Biochar works: Cameroon trial data show strong improvement in maize yield

Cameroon trial data show strong improvement in maize yield - summary report

Kumba, Cameroon, September 10, 2009 - Since December 2008, more than 1500 subsistence farmers in Cameroon's South-West Region (SWR) have been participating in the largest-ever field trial testing the effects of biochar on crop productivity. The first results of this ongoing experiment, based on maize planted in a large series of plots, are now available. The data can be described as 'remarkable', in that they demonstrate how biochar consistently helps to boost crop productivity in tropical soils, sometimes in a spectacular manner.

The preliminary results suggest that biochar may offer a solution to hunger and food insecurity amongst the world's poorest, as well as to soil depletion and tropical deforestation.

Go straight to our DATA PAGE or our PICTURE PAGE . Context The Cameroonian farmers are united in 'Common Interest Groups' (CIGs), comprising between 10 and 30 members each. CIGs are the most grassroot of all forms of association in the country. These associations voluntarily dedicated a small plot of their (often scarce) farm land to conduct the experiment.   The participants are subsistence farmers who make less than €300 per year from agriculture, even though some of them are smallholders who are also involved in cash-cropping (mainly cocoa). The majority of the participants are women.   The biochar trials are taking place in and around the town of Kumba, in a region which features a great diversity of tropical soil types ranging from poor, highly weathered oxisols, to fertile volcanic soils. Besides Kumba proper, the following villages are now home to a biochar test plot: Kake, Barombi Kang, Mambanda, Ikiliwindi, Teke, Mabonji, Mbalangi, Malende, Kossala, Ediki and Kendem (see map 1).   The test plots are located in farm land that is commonly used by the peasants to grow root-crops like cassava, yam and cocoyam, and plantain, beans, maize and fruit crops. The typical farming system is one based on mixed cropping.   The Biochar Fund and its local partner, Key Farmers Cameroon, chose to conduct the trials with maize, because this crop can be planted and harvested twice in a single year. This opens the possibility for the partners to collect a large number of data-sets. The growing season for the first maize runs from May to July, that of the second crop from August to October. Because of excellent agro-ecological conditions, maize in this region matures in less than 90 days.   Even though maize is a staple crop for the local population, average yields amongst the participating farmers are low (below 1.7 tons per hectare; see data-page: general data, figure 6). The key factors explaining this situation are the low fertility of most soils and a lack of (financial) access to fertilizers, poor farm management, a lack of access to quality seeds, and the absence of modern strategies to deal with pests and diseases.   The results after the first harvest of maize grown on biochar show that char is an effective soil amendment, boosting the yield of the crop, even without the addition of mineral or organic fertilizers. Detailed data for each test plot are available at the data page. Below we briefly discuss these first results. Plot design and inputs The 75 test plots used during this pilot trial measure 54 square meters and are divided into 12 sub-plots, each demarcated by a buffer zone measuring 75 centimeters (see figure 1). Maize was planted at a high density of 62,500 seeds per hectare.   The sub-plots received different applications of inputs. A first line of four sub-plots functions as the control (no char) and received no inputs (X), organic fertilizer only (O), mineral fertilizer only (F) and a combination of organic and mineral fertilizer (OF). The second line is similar but also received the equivalent of 10 tons of char per hectare (C10, C10O, C10F and C10OF). Finally, the soil of the third line received biochar at a rate equivalent to 20 tons per hectare (C20, C20O, C20F and C20OF). Both the organic and mineral fertilizers were used at quantities recommended for maize in the humid tropics, and more specifically for the agro-ecological zone in which the trial takes place.The biochar was produced from two categories of biomass: organic waste from smallholder farms, which is otherwise burned in the open (cassava stems, oil palm branches and common weeds), and wood (red wood and rubber wood). The char was produced using a pyrolysis process with the following parameters: residence time, 1 hour; temperature, ~500-600°C; quantity per batch: 10kg. The biochar was then graded, crushed and sieved through a 2mm sieve before being packaged and distributed to the farmers.   The maize used during the trials was obtained from the Rumpi Program, an agricultural extension program run by the Cameroonian government. The germination rate of this maize is approximately 96 percent. Data collection A large number of basic agronomic data was collected during this first trial, both by the farmers themselves as well as by dedicated staff (3 independent extension workers and 2 field workers from the Biochar Fund and Key Farmers Cameroon). These data include: germination date and rate, vigor of the plants at different stages of development (after 3, 6, 9 and 12 weeks), the presence and type of pests and diseases at different stages, differences in weed growth at different stages of development, and the tasseling date and rate. Most of these data are currently being analysed.   During the harvesting process, three basic quantitative and qualitative measurements were taken: weight and health of the belowground biomass (roots), weight and health of the aboveground biomass (stems), and the weight and quality of the maize cobs and grains. This biomass was stored, air dried and analysed at a wet basis moisture content of 20%. It is these data which we present in this preliminary report. Soil data are currently being collected and require further analysis.   This first harvest closes the first phase of the project. However, the same exercise will now be repeated on August maize, which the farmers will plant on the 15th of this month. Thus, at the end of this year, a set of robust data will emerge which will allow us to draw several definitive conclusions on the effectiveness of biochar.   Results Out of 75 test plots, 41 yielded complete data on biomass development, whereas 37 offer complete data on grain yields. 31 data-sets are complete for both biomass and grain yield data. Incomplete data series can be explained by a range of factors: theft of healthy maize cobs is the most common problem, with some groups whose plots were located deep in the forest reporting that all their maize was stolen (because it looked so good, in their own words). Other losses were due to observable bird and pest attacks, and misunderstandings on how to conserve and prepare the maize and the biomass correctly for measurements. Some groups sold or consumed the maize before we could collect data. Despite these losses, we think the series of data presented here are sufficiently large to draw conclusions on the effectiveness of biochar as an agricultural soil amendment in the tropics, and in particular on maize in relatively infertile soils. Biomass yieldThe relative biomass yield (roots, stems, cobs, maize grain) for all test plots shows that all combinations of soil inputs perform better than the control (general data, figure 1). The addition of 10 tons of char per hectare (C10) will increase biomass yields by around 40%, which is as much as the addition of either organic or mineral fertilizers (O = 33%, F = 46%). This shows that for the individual farmer, char may function as efficiently fertilizers, even though biochar is not a fertilizer in itself. The addition of char at a higher rate, equivalent to 20 tonnes per hectare, results in an even bigger increase (C20, an increase of 52%). The combination of organic and mineral fertilizers (OF) greatly increases biomass yield as compared to the control, almost doubling it (a 90% increase). However, when char is added, at either the equivalent of 10 or 20 tons, the effect will be even more outspoken (C10OF = 119%, C20OF = 113%). This demonstrates that char boosts the efficiency with which a soil makes nutrients available to the maize plant. Interestingly, the combination of C10 with mineral fertilizer (C10F = 84% increase in biomass yield) and the combination of C20 with organic (C20O =74%) or mineral fertilizer (C20F = 94%) alone, results in as high an increase in biomass yields as OF. In practise this means that a farmer has to use only one of either mineral or organic fertilizers and combine it with char (C10F, C20O or C20F), in order to obtain the same effect as the combination of both these expensive soil inputs without char (OF). When we look at individual test plots (general data, figure 9), we observe that in a small minority of cases (3 out of 41) the addition of any type of soil input will have a negative effect on biomass yields (Takie , Unity & Progress , and Njinjong). This may be due to the natural fertility of the soil, with additions of inputs distorting this balance. However, with soil analyses currently in progress, it is too early to discuss these exceptions. In about five cases the addition of char yields a slightly negative (< 5% decrease) ((Main dans la Main , Firm Hand Farmers) to a negligible effect (<3% increase or decrease) (Ntukia Women , Rainbow Farmers , Juliette) on biomass productivity. On the other end of the scale: in 12 cases the addition of char alone resulted in an increase in biomass productivity larger than 50%. Seven plots showed more than a doubling in biomass yields. In three cases, already identified as plots with poor oxisols (Oben , Man Must Try , Mekora), the addition of char at a rate of 20 tons per hectare even yielded a 'spectacular' boost in biomass productivity, with an increase bigger than 250%. Grain yield The main goal of both the Biochar Fund and Key Farmers Cameroon is the maximization of food production and the reduction of hunger. However, in a scenario in which carbon storage in soils based on the production of biochar obtained from farm residues is rewarded with a form of carbon compensation (carbon credits or other), it is interesting to assess the value of biomass productivity as it relates to grain yield. We will do this, below, by looking at the residue-to-product ratio. But let us first focus on food - the maize. Data on the relative grain yield for all plots show that, again, the introduction of any type of input yields more grain than plants on the control. Organic (O) and mineral (F) fertilizers increase grain yield by about 60%. The combination of both (OF) roughly doubles output (+94%). When char alone is added to the soil, at either the equivalent of 10 or 20 tonnes per hectare, grain yields are almost doubled (C10 = +85%; C20 = +89%). This means that char alone performs as well as the combination of organic and mineral fertilizers (OF). Biochar being considerably less expensive than these traditional inputs and yielding potential carbon compensations, the individual farmer may easily choose for the introduction of char to manage his soils and crop productivity. When char is combined with organic or mineral fertilizers, grain yields get a boost of between 116% (C20F) to 168% (C20OF). This demonstrates again that biochar helps improve the efficiency of nutrient storage and exchanges in the soil. Interestingly, the difference between the combination of char at a low input rate (C10) with other inputs (C10O, C10F) and char at a higher input rate (C20O, C20F) is small. At the C20 rate, mineral fertilizers even seem to perform less strongly on grain yield (C20F = +116%) than when combined with C10 (C10F = +144%). When all inputs are combined, maize grain yields increase by 145% (C10OF) to 168% (C20F). Increasing grain yield by two and a half times is obviously a very attractive prospect for subsistence farmers. Economics however will determine whether these combinations are cost-effective for them. Looking at individual test plots (general data, figure 10), we can observe great differences in the maize grain yield. In five cases (Yamba Women , Humble Ladies , Etoko Women , Nature is Life , Agbor), the addition of C10 brought about a lower grain yield than the control. In only four cases (Humble Ladies , Etoko Women , Unity and Progress , and Nature is Life) did the introduction of C20 affect grain yield negatively. In two cases (Rainbow Farmers , Ayuk), the addition of biochar (either C10 or C20) had no effect whatsoever. In all the other test fields, char helped improve grain yields. In fifteen cases, the utilization of biochar alone, at a rate of ten tons per hectare (C10), showed an increase of more than 50%. In eight of these, grain yields were more than doubled because of C10. Extreme results on the C10 sub-plots: +211% (Mekora), +240% (Tecla), +300% (Bih), +360% (Bate - to be uploaded) and +400% (Kofapru). With char added at 20MT/ha, we see a (more than) doubling in grain yield in eight cases. Extreme results were obtained at the plots of Antaze Dynamic (+249%), Kofapru (+300%), Mekora (+288%), Bate (+360% - to be uploaded), and Oben (+675%). Figure 6 in the general data page shows the absolute grain yield for all plots in the experiment. Currently, the subsistence farmers who participate in the trial produce less than 1,7 tons of maize per hectare on average. This can be considered to be a low yield. When post-harvest losses are considered, the final yield may be below 1,5 tons (compare this with maize yields in the EU or the US, which are between 7 and 9 MT/ha). With the addition of soil inputs, the picture changes. The farmer will be able to produce one ton more food per hectare, by adding either a combination of non-char inputs (OF) or biochar alone. Grain output can be doubled when organic and mineral fertilizers are combined with char. In conclusion: biochar may help farmers boost the grain yield of maize, particularly when combined with other inputs. In some notoriously poor soils, charcoal will greatly help retain nutrients and keep them available for the crop. In the tropical soils and under the specific agro-ecological conditions encountered in this experiment, biochar functions as effectively in the soil as more traditional inputs such as organic and mineral fertilizers. This means a farmer can grow more food, without introducing chemical fertilizers. A future of improved food security based on organic soil management thus becomes possible. Residue to product ratio Food insecurity and hunger remain extremely serious problems in much of Central Africa. Biochar will help solve this crisis by intervening directly at one of the structural roots of the problem: low agricultural productivity and soil infertility. Data on grain yields show that biochar boosts output: farmers can produce considerably more food, while at the same time introducing a soil improver that doubles as a carbon storage medium for which additional funds are available. With this in mind – the idea that biomass in itself is valuable because it can be transformed into a marketable, stable soil carbon element, but also knowing that food production remains the main goal – we look at the “residue-to-product ratio” (RPR). This ratio answers the question: how much biomass is available after the farmer has harvested the food grains, the production of which was improved? Let us not forget that carbon compensations will help the farmer gain access to better inputs, materials and knowledge, allowing him to overcome hunger and poverty even better. The RPR is calculated simply by substracting the absolute grain yield from the total amount of biomass produced by the plant (i.e., belowground biomass (roots) and non-grain aboveground biomass (stems and cobs)). (See figure 5, 6, 7 and 8 at the general data page). To obtain correct results, all the biomass in the equation needs to have an equal moisture content (approximately 20% wet basis). For practical purposes, the belowground biomass (roots) is substracted too, because under conventional management it is left in the soil. The RPR in this report thus simply indicates the total amount of stem and cob biomass available for the production of biochar or other organic soil inputs. A ratio of 8 to 1 means that for each ton of maize grains produced, some 8 tons of residual biomass will be available. Note that the RPR is a relative measure. A low ratio means that more grain is produced relative to a plot with a higher ratio. However, in absolute terms the grain yield may be lower than the one at that other plot. The data we collected illustrate this well.Interestingly, the RPR of the plots in our experiment shows that biochar helps in the production of maize grains, whereas the control plots (X, O, F, OF) favor the production of biomass at the expense of food (see general data, figure 4). Even though the biochar plots have a lower RPR, they show a higher biomass production than the control plots in absolute terms. This is a beneficial situation for the individual farmer: not only will he produce considerably more food with biochar, he will also produce far more biomass and have it available for the production of more biomass. Finally, the analytical distinction between belowground and aboveground biomass (see general data figure 1, 2, 3 versus figure 5, 6, 7, 8) is also important for the development of biochar implementation routines. If left in the field, root biomass will turn over to form part of the labile soil organic manner pool, decay in a matter of years, and end up as CO_2 in the atmosphere. In contrast, the aboveground biomass (stems and cobs) can be used for the production of biochar, which, when stored in soils, becomes part of the stable soil organic matter pool and constitutes a form of permanent carbon sequestration. Conclusion These first data of the biochar field trials in the villages around Kumba, presented here in summary, show that the soil amendment consistently improves both the biomass and grain production of maize. The increase in grain production is so high that it influences the residue-to-product ratio significantly: the production of grain is favored over the production of biomass, even though in absolute terms both product and residue experience an increase in output. After the harvest and the first analysis of the data, workshops were held in the town of Kumba and in the village of Kendem, during which all the participants in the project received dedicated data-sheets for their plots. The farmers were enthusiastic about the "instant effects" of biochar. However, they understand that instant effects are not the same thing as definitive results. This is why, during the event, they were briefed on how to implement the second phase of the project, which consists of repeating the exercise with August maize. This repetition allows us to study the so-called "residual effects" of the biochar intervention, and will offer a clearer picture of what char really does when a crop is repeatedly planted on the same soil. In the meantime, additional agronomic data and soil samples are being analysed. When they are available, the preliminary data presented here can be interpreted more in-depth.