Agroforestry and yield

Reference 1

Kuyah, S; Whitney, CW; Jonsson, M; Sileshi, GW; Oborn, I; Muthuri, CW; Luedeling, E. 2019 Agroforestry delivers a win-win solution for ecosystem services in sub-Saharan Africa. A meta-analysis. Agronomy for Sustainable Development 39, 47 doi: 10.1007/s13593-019-0589-8

Background and objective

Hypothesis is that agroforestry reduces trade-offs between provisioning (crop yield) and regulating/maintenance ecosystem services (including soil nutrients, soil erosion control, soil organic carbon). This meta-analysis addresses the following questions: 1) What is the impact of agroforestry on crop yield, soil fertility, erosion control, and water regulation?; 2) Under which ecological conditions (agro-ecological zone, elevation, and soil type) does agroforestry have a positive or a negative effect?; 3) What is the impact of management (site of trial and agroforestry practice) on agroforestry's effect on crop yield, soil fertility, erosion control, and water regulation?; 4) How do different shrub and tree species differ regarding their potential to regulate these ecosystem services? Here, only results regaring crop yields are reported.

Search strategy and selection criteria

A literature search was conducted in Web of Science covering all years from 1945 until June 2018. Other sources include a recent structured vote count review, a meta-analysis and a narrative review. All studies and bibliographies were screened for other relevant publications. Criteria: 1) Paper published in a peer-reviewed scientific journal; unpublished literature and grey literature were excluded. 2) Study conducted on a research station or farmer's field in SSA. 3) Study investigated the effect of trees on ecosystem services with a suitable control, i.e., a tree-based system compared with tree-less, or investigation beneath tree crowns compared with investigation outside tree crowns. 4) Original field observation or experimental studies, excluding laboratory studies, greenhouse experiments, modeling studies, anecdotal observations, and reviews. 5) Studies reporting quantitative information on the sample size and the mean value of the response variable.

Data and analysis

Response Ratios (RR) were calculated for all pairs (agroforestry and non-agroforestry) of independent data points, hereafter referred to as observations. Bootstrapping methods were used to estimate 95% confidence intervals around weighted means of RR for different categorical variables through the application of 10,000 iterations using the boot package in the R programming language 3.4.2. Analyses of trade-offs were performed on studies that recorded both yield and soil fertility or water regulation. The percentage of observations belonging to win-win, trade-offs, and lose-lose situations was calculated and the data were plotted in a Cartesian plane to facilitate visualization. Spearman's rank correlation tests were performed between effect sizes of different ecosystem service indicators to determine whether they co-varied positively.

Number of papers	Population	Intervention	Comparator	Outcome	Quality score
73	Agricultural systems in sub-saharan Africa.	Agroforestry practices: alley cropping, dispersed intercropping, hedgerow, planted fallow, and crops planted under tree canopies in parkland agroforestry systems.	Non-agroforestry practices (includes sole cropping, continuous cropping without trees, and plots outside tree crowns in the case of parklands).	Ratio of crop yields in agroforestry to crop yields in non-agroforestry practices.	81%

Results

- Average crop yield was almost twice as high in agroforestry as in non-agroforestry systems. Agroforestry increased crop yield when either trees or shrubs were grown compared to controls. Similarly, crop yield was enhanced when both nitrogen-fixing or non-fixing species were grown compared to controls.
- Crop yield was higher in both humid and semi-arid situations compared to the control. A similar pattern was observed for elevation, where agroforestry increased crop yield for trials at lowland and highland locations compared to the control.
- With regard to soil types, yields were two times higher under agroforestry with Acrisols, Cambisols, Lixisols, Luvisols, and Nitisols compared to controls. These soils also had the highest number of cases with RR > 1. On the contrary, Arenosols and Andosols had some occurrences where the RR was less than 1.
- Crop yield was higher than controls when alley cropping, biomass transfer, and planted fallows were used, but not for hedgerows. Alley cropping, biomass transfer, and planted fallows increased crop yield in 77, 93, and 85% of all cases, while hedgerows increased crop yield in 54%.
- In most of the studies, yield was increased sufficiently to offset reduction caused by the presence of trees.

Factors influencing effect sizes

Agroforestry increased crop yield for trials conducted on both farms and research stations in 77 and 68% of all cases. The studies reviewed suggest a combination of causes for increased crop yield, for example improved soil fertility due to nitrogen input from biological nitrogen fixation and nutrient cycling in organic inputs from trees, improved water regulation through increased infiltration and higher soil moisture content,improved microclimate, and better soil physical properties. Positive and significant correlations were found between crop yield and available P ($r_s = 0.360$, $N = 34$, $P < 0.05$), suggesting that soil nutrient availability was a main driver of crop yield in this meta-analysis.

Conclusion

The findings provide evidence that agroforestry can significantly increase crop yield.