Highlights of CIMMYT's achievements in the project 'Trees for food security'

Improving sustainable productivity in farming systems and enhanced livelihoods through adoption of evergreen agriculture in eastern Africa




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How do scattered trees affect the microclimate and resources available to maize/wheat?

F. albida had a positive impact on wheat yield every season. Yield under *F. albida* was up to 25% higher (e.g., in 2015 see Fig. 1a) and decline exponentially with increasing distance from the tree (the tree had no influence on wheat yield beyond 7 m; Fig. 1a). From modelling work conducted in partnership with CSIRO and from detailed analysis of the data, this facilitative effect appears to be caused by a delayed phenology of wheat – due to lower temperature (Fig. 1b) - combined with the availability of more soil moisture under the tree. The additional moisture under the tree appears to be a result of lower evaporation, perhaps combined with hydraulic lift. Although this facilitative effect appears substantial, our data suggests that it could be increased further: indeed the number of fertile tiller at harvesting time for wheat under the canopy of *F. albida* is generally lower than the number of tillers at the beginning of grain filling (e.g. 60 days after planting). In 2014 for example, the mean number of fertile tillers per plant at harvesting time was 4.25, but the mean number of tillers at the beginning of grain filling was 4.78. This suggests that with appropriate management (probably by modifying fertilization and by choosing of a genotype better adapted to agroforestry conditions), wheat yield under *F. albida* could be increased by more than 10% (see section below for the exploration of some of these management options).

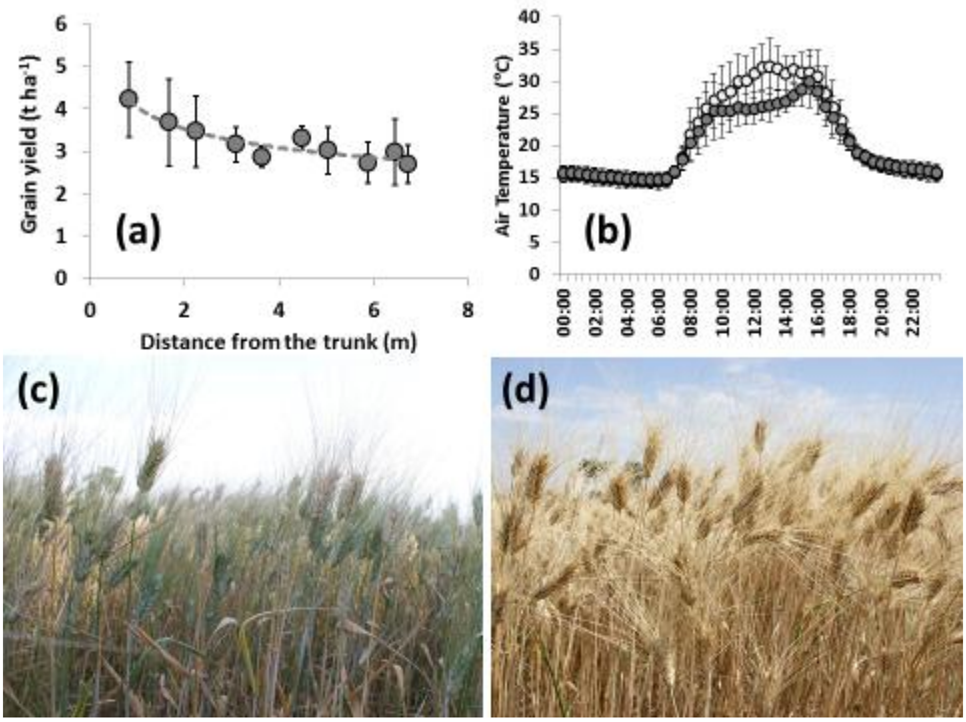

Figure 1 – (a) wheat grain yield as a function of distance to *F. albida* in 2014; (b) air temperature during the day at anthesis under and away from the canopy of *F. albida*; (c) wheat under *F. albida* at the end of grain filling; and (d) wheat away from *F. albida*. Pictures in (c) and (d) where taken the same day few meters apart.

In opposition, *A. tortilis*, *M lutea*, and *S. spectabilitis* had a negative impact on maize yield every year. This appears to be due to competition for resources including radiation, water and nutrients.

Competition for water plays a major role (Fig. 2a), in particular through canopy interception (Fig. 2b). The use of NDVI maps (Fig. 3) enabled us to sample the crop strategically in order to detangle above-ground effects from below-ground ones. Although the 3 tree species mentioned here have a negative impact on crop yield, they are nevertheless important for rural livelihoods (provision of timber wood, fuelwood, fencing material, etc). Therefore, research should focus on devising management practices that reduces these competition (e.g. by choosing genotypes better adapted to agroforestry conditions, see below).

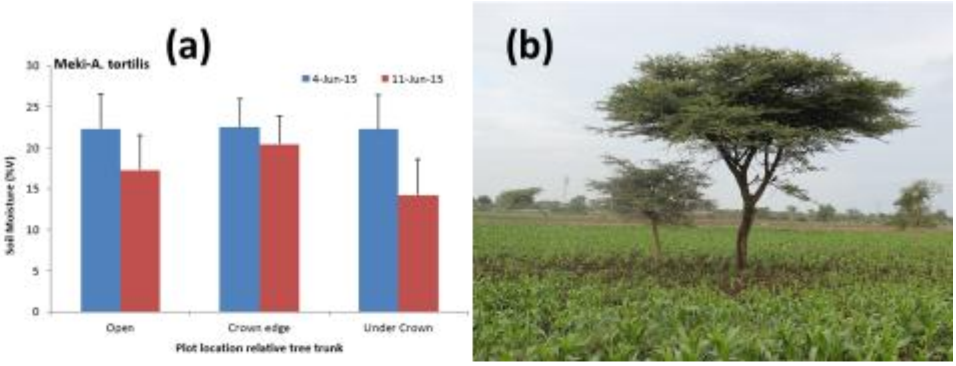

Figure 2 – (a) Soil moisture in an open field of maize, on the edge of the crown of *A. tortilis* and under the crown of *A. tortilis* at planting and a week after planting; and (b) illustration of rainwater interception by the canopy of *A. tortilis*.

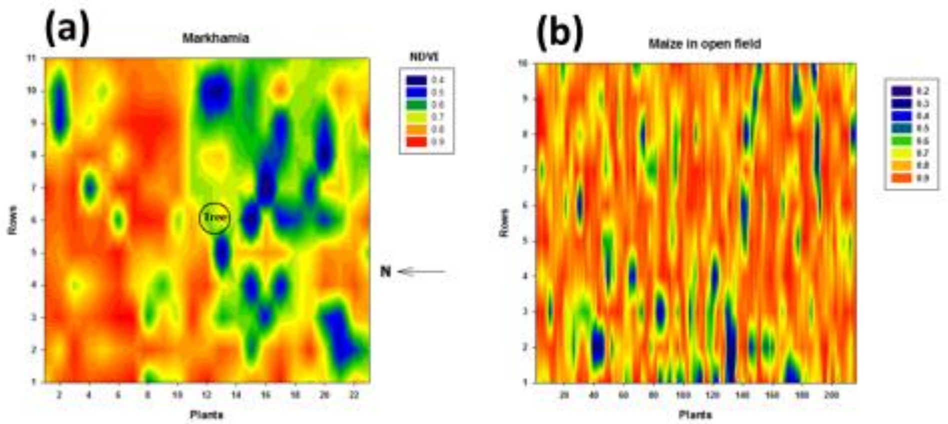

Figure 3 – (a) NDVI map of a maize plot under *M. lutea* clearly displaying an area of low NDVI (blue and green area on the right part of the diagram) corresponding to the area most affected by shading: both above and below-ground interactions take place in this section of the plot. The left part of the diagram corresponds to a section of the plot where most of the tree-crop interactions are below ground. (b) The NDVI map of a plot of sole wheat is much more homogeneous.

A. acuminata and *G. robusta* had a positive effect on maize yield in some seasons (particularly seasons receiving above-average rainfall), and a negative one in others. This is a result of the complex interplay of both competitive and facilitative interactions. For instance, *A. acuminata* reduced the quantity of photosynthetically active radiation and rainfall reaching the crop growing underneath (Fig. 4). But the tree may also fix atmospheric N benefiting the crop. This may explain the fact that *A. acuminata* had a positive effect on maize yield during season receiving above-average rainfall, but a negative one during other seasons.

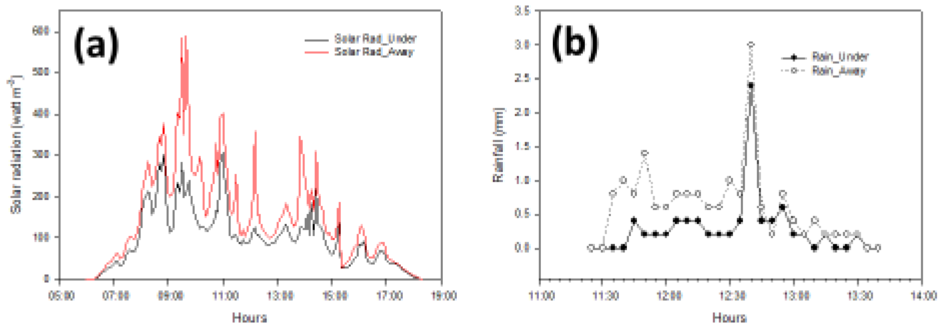

Figure 4 –Comparison of (a) the incident radiation reaching maize and (b) the rainfall received during one rainy event in season 2016A under and away from the canopy of *A. acuminata*

What maize genotypes minimize tree-maize competition?

Except for *F.albida*-wheat, where a facilitative effect was observed, all agroforestry systems under study were characterized by competition for resources between trees and maize growing underneath. It was hypothesized that this competition could be reduced by selecting maize genotypes better adapted to agroforestry conditions.

Both in Ethiopia and Rwanda, hybrid varieties tended to perform better than open pollinated varieties in agroforestry systems (Fig. 5). Only with the most competitive tree species (e.g., *S. spectabilitis*, which is characterized by a thick canopy; Fig. 5) did OPV varieties perform better than hybrids.

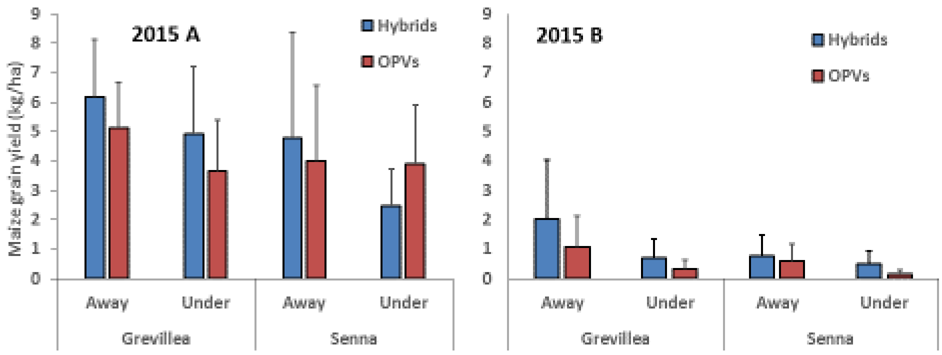

Figure 5 - Maize grain of hybrid and open pollinated varieties of maize in Bugesera growing under and away from the canopy of *Grevillea* and *Senna* during a good season in 2015 A (320 mm of in-season rainfall) and a poor one in 2015 B (190 mm of rainfall). Data are averages of 3 replicates for 4 hybrids and 4 OPVs and the error bars represent standard deviation of means.

What fertilization practices minimize tree-maize competition?

Trials were conducted with *G. robusta* in Rwanda (Bugesera) and *F. albida* in Ethiopia (Mojo).

Results from Rwanda suggest that *G. robusta* does not increase the availability of N and P for maize but instead competes strongly with the crop for both elements (Fig. 6).

Result from Ethiopia suggest that *F. albida* contributes a significant amount of mineral N (in the order of 69 kg ha^{-1} N, as the presence of *F. albida* had an effect on wheat yield similar to the application of 69 kg N ha^{-1}; Fig. 6). These results imply that good yields may be achieve under *F. albida* with minimum N fertilization (further research is needed to assess what the optimum stage is to apply this small amount of N: at planting, booting or first node stage). These results also suggest that farmers practicing agroforestry with *F. albida* should invest their limited resources on P fertilization instead of N fertilization.

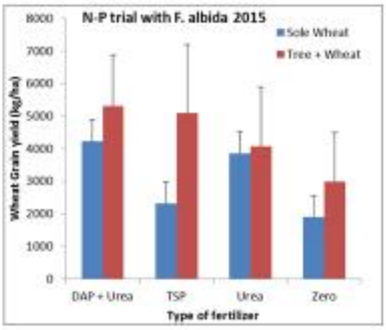

Figure 6 – Wheat yield under and away from the canopy of *F. albida* with the application of both DAP and Urea (46 kg ha^{-1} P and 69 kg ha^{-1} N), TSP only (46 kg ha^{-1} P and 0 kg ha^{-1} N), Urea only (0 kg ha^{-1} P and 69 kg ha^{-1} N), and no fertilization. The picture illustrate a 10 m × 10 m wheat plot with a *F. albida* tree in its centre, used as part of the experimental design.

What tillage practices minimize tree-maize competition?

Trials were conducted with *G. robusta* and *S. spectabilis* in Rwanda (Bugesera) and *A. tortilis* in Ethiopia (Meki).

Maize grain yields were constantly higher in conventionally tilled plots compared to plots that were not tilled (Fig. 7 for Rwanda during the 2015 A season), except when the OPV variety Gibe 2 was used (in Ethiopia). In the vast majority of cases, ploughing appears crucial in agroforestry systems to control the shallow roots of the trees and minimize competition for water and nutrient. These results suggest that 'Conservation Agriculture With Trees' (CAWT) – as promoted by ICRAF – may not be a viable crop management in the vast majority of cases.

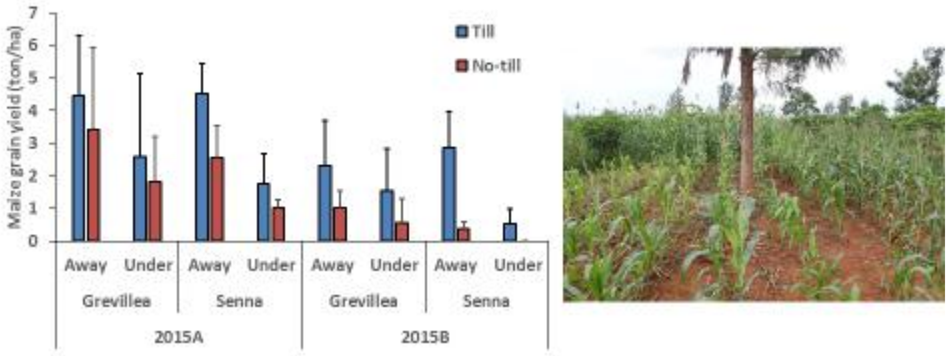

Figure 7 - Maize grain yield under and away from trees under conventional tillage (till) and no tillage (no till) during the 2015 A season. The picture illustrate a 10 m × 10 m maize plot with a *G. robusta* tree in its centre, divided into one half which was tilled, and another half which was not.

Is the recruitment of *F. albida* adequate to maintain the F. albida agroforestry system?

F. albida-wheat appreas to be an interesting agroforestry system in the Central Rift Valley of Ethiopia. But is the population of *F. albida* being maintained or is recruitment too low? To answer this question, the age structure of the *F. albida* population in Mojo was assessed, after developing an allometric model to estimate the age of individual *F. albida* trees based on their DSH, DBH, and height (a dendrological assessment of tree rings from 60 trees was carried out for that; Fig. 8).

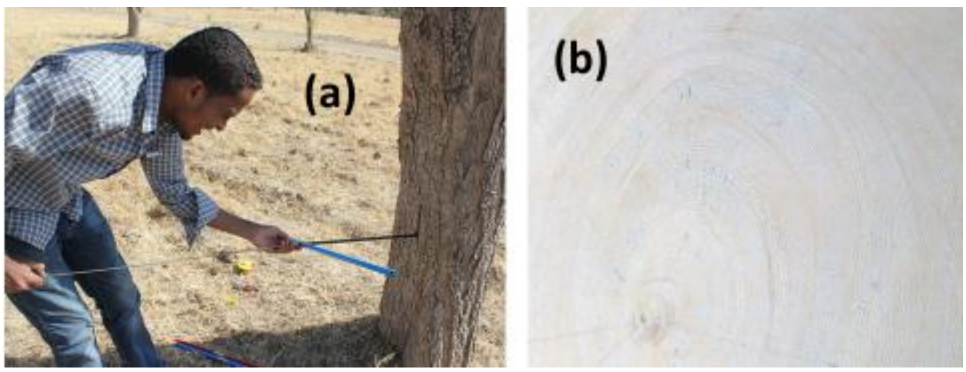

Figure 8 – (a) sampling of a tree ring from a *F. albida* tree; and (b) cross-section of a *F. albida* trunk where ring boundaries were can be identified from their continuity and change in tracheid size and morphology

Data analysis is still in progress, but it appears that the population distribution of *F. albida* is skewed towards older age classes. To test the impact of different management practices on the recruitment of *F. albida*, a recruitment model was developed (Fig. 9). A number of rates have been measured empirically (germination rate, and mortality rates of seedlings and saplings as affected by tillage and communal grazing). Other rates will be estimated from the literature or determined through parameterization using the age structure of the *F. albida* population in Mojo as response variable.

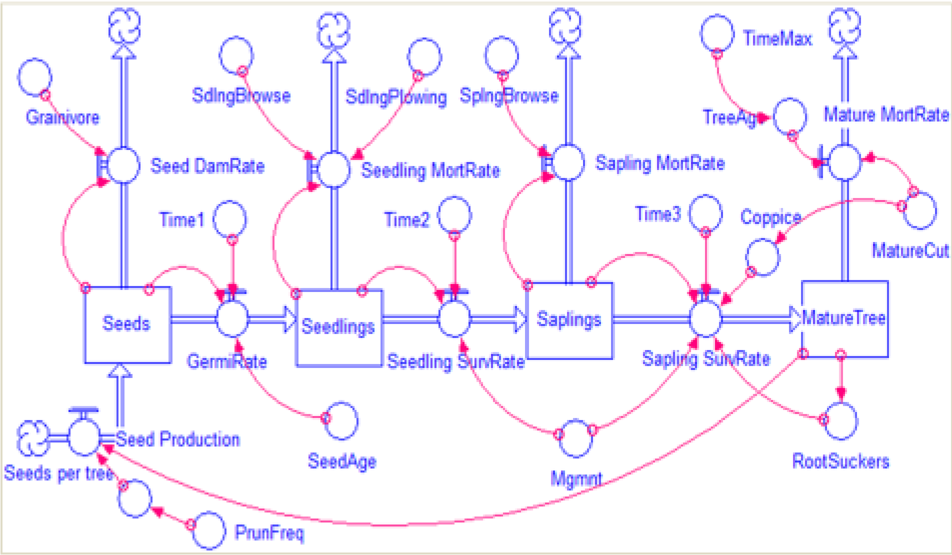

Figure 9 – Recruitment model used to estimate the viability of the population o *F. albida* in Mojo and assess alternative management options that could increase the recruitment of *F. albida*.

In what circumstances is growing in-situ mulch for coffee attractive?

In the Kivu lake border agro-ecological zone of Rwanda, the productivity of coffee heavily depends on the quantity of biomass applied as mulch in the plantation. Therefore, farmers tend to apply the bulk of the crop residue produced on farm in their coffee plantation: this results in large transfers of nutrients from food crop fields to coffee plantation, with negative consequences on the nutrient balance of food crop fields, raising concerns about the long-term productivity of these fields.

Previous work has demonstrated the possibility of growing mulch in situ using the agroforestry species *Tephrosia vogelii*. However, the recommendation domain for this practice has not yet been established. Therefore, 30 farms of contrasting soil fertility (different position on the landscape catena) were selected to host trials to quantify the productivity of *T. vogelii* in coffee plantation as a function of soil fertility status. The response of coffee productivity as a function of the quantity of mulch of *T. vogelii* will also be assessed.

Figure 10 – (a) heavy mulch of maize residues in a coffee plantation Kivu lake border agro-ecological zone, and (b) excellent establishment of *T. vogelii* in a coffee plantation in the same zone.