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COMMENTS ON COE *ET AL.* (2019)–'LOADING THE DICE IN FAVOUR OF THE FARMER . . .'

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SUMMARY

In the past two decades, a growing body of work on research stations and farmers' fields in Southern Africa has provided evidence that fertilizer trees can improve the productivity of land, increase crop yields and contribute towards climate change mitigation and adaptation. In a recent issue of Experimental Agriculture, Coe *et al.* (2019) published analysis of risks associated with adopting agroforestry in Malawi. The article contains several factual inaccuracies about agroforestry and misinterpretations of earlier work. Our aim in this correspondence is, therefore, to point out the key problems, seek clarification from Coe and co-workers, and stimulate wider scientific debate on the perceived risks of adopting agroforestry.

INTRODUCTION

In the past two decades, a growing body of work on research stations and farmers' fields in Southern Africa has provided evidence that fertilizer trees can improve the productivity of land, increase crop yields (Ajayi *et al.*, 2011; Akinnifesi *et al.*, 2009; 2010; Chirwa *et al.*, 2007; Makumba *et al.*, 2009; Sileshi *et al.*, 2008; 2010; 2014), household incomes (Ajayi *et al.*, 2009; Kamanga *et al.*, 2010) and contribute towards climate change mitigation and adaptation (Campbell *et al.*, 2014; Kim, 2012; Luedeling *et al.*, 2011; Rusinamhodzi *et al.*, 2012). In a recent issue of *Experimental Agriculture*, Coe *et al.* (2019) published analysis of risks associated with adopting agroforestry in Malawi. Unconventionally, the authors interpret variability in yield difference between two 'treatments' as a measure of yield loss and risk to farmers. Our aim in this correspondence is, therefore, to point out the key errors in their analysis and their interpretation of previous work and stimulate wider debate on the perceived risks of adopting agroforestry.

DATA ANALYSIS

For their analysis, Coe *et al.* (2019) used data collected by Sileshi and co-workers as part of the Malawi Agroforestry Food Security Program. However, their analyses were neither informed by the design of the study nor the nature of the data. Having been involved in the design and supervision of the project, we are familiar with the

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challenges in the dataset. Originally, our data collection was aimed at establishing baselines for the project, but risk analysis was not one of its objectives. Since this was a scaling-up project, a large number of farmers were involved, and as such it was extremely challenging to standardize many management practises. What farmers did on their plots were also beyond the control of researchers. In some cases, the trees (e.g. *Faidherbia albida*) were planted decades ago by farmers or were a product of farmer managed natural regeneration. As such, the age of trees ranged from 3 years to over 30 years. *Gliricidia sepium* trees aged between 3 years and 4 years, and the frequency and method of pruning (coppicing) varied among farms. In addition, the maize in agroforestry plots was fertilized on some farms, manured on others and not fertilized on the remaining sites. Similarly, sole maize was not a single intervention; on some farms it was fully fertilized, while on others it had received small doses of fertilizer, animal manure, green manure or no external input at all. In reality, therefore the sole maize, which was treated by Coe *et al.* (2019) as the control was a mixture of 'treatments'. Other agronomic practises were also not the same on the treatment and sole maize plots. Where fertilizer was applied to maize the rates also varied widely across farms. It is not surprising that the 'control' in Coe *et al.* (2019) had higher yields (2.73 t ha^{-1} in 2011/12 and 2.78 t ha^{-1} in 2012/13 seasons) than the typical control in Malawi. According to several assessments in Malawi the median yield of the control is about 1 t ha^{-1} (Snapp *et al.*, 2014).

While Coe *et al.* (2019) acknowledge some of the sources of heterogeneity they did not address them when calculating yield differences (Yd). In fact, they calculated Yd as Ya−Ys where Ya is maize yield of the agroforestry plots, and Ys is yield of the sole maize. For the reasons given above, neither Ya nor Ys came from homogeneous sets of plots across sites. According to the nutrient inputs in the sole maize plots, Ys should have been decomposed as follows: fertilized (Yf), manured (Ym) and absolute control (Yc). Since the fertilized sole maize has received different rates of fertilizer, Yf should have also been further decomposed according to the application rate. Coe *et al.* (2019) collapsed all these categories into Ys when calculating Yd. Therefore, we believe that the Yd values in Table 2 and Figures 1 and 2 of Coe *et al.* (2019) do not represent the 'correct Yd'. Ideally, the correct Yd is calculated as Ya−Yc because the absolute control (i.e. Yc) can be clearly defined as maize grown without any nutrient input, which is the *de facto* resource-poor farmers practise (Sileshi *et al.*, 2010). When the interest is in Yd relative to a fully fertilized control plot, the correct Yd could be calculated as Ya−Yf. In addition, the authors have not accounted for well-known sources of variation, such as soil type (Sileshi *et al.*, 2010), planting date, tree management (Akinnifesi *et al.*, 2009) and tree age (Sileshi, 2016). Disregarding all the above complications, Coe *et al.* (2019) focussed on discussing Yd in much of the paper and made inadequate comparisons of their results with earlier studies (Sileshi *et al.*, 2008; 2010).

Coe *et al.* (2019) also interpreted all unexplained variations in Yd as representing risk to farmers. The authors further claimed that a farmer adopting any of these agroforestry practises faces a risk of substantial loss. It is unclear what the cause of the loss is and what the sources of vulnerability are. Conceptually, risk is the probability of an adverse outcome due to hazards (e.g. drought, flooding, frost, pest and disease outbreaks, etc.) or loss of value due to market volatility. As such risk (R) is a function of the vulnerability (V) of the system and the severity of hazard (H), hence R = f (H, V). Therefore, not only is the approach used in Coe *et al.* (2019) inappropriate for assessing risks but the results also contradict earlier analysis done in Malawi (Kamanga *et al.*, 2010; Sirrine *et al.*, 2010; Snapp *et al.*, 2014) and Zambia (e.g. Ajayi *et al.*, 2009). According to Kamanga *et al.* (2010), maize intercropped with pigeon pea (*Cajanus cajan*) or *Tephrosia* was less risky for resource-poor farmers compared to fully fertilized maize, which had acceptable risk only for resource-endowed farmers in central Malawi. Indeed, maize intercropped with pigeon pea was found to be the least risky technology for all resource groups (Kamanga *et al.*, 2010). Similarly, Sirrine *et al.*, 2010) found that the most vulnerable households in southern Malawi are better of intercropping pigeon pea or *Tephrosia* with maize than growing maize with the recommended fertilizer. Using historical rainfall records and simulated yield in northern Malawi, Snapp *et al.* (2013) also showed that pigeon pea–maize intercropping can meet the household food needs (calories and proteins) in 73–100% of the years across variable rainfall patterns, while fully fertilized maize can achieve this in only half the households. In terms of returns to land and labour, the net present values (NPV) and benefit cost ratios (BCR) show that fertilizer trees are either comparable or better than inorganic fertilizer. In central Malawi intercropping maize with pigeon pea had consistently positive returns across the farmer resource groups indicating its suitability to a wide range of environments and for the poorer farmers (Kamanga *et al.*, 2010). Over a five-year cycle, the discounted net benefit of maize grown with *Gliricidia* (US\$327 ha^{-1}), *Sesbania* (US\$309 ha^{-1}) and *Tephrosia* (US\$233 ha^{-1}) compared favourably with maize grown with the recommended inorganic fertilizer (US\$349 ha^{-1}) in Eastern Zambia. With respect to returns per investment, fertilizer trees even performed better (BCR: 2.8–3.1) than the recommended fertilizer purchased at market price (BCR: 1.8) or at 50% government subsidy of fertilizer (BCR: 2.6) in Eastern Zambia (e.g. Ajayi *et al.*, 2009).

The interpretation of results by Coe *et al.* (2019) is also contrary to the role trees play in sustainable intensification and household energy security. For example, pigeon pea is an important food and cash crop widely intercropped with maize by farmers in Malawi (Akinnifesi *et al.*, 2009; Smith *et al.*, 2016). In Malawi and Mozambique, intercropping pigeon pea with maize has been demonstrated to reduce the risk of crop failure and improve profitability (Rusinamhodzi *et al.*, 2012; Snapp *et al.*, 2010). Farmers in Malawi also highly value the contribution from pigeon pea to household fuelwood supply (Orr *et al.*, 2015). According to Kamanga *et al.* (1999), 92–101% of the domestic fuelwood needs were met from a hectare of 2–3 year old *Sesbania* trees in Malawi. Pigeon pea production has also been successfully integrated with energy-saving stoves, and this has reduced the frequency of buying and collecting fuelwood in parts of Malawi (Orr *et al.*, 2015). Therefore, the contribution of fertilizer trees should be judged not by the mere increase/decrease in maize yields but by the greater benefits that accrue to the household (e.g. nutrition, cash income, fuelwood and soil fertility) and the environment. Planting of fertilizer trees on farmland can increase access to fuelwood by women, and thus the time and labour spent in search of fuelwood can be reallocated to food production and childcare (Orr *et al.*, 2015; Sileshi *et al.*, 2014). This can also help reduce deforestation.

MISLEADING COMPARISONS

Coe *et al.* (2019) stated that the yield increases they calculated are much smaller than the increases of several hundred per cent reported from Malawi (Akinnifesi *et al.*, 2007; 2009; 2010) and more generally for sub-Saharan Africa (Sileshi *et al.*, 2008). Important methodological differences exist between Coe *et al.* (2019) and the studies they cited. The reason why their results are at variance with results of Akinnifesi *et al.* (2007; 2009; 2010) and Sileshi *et al.* (2008) is clearly due to the incorrect use of the sole maize as the control in Coe *et al.* (2019). In Akinnifesi *et al.* and Sileshi *et al.* for each treatment there was a corresponding absolute control managed in the same manner. As such the correct Yd was calculated as Ya−Yc. Their comparisons will only be justified if they had analysed the data after disaggregating Ya and Ys as follows:

- Fertilized maize plots + tree species X: Yd = Y(x+f)−Yc, where Y(x+f) is yield of plots in which trees and fertilizer were combined and Yc is yield of the absolute control.
- Unfertilized plots with tree species X: Yd = Yx−Yc
- Fully fertilized sole maize: Yd = Yff−Yc where Yff is yield of ‘fully fertilized’ maize plots, where the fertilizer application rate is the same across all sites.
- Fertilized sole maize: Yd = Yfh−Yc, where Yfh is yield of maize plots that received half or less of the recommended fertilizer application rate.

This way the heterogeneity in Yd can be reduced and balanced comparisons among the different interventions can be made. This kind of careful analysis is already available for *Gliricidia*, *Sesbania* and *Tephrosia* in Sileshi *et al.* (2010) and for *Faidherbia* in Sileshi (2016).

FACTUAL INACCURACIES

The first inaccuracy is found in Coe’s claim that agroforestry promotion was biased towards more fertile than average fields and more industrious than average farmers. This is patently wrong in the context of Malawi. Indeed, studies that carefully compared the performance of fertilizer trees under resource-poor and resource-endowed farmers’ conditions have been widely published (see Kamanga *et al.*, 2010; Sirrine *et al.*, 2010). In addition, Coe and colleagues claimed that fertilizer trees were being promoted as an alternative to inorganic fertilizer. On the contrary, trees were promoted as complementary inputs to inorganic fertilizer (Sileshi *et al.*, 2014), and the combined use of inorganic fertilizer and fertilizer trees is an accepted farmers’ practise (Akinnifesi *et al.*, 2009; Kamanga *et al.*, 2010). Fertilizer trees were being promoted as a strategy for crop diversification, increasing productivity and the stability of the production system.

Coe *et al.* (2019) also make strong claims about 'yield loss', 'yield reduction' and 'negative effects' on agroforestry plots; they stated that (i) a farmer adopting agroforestry practises faces a risk of substantial loss, (ii) a larger proportion of farmers experienced yield reduction on their agroforestry plots compared to sole maize and (iii) the largest negative effect is with low tree density at high altitude and fertilizer applied to the sole crop plots. In reality, Coe *et al.* (2019) have neither quantified yield loss nor negative effects of trees or risks, for that matter. Simply deducting values of one treatment from another does not give an estimate of yield loss or gain.

Other factual inaccuracies are also evident in the claim by Coe *et al.* (2019) that (i) there was no synergy between *G. sepium* and fertilizer and (ii) *G. sepium* is competitive rather than complementary with maize. Indeed, studies on farmers' fields (Akinnifesi *et al.* (2009) and research stations (Akinnifesi *et al.*, 2009; Chirwa *et al.*, 2007; Makumba *et al.*, 2009) in Malawi show quite the opposite.

Coe *et al.* (2019) also used Yd as a measure of the adoption potential of agroforestry practises. For example, they claim that it is farmer-obtained yields and yield increments that are most relevant to farmer decision to adopt a new technology. This contrasts with the current state of knowledge. Our work in Malawi (Meijer *et al.*, 2015a; 2015b) shows that farmers' adoption decisions are more complex than just crop yield. The recommendations in Coe *et al.* (2019) are in sharp contrast with the wider consensus on agro-ecology, diversification and sustainable intensification for reducing production risks (Campbell *et al.*, 2014; Kamanga *et al.*, 2010; Rusinamhodzi *et al.*, 2012; Sirrine *et al.*, 2010; Snapp *et al.*, 2010). Merely focusing on yields, the recommendations also ignored the various ecosystem services provided by fertilizer trees on farmers' fields (Sileshi *et al.*, 2014), which should be the bigger picture.

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