Regional and cropping systems scale modeling of scenario of climate change adaptation for maintaining soil organic matter stocks in the Caribbean

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REGIONAL AND CROPPING SYSTEM SCALE MODELING OF SCENARIO OF CLIMATE CHANGE ADAPTATION FOR MAINTAINING SOIL ORGANIC CARBON STOCKS IN THE CARIBBEAN

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1 Introduction

Small changes in the SOC pool can significantly affect atmospheric carbon dioxide concentrations, and therefore climate change. SOC pool is strongly affected by farming practices and, in particular, SOC in the tropics is more sensitive to changes in land use and tillage practices than SOC in temperate regions (Ogle et al., 2005). Modelling SOC dynamics is one of the most effective tools to evaluate trends in SOC over time and the impact of changes in cropping practices under a climate change scenario (Muñoz-Rojas et al., 2017). However, the effect of climate change on SOC remains uncertain. Simple models of SOC balance calibrated and tested locally, which require minimal data inputs and few parameters are a good alternative to reduce uncertainties in regions with low data availability like the Caribbean (Sierra et al., 2015; Muñoz-Rojas et al., 2017). In this study, we hypothesize that the current trend of Caribbean agriculture towards the replacement of export crops by local market crops will be detrimental to SOC stocks particularly under a climate change scenario, but that adaptation strategies, including implementation of reduced tillage and the use of organic amendments, can reduce SOC decrease. In order to test this hypothesis, we analyse the evolution of SOC change in cropping systems with a calibrated and validated soil carbon model, Morgwanik, for Guadeloupe, a 1.600 km^2 French archipelago.

2 Materials and Methods

We describe and simplified the diversity of the biophysical content in Guadeloupe by describing five AgroEcological Regions (AERs) as input of the Morganik soil carbon model with information on climate, soils and crops. Average temperature varied over the area ranging from 23.7°C in AER 3 to 26.4°C in AER 5 in 2015 that increase to up to 24.4°C and 27.1 °C in our climate change scenario in 2045. For each AER we provided the proportion of land in each initial SOC content class. For instance AER5 has 67% of soil in class 10-20 mg C kg^{-1} and 33% in 20-40 mg C kg^{-1}. The coefficient of mineralization of the soil carbon was increased over the period in link with temperature. The bulk density was considered stable fixed in time with different values of each AERs. The proportion of each crop was described by using land area statistics. The crop coefficient affecting the soil carbon mineralization was set up for each crop according to tillage intensity with low values for perennial crops and high values for intensively tilled land.

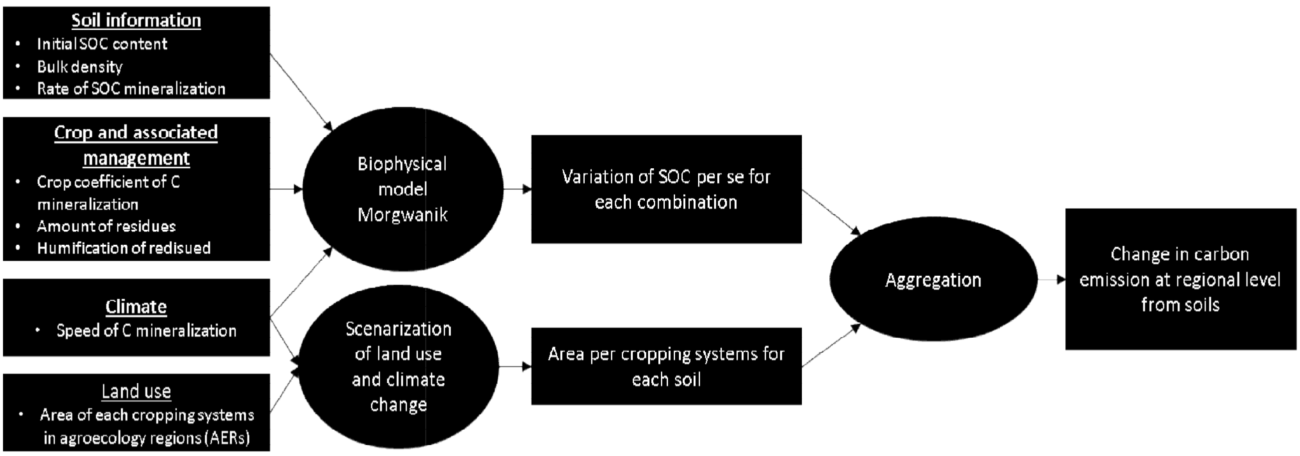
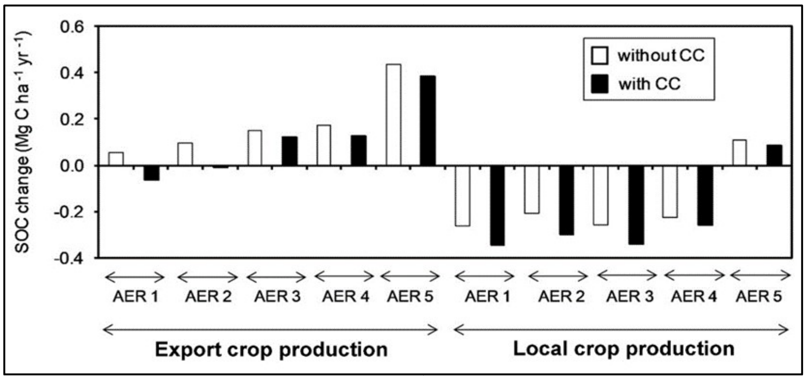


Figure 1: method used with i) biophysical modelling at cropping system level and ii) upscaling at regional level via aggregation accounting for land use change. Inputs and outputs are represented in square boxes and processes in circles.

For each crop, several cropping system were described and their proportion in the crop categories was set based on farmers´ survey. Description of cropping systems included the crop rotations (e.g., 5 years of sugarcane and 5 years of vegetables), the average use of amendment and the average yield of each crop in the AERs. Measurements were made to estimate crop residues, the C content of residues and the coefficient of humification. Yield change in climate change scenarios was estimated using prediction of C4 and C3 yield variation with CC in the Caribbean (Brisson et al., 2011). The Morgwanik model was then used with this data to simulate SOC balance at plot scale as a function of annual C inputs and outputs. Carbon inputs comprise crop residues (aboveground and roots) and organic amendments. Carbon outputs are calculated using two coefficients: the mineralisation rate constant kAER (yr^{-1}), which is specific to each AER and reflects the impact of soil type and climate on SOC dynamics, and kcrop (unitless), which affects kAER and is specific to each crop. Simulations are run for a given cropping system × AER × scenario situation. We then obtain for each cropping system in scenarios a variation of SOC which is then upscaled to regional level considering the area represented by the cropping systems. Scenarios modelled and compared were a current agriculture scenario Vs. a development of local with an increase by 50% in each AER of crops for the local market (vegetables, tubers, orchards) i) with a potential increase in 50% of the area with use of amendment aligned with the availability of amendment locally and ii) a change of tillage in local crops from deep tillage to reduced tillage. Each scenario was tested with and without climate change.

3 Results – Discussion

Figure 2: Variation in SOC change in each AERs with and without CC



Results at cropping system level are shown in Figure 1. It shows that export crop contribute to positive SOC change compared to crops for local markets and that some AERs contribute to C sequestration for both type of production. The impact of CC appear to be significance in some AERs although its overall impact is less important than the variability of SOC change among the AERs.

Then results are upscaled at regional level to see the overall production of CO2 eq from the SOC change in soils (Figure 3). At the regional scale, SOC changes were negative for all combinations of cropping practices, but some of them limited SOC losses (Fig. 3). Reduced tillage was the major factor affecting SOC changes, followed by land use and area receiving organic amendments. On average, SOC losses were 4.3-fold lower for reduced than for conventional tillage.

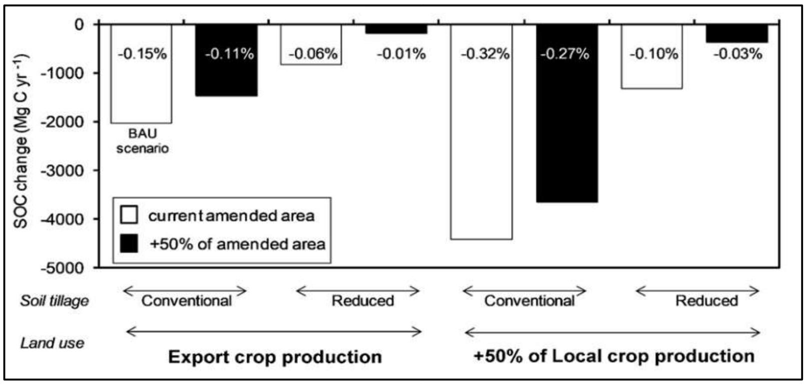


Figure 3: Variation in SOC change in soil at the regional level in each scenarios

SOC losses decreased 1.5-fold when the area receiving organic amendments was increased by 50% and increased 2.2-fold when the area occupied by local market production was increased by 50%. The impact of reduced tillage was higher under the scenario with an increase in local market production (4.8-fold reduction in SOC losses compared with conventional tillage) than for the current land use scenario

4 Conclusions

Fostering the adoption of reduced tillage and, secondarily, the use of organic amendments can significantly decrease the negative impact of climate change on SOC stocks under the scenario of increase of the local market production. The overall effects of land use and cropping practices is more important in determining SOC changes than those linked to climate change and pedoclimatic conditions in the climate change scenario used in this simulation study.

References

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