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1 Introduction

There is an urgent need to ensure that farming systems not only provide high yields, but also the provision of ecosystem services (ES) on which agriculture and farmer households depend. We compared the provision of four ES indifferent types of coffee agroecosystems: i) regulation of pests and diseases (P&D); ii) provision of agroforestry products (coffee, bananas, fruits, timber); iii) maintenance of soil fertility; andiv) carbon sequestration. We provide key insights on how coffee agroecosystems could be most effectively managed to ensure the continued provision of ES.

2 Materials and Methods

We established a coffee research network (69 coffee plots) in Turrialba, Costa Rica for two years of field measurements (2014-2015). Coffee agroecosystems were selected according to the combination of three factors: i) Altitude: low (<850m.a.s.l.) and high (>850m.a.s.l.); ii) Shade: full sun coffee, simple shade (dominated by *Erythrinapoeppigiana*) and diversified shade (musaceas, service trees, fruit trees and timber trees); iii) Management: low (few cropping practices and low inputs) and high (many cropping practices and high inputs). We calculated the areas under the disease progress curve (AUDPC) of P&D, registered the severity, and counted the number of dead branches. We also assessed the effectiveness of coffee agroecosystem in regulating P&D by estimating the coffee yield losses (=attainable yields minus actual yields; estimated by modelling). Yields, costs and incomes of agroforestry products were used to calculate economic indicators and to assess their overall contribution to farmer households (Cerda *et al.,* 2014). Soil fertility was determined by laboratory analysis. Above-ground biomass carbon was estimated with the use of allometric equations.
Statistical analysis: analyses of variance using general linear mixed models and the test LSD (Fisher) with p <0.05 to compare the effect of the three factors (altitude, shade and management) and their interactions on the provision of ES.

3 Results – Discussion

The interaction of shade and management was the most important for explaining the regulation of P&D. Coffee leaf rust (*Hemileiavastatrix*), the severity of P&D attacks and the number of dead branches were higher in full sun coffee plantations with high management as well as in coffee under diversified shade with low management; indicating that none of those extremes are good for avoiding P&D. Coffee under diversified shade with high management showed fewer P&D impacts, suggesting that complex agroforestry systems can contribute to the regulation of P&D (Fig. 1).

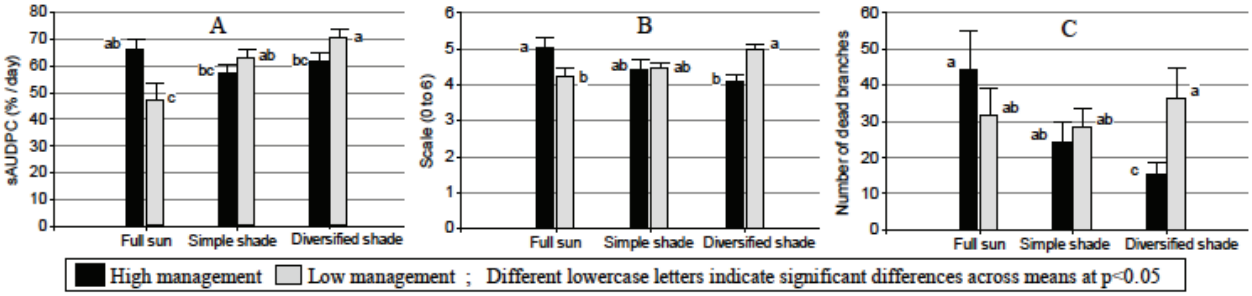


Fig. 1.A) Coffee leaf rust, B) Maximum severity, and C) Dead branches, according to shade and management.

Attainable yields and actual yields of coffee were similar among coffee in full sun with high management and coffee agroforestry systems, but coffee under diversified shade with high management tended to have the lowest yield losses

(Fig 2). These results reinforce the idea that diversified shade systems can help to regulate P&D (Fig 1). These findings become important knowledge for the development of agroecosystems that are capable of balancing high yields and reduce the impacts of P&D (Avelino *et al*., 2011).

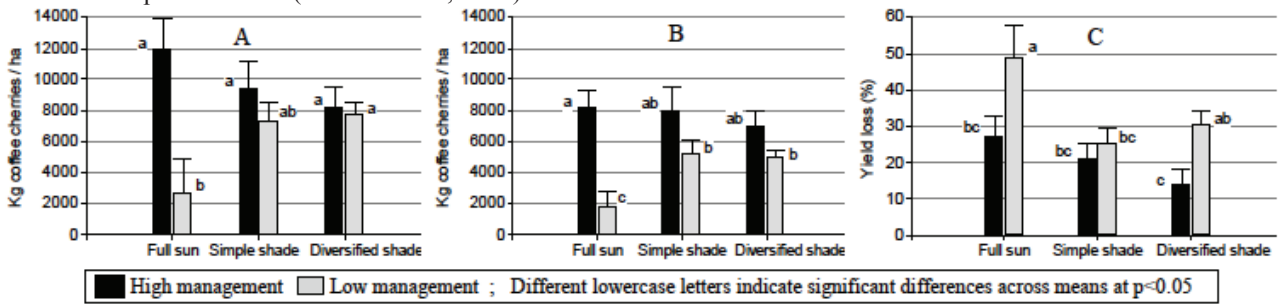
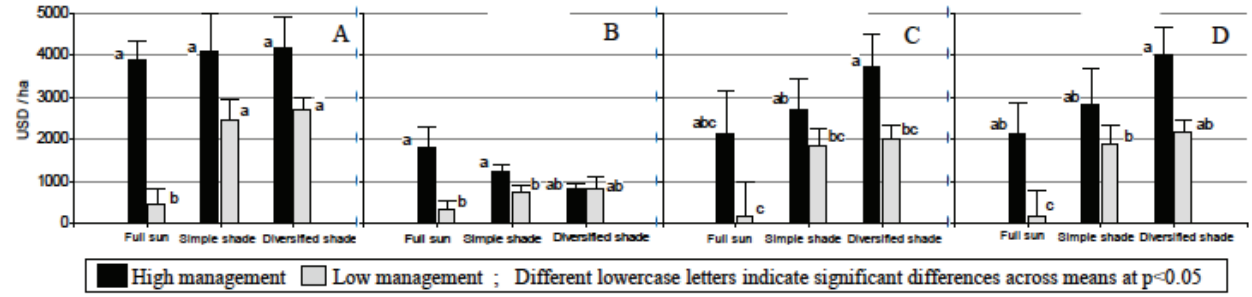


Fig. 2.A) Attainable yields, B) Actual yields, and C) Yield losses of coffee, according to shade and management.

Only high coffee yields would not always be the best for farmer households. Cash costs of coffee in full sun were high and therefore its cash flow tended to be lower than in agroforestry systems. Besides, the agroforestry products of shade canopies increased even more the cash flow, the domestic consumption, and therefore, the family benefit (Fig. 3).



Cash flow = Gross incomes – Cash costs; Family benefit = Cash Flow + value of domestic consumption of agroforestry products

Fig. 3.A) Gross income, B) Cash costs,C) Cash Flow, and D) Family Benefit,according to shade and management.

The sole effect of shade was the most important on soil and carbon. Most elements of soil fertility were better in coffee under diversified shade, as in the case of acidity and potassium (Fig. 4), two key indicators of soil quality. Finally, agroforestry systems had at least double the above-ground carbon compare to coffee in full sun (Fig. 5).

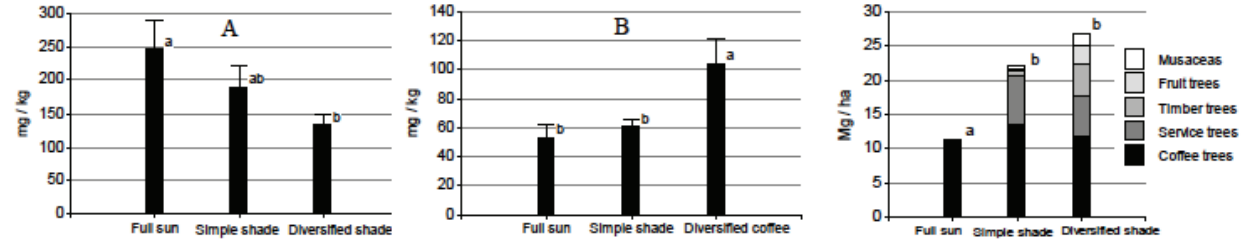


Fig 4.A) Acidity, and B) Potassium in soil. **Fig. 5.Above-ground biomass carbon.**

4 Conclusions

The provision of ES varies across different types of coffee agroecosystems. The best ES are provided by coffee agroforestry systems. Coffee farming systems should be designed with the inclusion of productive shade canopies and managed with constant cropping practices, trying to reduce as much as possible the cash costs for a higher family benefit; being also the best alternative to reduce yield losses.

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