 1b), which led to soil C concentrations (0-20 cm depth) under trees without litter or manure additions declining less than those in crop-only areas. This effect explained 45% of the relative soil C increase in the 0-2 m radial tree zone by the end of the simulation compared to the crop-only zone (Fig. 2a).

- High litter and manure inputs explained only a further 8% increase (Fig. 2a). Almost no effects were observed at lower depths, which could partially be explained by a lack of simulated below-ground tree litter inputs and C leaching (Fig. 2b).

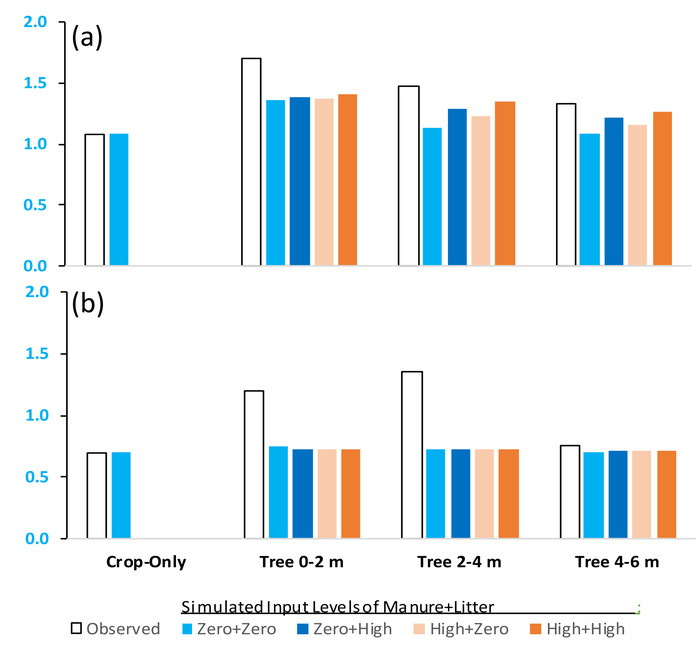

Fig. 2. (a) Microclimate and inputs of litter and manure were simulated to result in relatively higher soil C concentrations, but not to the extent of those observed in 0-20 cm soil. (b) Almost not effects were simulated at lower depths in contrast to those observed (only 60-80 cm depth shown)

- As the high manure and litter input rates simulated were probably higher than could be expected in this heavily pollarded and low-stocked system, these simulation scenarios probably overestimated the C contributions of these mechanisms.
- Other contributing factors might have been preferential tree establishment on pre-existing fertile microsites, soil organic matter displacement via erosion from crop-only areas, and bird manure stimulating crop growth and C inputs under trees.

Conclusions

- This simulation approach is useful for quantifying hypotheses about C cycling in agroforestry systems.
- Measurements of long-term pools and fluxes of C are needed.
- Contributing factors to relatively elevated soil C levels under trees are likely to be:
  - Micro-climate
  - Tree litter inputs
  - Manure inputs that transfer crop residue C from crop-only areas
- But other factors also need to be considered:
  - Preferential tree establishment on re-existing fertile microsites
  - Soil organic matter transfers via erosion from crop-only areas
  - Bird manure stimulating crop growth and residue loads

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