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PRODUCTION OF ELECTRICITY FROM ENERGY CANE IN SMALL TROPICAL ISLANDS: AN EX ANTE AGRO-ENVIRONMENTAL, ECONOMIC AND INDUSTRIAL ANALYSIS IN GUADELOUPE.

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Abstract
Interest in renewable energy from agricultural biomass has increased in recent years. Among renewable energy sources, biomass is considered indeed as an attractive option for sustainable energy production. This is particularly true in the case of small tropical island states, where energy demand is increasing and the energy mix currently heavily relies on fossil imported resources. Diversifying and orientating the energy mix toward locally grown energy crops could therefore be a promising sustainable option. However, the introduction of such bioenergy systems under existing conditions and current agricultural models is still rather uncertain and requires achieving several sustainable goals. In order to build new sustainable energy systems, assessing the conditions for a sustainable and profitable biomass supply is a critical step prior to industrial investment. In this paper we present the results of an interdisciplinary research program aimed at identifying the agro-environmental, economic and industrial conditions for producing electricity from energy cane in Guadeloupe.

Materials and methods
The study was made of three components: 1) an agronomic component to identify best varieties and crop management systems, 2) an economic and environmental assessment of the agricultural supply chain, 3) an industrial analysis of the power plant scenario.
The main objectives of the agricultural component were to identify: (i) most efficient sugarcane varieties under the conditions of the study for dry biomass production, (ii) sustainable farming practices, including the ability to harvest all the year, (iii) the criteria of quality for biomass transformation: humidity, low heating value (kJ/g) and chlordecone (CLD) content in the plant (Chopart et al., 2013). Seven statistical experimental trials were conducted for two to five years in the south of Guadeloupe in a farmer's field. The objective was to select best varieties, studying their performance compared to a local commercial sugarcane (CSC) variety. Several agricultural practices were also tested. We measured fresh and dry biomass of leaves and stems, as well as their calorific content.
The goals of the economic analysis was to calculate the profitability of energy cane growing and harvesting, to assess the willingness of farmers to adopt this new crop through a survey on 520 farmers, and to model the agricultural production at the scale of the island under different scenario of plant localization and market price (Chopin et al., 2015). The environmental analysis consists in the definition of sustainable ways for maintaining soil carbon content as a function of biomass removal and compost amendment (Sierra et al., 2016) 2) a life cycle assessment of electricity production.
The objective of the industrial analysis was to clearly determine the technical, economic, regulatory and social conditions that allow the realization of biomass cogeneration plants in Guadeloupe in a few years. The locks were identified and opportunities to unlock analyzed. The analysis was made of three steps: 1) chemical and physical characterization of energy cane, technical study of conversion process into heat and electricity, selection and sizing of equipment (drying and storing the biomass, possibilities of recovery of low pressure heat for cold production, operating scenarios of the power plant), 2) an economic study to define the conditions of feasibility of an industrial project and its economic impacts in the island.

Main results
Two varieties (WI81456, WI79460) imported from WICSBS (Barbados) proved to be very efficient and well-adapted. The dry entire aboveground biomass (DEAB) was 81 T/ha/year in experimental plots (Chopart and Bachelier 2012; Chopart, 2016) and the low heating value of this DEAB was 16.45 kJ/g (Chopart et al., 2013), meaning that the two best varieties produced a high energy yield: 133 MJ/m² after a 12-month cropping cycle. Dry/wet biomass ratio was 0.37 in the EA. These high-energy cane varieties were cropped using the same conventional practices as local commercial sugarcane (CSC), but yields were higher: + 33% for stalks and + 71% for dry DEAB. Mechanical harvesting was possible almost throughout the year. Cumulated DEAB after three 8-month cropping cycles or two conventional 12-month cropping cycles were close (Chopart et al. 2015). In CLD-polluted soils, CLD remains in the roots and migrates only slightly in the first centimeters of stalks.

A survey of a sample of more than 500 farms showed that the interest of farmers for growing energy cane is strong. Farmers in fact consider this opportunity as a way of securing and diversifying their income. Several conditions have to be met for this crop to be adopted by farmers: 1) a sufficient level of profitability (between 2500 and 3500 €/ha/year), 2) a support for production, particularly as regards the logistics to ensure harvest, and financial support through the pre-financing of crop costs. With aa area of between 1200 and 1800 ha, the biomass required to supply a 12MWe plant can be produced for a purchase price of energy cane to be around 55 €/ton. In environmental terms, with the emission of 0.25 kg of CO2 eq./kWh for the electricity produced from biomass against 0.76 and 1.07 kg CO2 eq./kWh for fuel and coal, the impact on climate change are reduced by more than 70%. However, in order not to degrade the soil organic matter, it is recommended to condition the crop to regular and systematic amendment of compost for a sustainable management of biomass and organic matter in the fields (Sierra et al., 2016).

The industrial analysis allow to design a 12 MWe power plant scenario, corresponding to 40 MWth with a biomass feedstock made of 70% of energy cane and 30% of imported wood pellets. Fresh biomass will be chipped and dried before storing (in order to adapt the fuel mix to supply variation and ensure the power plant's functioning). The boiler yield could be of 89% and produced ashes could serve as agricultural amendments. The economic balance of the power plant also depends on electricity sale price, which will be negotiated with energy leadership (Energy Regulatory Commission) on the basis of a 25 years guaranteed purchase contract.

Conclusion

Varieties WI81456, WI79460 could be considered as good feedstock for a biomass electric power plant. They can be cropped like CSC, but they need to be dried before being used as fuel. Growers are informed of the potential yield of tested varieties (although they were obtained in small plots), and purchasers are able to assess the quality of this feedstock. It is possible to maintain soil organic matter in energy cane cropping systems with compost amendment every 5 years. From an economic point of view, our study shows that it is feasible to develop a sustainable biomass energy industry in Guadeloupe. The plant activity of a 12 MWe industry could contribute to local employment and satisfy 5% of the electricity demand in Guadeloupe (85 GWh per year) with 5% of the agricultural area of the island. Strong choices must however be made to ensure the success of this bio-economic activity. These choices relate to the crop management systems, the conditions of remuneration and support for farmers, and the design and location of the power plant.

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