Agroforestry systems may play vital role in mitigating climate change

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ABSTRACT

Agroforestry systems may play an important role in mitigating climate change, having the ability to sequester atmospheric carbon dioxide (CO_2) in plant parts and soil. A meta-analysis was carried out to investigate changes in soil organic carbon (SOC) stocks at different depths, after land conversion to agroforestry. Overall, SOC stocks increased when land-use changed from less complex systems, such as agricultural systems. However, heterogeneity, inconsistencies in study design, lack of standardized sampling procedures, failure to report variance estimators, and lack of important explanatory variables, may have influenced the outcomes.

INTRODUCTION

One of the strategies to reduce atmospheric CO_2 concentration is carbon (C) sequestration, which involves removing C from the atmosphere and depositing it in a reservoir (Nair et al. 2009a). Soil plays an important role in C sequestration, being able to store 1.5-3 times more C than in vegetation (Young 1997), and agroforestry soils has the potential to sequester and store atmospheric CO_2 over long periods (Albrecht and Kandji 2003; Lorenz and Lal 2014). However, the potential of agroforestry appears to be based on opinions rather than quantifiable data. The main objective of this study was to investigate the effects of agroforestry on soil carbon stocks.

MATERIALS AND METHODS

A survey of peer-reviewed publications was carried out, including 250 observations from 52 publications from over 20 countries. Different sampling depths were considered: (1) 0–15 cm, (2) 0–30 cm, (3) 0–60 cm, (4) 0–100 cm, and (5) 0 > 100 cm. Agroforestry systems were grouped according to the classification proposed by Nair (1987): (1) agrisilviculture; (2) silvopastoral; (3) agrosilvopastoral. Non-agroforestry land uses were grouped into five categories: (1) agriculture; (2) forest; (3) forest plantation; (4) pasture/grassland; (5) uncultivated land/other.

DATA ANALYSIS

The effect of agroforestry on SOC stock was quantified by calculating the natural log of the response ratio using MetaWin 2.0. Mean effect size for each observation was calculated with 95% confidence intervals (CIs). For each sampling depth, two meta-analyses were performed: (1) a meta-analysis investigating the overall effect of agroforestry, (2) a meta-analysis investigating the effect of each agroforestry systems.

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RESULTS AND DISCUSSION

Land-use conversion from forest to agroforestry decreased the SOC stocks because agroforestry systems lack diversification, density, and structural complexity typical of natural ecosystems, and the quantity of C retained in the upper soil layer is less than natural forests. The conversion of agricultural land to agroforestry significantly increased SOC stocks thanks to the presence of trees and reduced inputs such as tillage. A significant differences were observed in the conversion from pasture/grassland to agroforestry in the upper soil layers. The conversion from uncultivated/other to agroforestry yielded contrasting results for the top layers, where both significant and not significant effects were detected. The high variability of the land-uses in uncultivated/ other category caused the diverging results. No significant differences in SOC stocks were detected in the conversion from forest plantation to agroforestry.

Fig. 1. Effects of agroforestry (AF) on SOC stocks (0–15 cm sampling depth). (a) shoes the effect size and 95% confidence intervals (CIs). (b) indicates % change of SOC stocks. Effect size is significant when CIs do not overlap with zero. Numbers in parentheses indicate number of observations, and * denotes results generated when land-use changes from forest and uncultivated/other to agroforestry were excluded from the analysis.

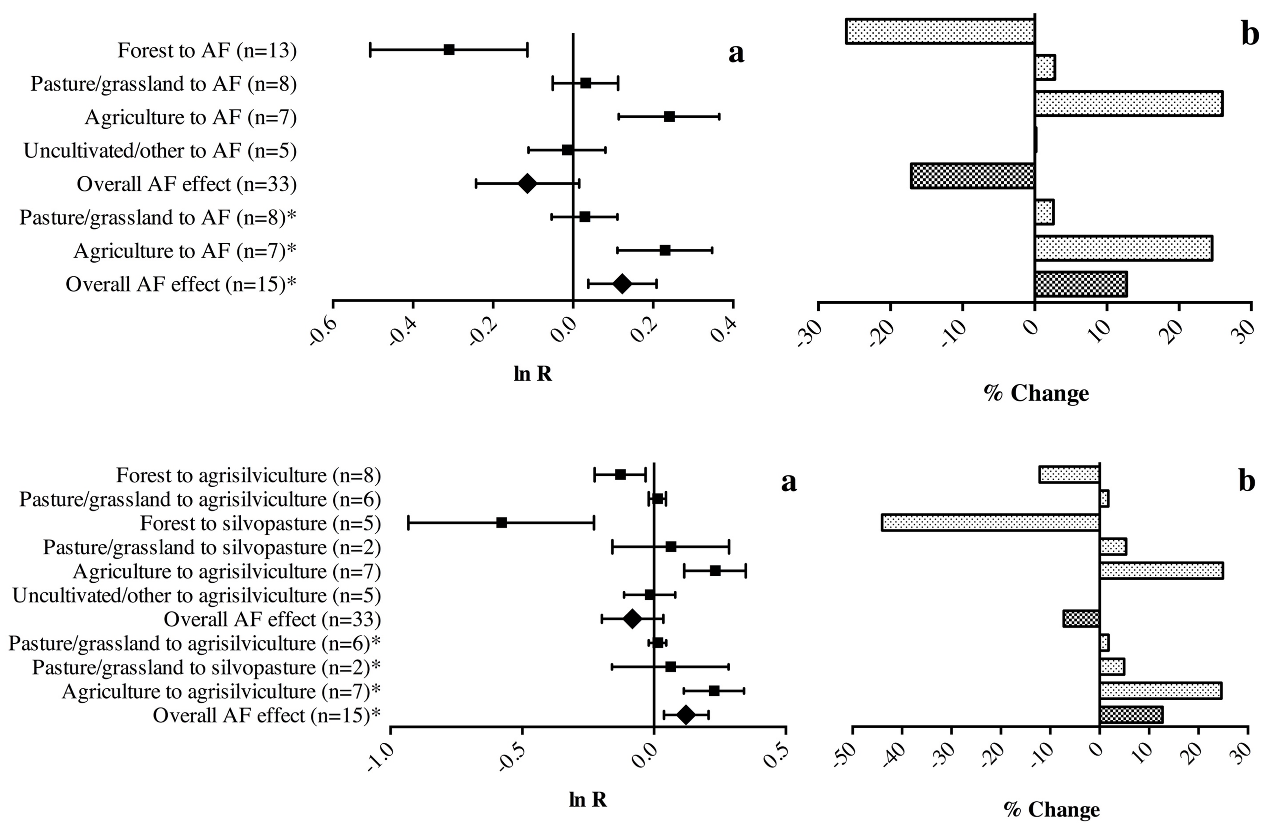


Fig. 2. Effects of agroforestry (AF) on SOC stocks (0–30 cm).

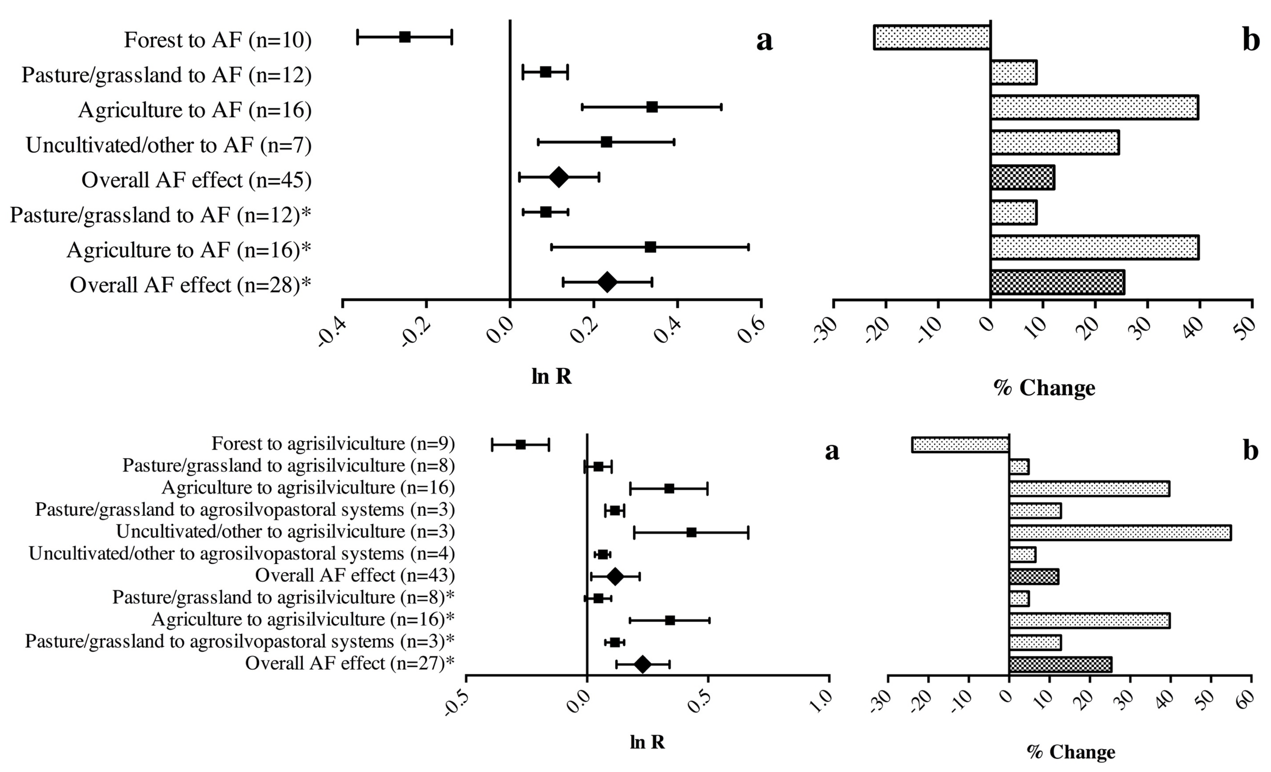


Fig. 3. Effects of agroforestry (AF) on SOC stocks (0–60 cm).

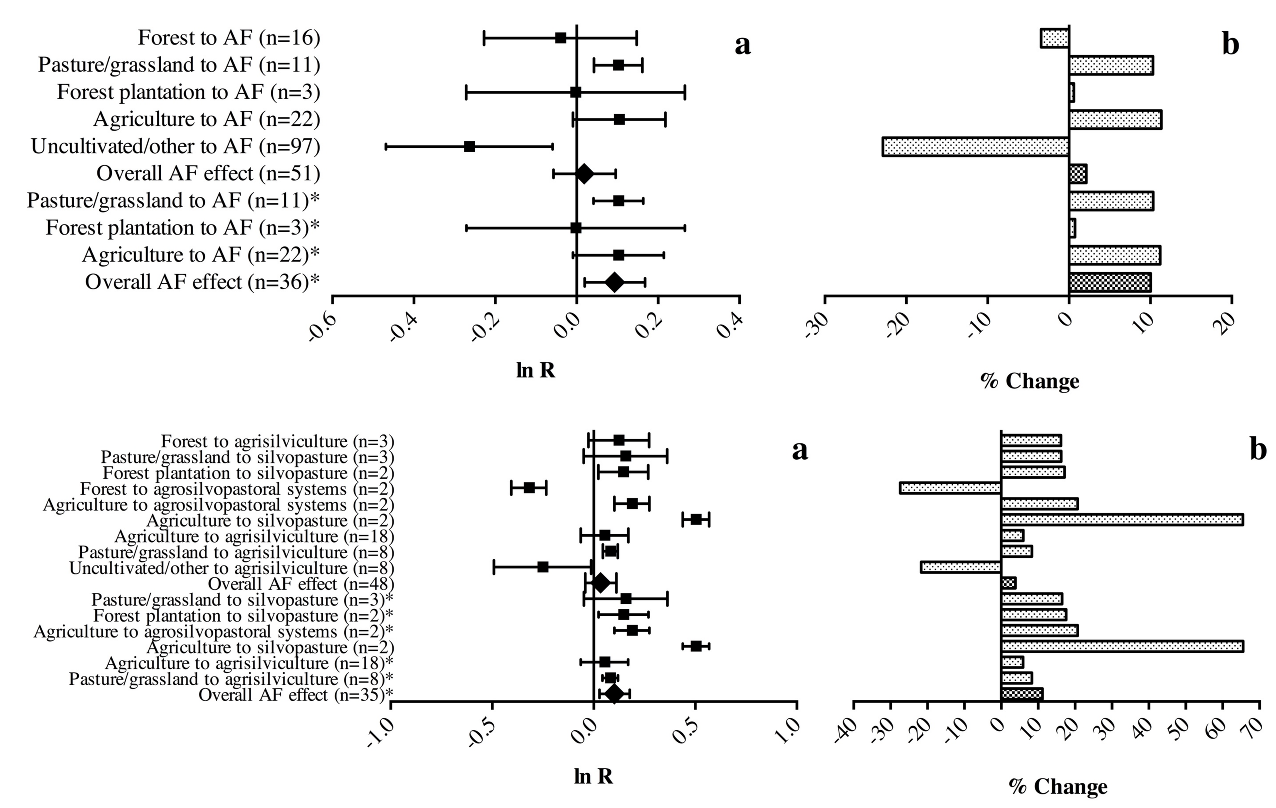


Fig. 4. Effects of agroforestry (AF) on SOC stocks (0–100 cm).

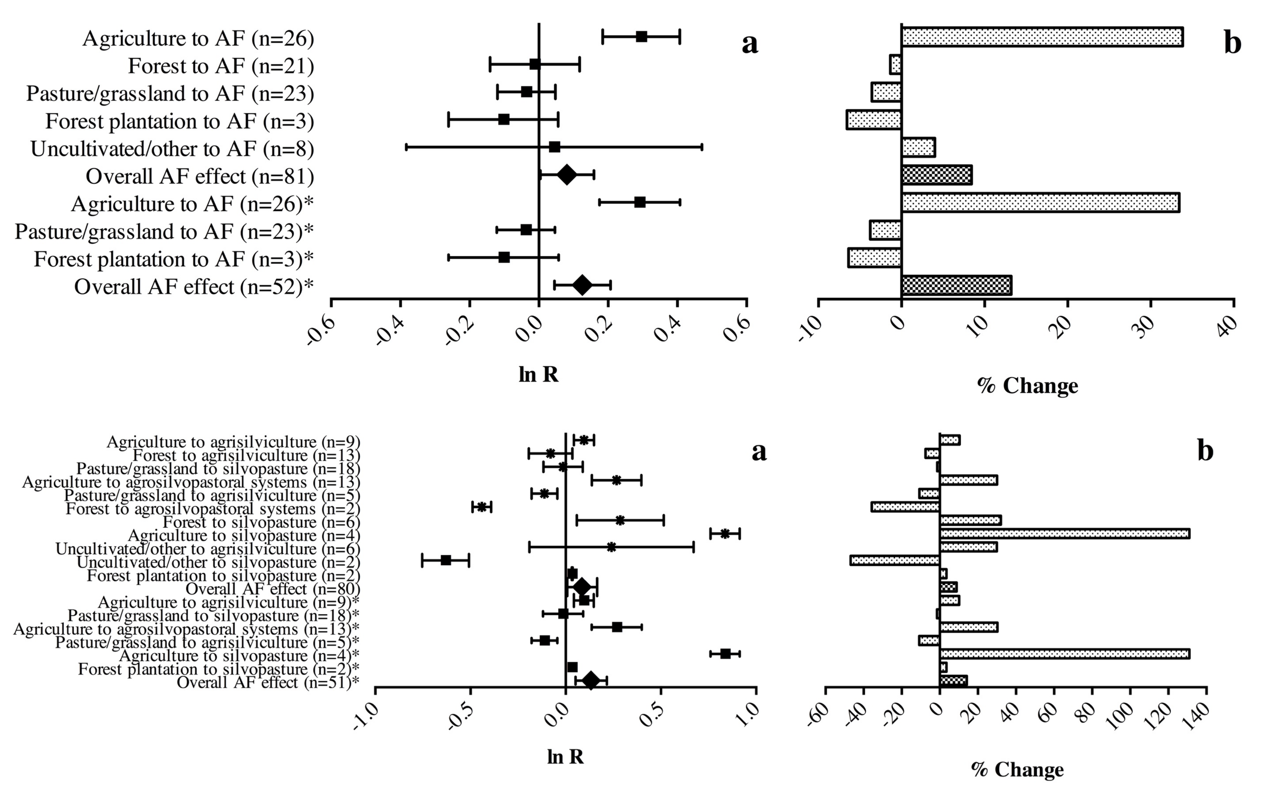
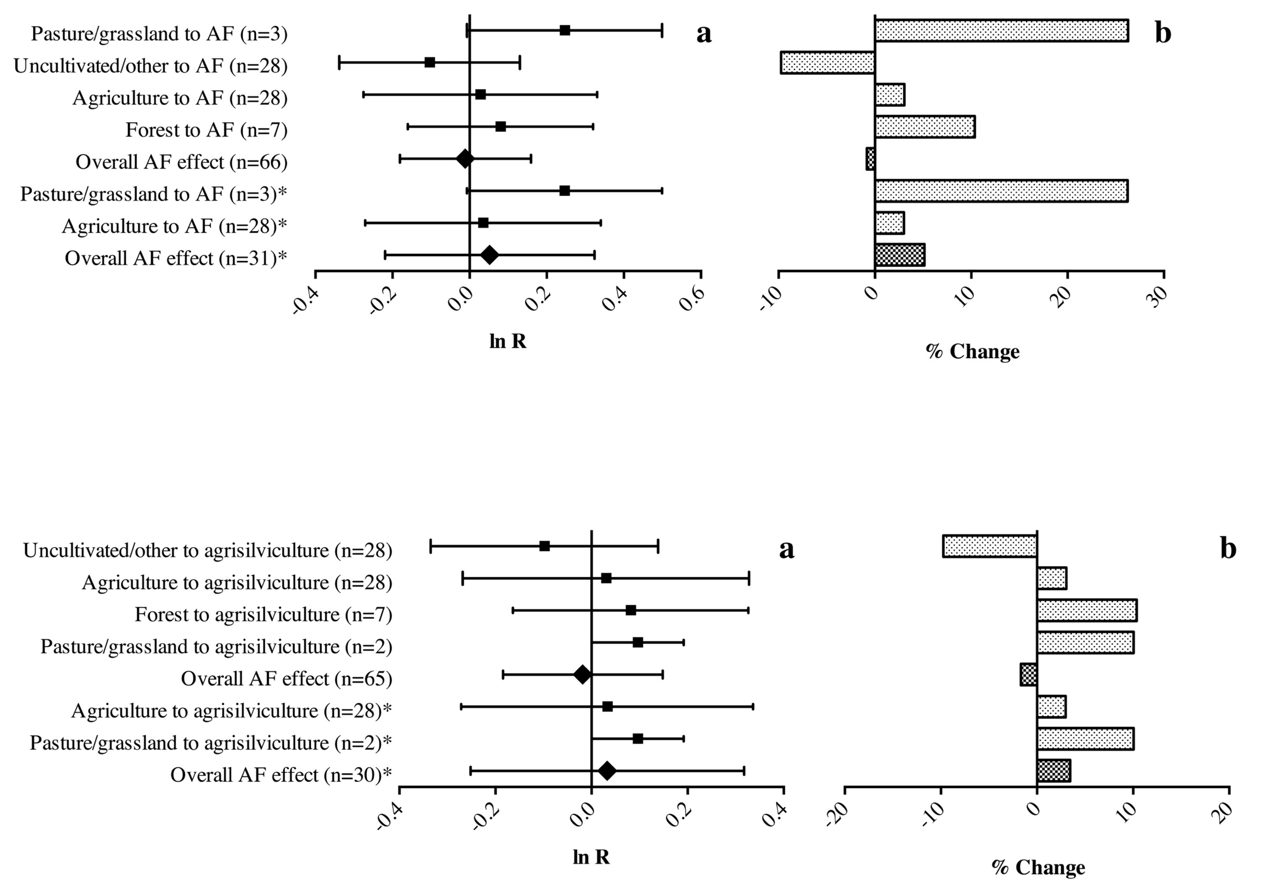


Fig. 5. Effects of agroforestry (AF) on SOC stocks (>100 cm).



CONCLUSION

Overall, SOC stocks increased when land-use changed from less complex systems, such as agricultural systems, while the conversion from forest to agroforestry lead to losses in SOC stocks in the top layers. However, important methodological issues, lack of information, and knowledge gaps might bias the outcome of the metanalysis. Specific efforts are needed to build a more robust database for future research.