Optimizing agroforests for sustainable agricultural development in West Africa

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Research Summary

Problem outline

Over 80% of the worldwide production of cocoa is grown on smallholder farms and provides the main source of income for 40-50 million people worldwide. But cocoa production is threatened by decreasing soil fertility, increasing pest and disease prevalence, and climate change. To meet growing demand for cocoa in the past, the area devoted to cocoa cultivation has expanded at the expense of native forests, thereby reducing carbon stocks and biodiversity. Aging trees and traditional cocoa farming practices, which place little value on environmental sustainability, continue to worsen the cycle of agricultural and environmental degradation, posing a significant threat to farmers' livelihoods.

Agroforestry – the deliberate inclusion of shade trees in cropping systems – could help to simultaneously solve many of the problems facing the cocoa sector. Agroforests are widely expected to improve soil fertility, regulate pests and pathogens, and buffer crops from climate change. Moreover, shade trees have the additional benefit that they can provide other important ecosystem services such as the conservation of biodiversity and carbon sequestration, and can also provide additional income through timber and fruit production. However, although they are widely advocated, and are currently being implemented across large areas of Africa, Asia, and the Americas, agroforests generate costs and many of their presumed benefits, while intuitive, are often untested. For example, shade trees can reduce cocoa production through competition, they may reduce soil moisture thereby exacerbating drought, and agroforests are unlikely to match the diversity and service provisioning of primary forests. Unless agroforests are implemented in a way that optimizes the trade-offs between their costs and benefits, this effort in climate-smart, sustainable agricultural intensification may simply compromise the ability to meet production, climate, sustainability and conservation goals. Until now, however, there has been no definitive, evidence-based recommendations for how to best implement agroforests with shade levels and shade-tree species that best provide multiple benefits while minimizing multiple costs.

Project overview

The goal of my project was to provide clear and achievable recommendations for implementing cocoa agroforests based on measurements of the balance of their costs and benefits. First, this required simultaneous measurements of the multiple effects of agroforests to identify the trade-offs inherent to their implementation. Second, it required understanding how these costs and benefits accrue with changes in shade tree cover (Fig. 1). And third, it required understanding how different species of shade-trees – particularly those related to alternative incomes for smallholders – influence the effectiveness of agroforests. To achieve these goals, over a period of two years I measured cocoa yields, losses to disease, soil fertility, temperature, relative humidity, soil moisture, carbon stocks, and biodiversity of multiple taxa in 20 smallholder cocoa agroforest plots selected systematically along a gradient of shade-tree cover in a globally-significant cocoa growing region in Ghana, West Africa. I then further assessed the effects of 26 different species of shade-tree each with different traits on each of the same response variables, as well as on their potential to provide additional economic benefits. Because it was important to isolate the effects of shade trees from other confounding factors such as differences in farm management, soil type and local micro-climate, I used a unique sampling design in which the effects of all agroforest plots were compared with paired monoculture plots on the same farms.

Research findings and recommendations

My uniquely comprehensive dataset demonstrates that agroforestry can optimize the trade-off between agricultural yield and the provisioning of other ecosystem services at shade levels around 30% cover (Fig. 1). Agroforests with ~30% cover are far superior to monocultures because they do not strongly compromise production, while providing benefits for disease management, climate mitigation and adaptation, and biodiversity conservation. As shade-tree cover increases above 30%, agroforests become increasingly less likely to generate win-win scenarios (Fig. 1). This is mostly caused by the negative effects of shade trees on cocoa yields due to a reduction in light and competition for water.

My results also demonstrate that shade trees with different economic uses differ in their effects on cocoa yield. Most fruit trees are shorter and have shallower roots than many timber trees, which leads to higher direct competition for light and water with cocoa, resulting in a negative effect on cocoa yields. Planting timber rather than fruit or other service trees could therefore provide an additional pathway for minimizing the trade-offs and maximizing the benefits of shade trees in smallholder farms.

Together, my results demonstrate that careful management of the level of shade (~30 % cover) and the prioritization of timber trees, are likely to yield more favorable outcomes for smallholder cocoa producers and for the environment than current *ad hoc* implementation practices. Importantly, shade levels of ~30% are higher than those most commonly implemented in this region, suggesting substantial additional potential for increasing the benefits of agroforestry, without compromising production.

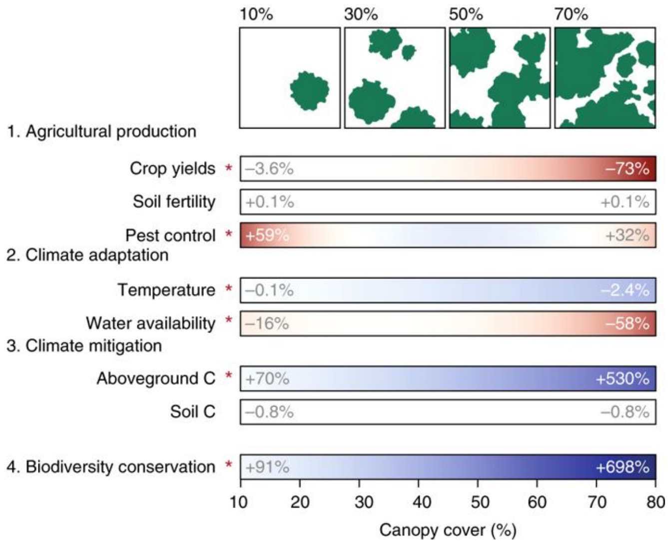

Figure 1 Optimizing shade levels in agro-forests. Agroforests with ~30% cover are ideal for optimizing the trade-off between the costs (red) and benefits (blue) for yield and the provisioning of ecosystem services such as climate adaptation, climate mitigation and biodiversity along a gradient of shade-tree cover, relative to paired monocultures. The actual predicted percent difference for each variable is indicated with minimum and maximum values (% difference) at the ends of each bar. The top four panels give a schematic aerial view of representative plots along the cover gradient. Blaser et al., *Nature Sustainability* (2018).

Solutions and impact for development, outreach and partnerships

The key contribution of my project for development is an evidence-based, quantitative solution for climate-smart, sustainable cocoa production in West Africa. What is unique about the recommended solution is that it is based on the simultaneous assessment of nearly the full range of costs and benefits presumed to be associated with shade-trees in agroforests. My research was performed in low-input smallholder cocoa farms, in close collaboration with local farmers and local researchers. A focus on cocoa systems of smallholder farmers was important to me because it allowed me to develop recommendations that provide benefits for smallholders to improve their livelihoods.

Throughout the project, I engaged local farmers about the project goals, outcomes, and recommendations. In addition to direct exchange with farmers, I am currently developing teaching materials for high school students in Ghana and Cameroon. I also communicated my results in seminars to local research organizations in Ghana (SRI, KNUST, FORIG, CRIG, IITA), two international scientific conferences, a large public event (Expo Milano), and in online articles and blogs. These outlets ensured that researchers, extension agents, and other stakeholders in the cocoa industry can use my data and recommendations for their research and outreach purposes. So far, my work has yielded two publications in internationally peer-reviewed journals. My recent publication in *Nature Sustainability* was well received by the cocoa industry (e.g. the World Cocoa Foundation, Olam Cocoa, UTZ Certified), which considered it an important step in the debate on optimal shade levels in cocoa.

The development of a larger, ongoing collaborative research effort between Switzerland and Ghana was an important objective of this project, in line with the goals of SARECO who partially funded this work. Including local partners from the onset of the project allowed me to specifically address local concerns and increased the acceptance of our results, but also contributed to the development of knowledge and expertise in agricultural research in Ghana, where I supervised a local PhD student, a Masters student, and a Bachelors student, and I also helped to build the capacity of local researchers.