Agroforestry and soil nutrient

Reference 1

Muchane, MN; Sileshi GW; Gripenberg, S; Jonsson, M; Pumariño, L; Barrios, E. 2020 Agroforestry boosts soil health in the humid and sub-humid tropics: A meta-analysis. Agriculture, Ecosystems & Environment, 295, 106899. doi: 10.1016/j.agee.2020.106899

Background and objective

Although several studies assessing the effects of agroforestry on various soil properties have been published in the last three decades, a quantitative synthesis of the results from those studies is still lacking. Quantify the contribution of agroforestry practices to soil-mediated ecosystem services, specifically: 1) regulation of soil erosion, 2) storage of soil carbon (C), 3) storage of soil nitrogen (N), 4) availability of soil N, 5) availability of soil phosphorus (P), and 6) alleviation of soil acidity. Here, only results regarding objectives 3,4,5,6 are reported.

Search strategy and selection criteria

Literature search was focussed on well-designed and randomized studies that compared plots where crops were associated with trees (agroforestry) with adjacent plots where crops were grown without trees (crop monocultures). Publications for the meta-analysis were first identified using the ISI Web of Science focusing on literature published up to July 2017. They searched published studies that reported the effects of agroforestry on soil health covering the aggregate ecosystem functions of soil structure maintenance and nutrient cycling. 1)The study originated in the humid or sub-humid tropics; 2) The study compared plots representing one or more simultaneous or sequential agroforestry practices with plots of crop monocultures. Studies in which the agroforestry practice involved organic inputs coming from outside (e.g. biomass transfer systems) or in which the tree effect could be confounded with other inputs (e.g. manure inputs as in silvopastoral systems) were excluded from the analysis. Furthermore, rotational woodlots (trees grown>3 years) and home-gardens, often classified as agroforestry practices, were excluded from the current analysis due to lack of studies reporting a proper control plot; 3) The study had the same crop species grown in the agroforestry plotand the corresponding control plot; 4) The study quantified one or several of the indicators of aggregate ecosystem function and soil health; 5) Only studies conducted on research stations and at the farm scale were included, but those at landscape scale and in the laboratory were excluded.

Data and analysis

Data were extracted from the results section, tables, appendices, graphs and figures from each of the papers. Data from graphs were extracted using IMAGE J software. Whenever multiple agroforestry treatments with different tree species were presented in a given paper, each treatment by control comparison was considered as a separate data point in the meta-analysis. The study also considered treatments based of different tree species compared with the same control as unique observations. If a paper reported results from more than one soil depth, only the upper soil layer (till layer) was considered. In cases where tests were repeated over the growth period, the authors selected the soil measurements made before the last growing season of the experiment to capture the cumulative effects.

Number of papers	Population	Intervention	Comparator	Outcome	Quality score
48 (total N), 34 (soil inorganic N), 49 (soil inorganic P), 46 (soil pH)	Crop production systems in tropical climates.	1)simultaneous agroforestry where trees and crops occur on the same piece of land during the same cropping season (e.g. alley cropping, intercropping, multi-storey agroforests); and 2) sequential agroforestry where trees and crops occur on the same piece of land but in a temporal sequence as part of a rotation (e.g. improved fallows).	Crop monocolture.	Logarithm of ratio of soil nutrients properties (soil microaggregates, soil total nitrogen, soil inorganic nitrogen, soil phosphorous and soil pH) in agroforestry practices to soil nutrients properties in crop monoculture.	75%

Results

- Soil N stocks under agroforestry were 13% higher than in crop monocultures (overall mean effect size (RR = 1.13; CL: 1.08–1.19) was significantly greater than 1). Soil inorganic N under agroforestry was 46 % higher than in crop monocultures (overall mean RR (1.46; CL: 1.32–1.59) was significantly greater than 1). The increase in soil inorganic N was most readily detected as nitrate-N rather than as ammonium-N.
- The effect sizes for total N in simultaneous systems did not significantly differ from the sequential systems. Soil inorganic N did not significantly vary with agroforestry management.
- Soil macroaggregates (> 0.25 mm) and mean weight diameter (MWD) were significantly higher under agroforestry than in the crop monocultures; the increases being 22 and 30 % for macroaggregates and MWD, respectively. Aggregate-associated N was significantly higher under agroforestry than in the crop monocultures. Closer examination using soil physical fractionation techniques shows that 22–43 % more soil N is stored in macroaggregates under agroforestry practices.
- Agroforestry practices significantly increased soil-phosphorous; the overall mean RR was 1.11 (CL: 1.05–1.68), significantly greater than 1.
- Agroforestry practices significantly increased soil pH (RR = 1.02; CL: 1.01–1.03) over the crop monoculture. The effect sizes did not significantly differ with agroforestry practice. RR values greater than 1 were found in pH below 6, while above pH 7 the RR values remained close to 1. The effect of agroforestry on soil pH also marginally differred with soil type; the most significant increase in pH being on Nitisols, Ferralsols and Acrisols, which are naturally prone to acidification.

Factors influencing effect sizes

Increase in Total N was significantly higher in sandy soils than loamy soils. Agroforestry increased soil inorganic N by up to 52 % on clay soils as compared to the 25 % increase on loamy soils. P availability was significantly higher on loamy soils than sandy soils.

Conclusion

Agroforestry practices significantly increase N storage, increase the availability of inorganic N and marginally increase the availability of inorganic P and pH in the soil compared to crop monocultures. As such, agroforestry can be an option for increasing soil nutrient availability to crops when access or use of mineral fertilizers is limited. Furthermore, by facilitating the combined application of organic and mineral nutrient inputs to soil, agroforestry can significantly improve nutrient use efficiency through greater synchronization of nutrient release to soil and crop demand and use.