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Carbon Sequestration in Sugarcane Plantation in the Niari Valley in Congo

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ABSTRACT

This study targeted for evaluating the carbon sequestration in the industrial plantations of sugarcane in the Niari valley (4-4°15'S and 12-13°E). The industrial plantations of sugarcane occupy an area of about 16,000 hectares. The sequestration evaluation of the carbon by the sugarcanes plantations in the Niari valley has been carried out on the basis of different varieties of the sugarcane from the measures of the biomass. The results show that the carbon sequestration in the sugar cane plantations of the Niari valley amounts to 50 tons per hectare. This carbon sequestration presents important values ranging from 60 to 80 tons per hectare ($p<0.05$) during the first two years of the new sprout (R 570 and Co 997) and a more or less stationary level up to the tenth new sprout of sugar cane for the variety NCO 376. These results depend on the environment conditions, the burning of sugarcane fields before harvesting to facilitate the processing of sugarcanes and also the flexibility in terms of adaptability of the sugarcane varieties cultivated. The sugarcane plantations contribute a great deal in the struggle against climate changes and their use in terms of bio fuel.

Key words: Carbon sequestration, sugar cane varieties, bio fuel, biomass burning

INTRODUCTION

Granier *et al.* (2000) show that the industrial plantations with applied agriculture practices and their homogeneous character represent an appropriate model for the studies of the carbon sequestration in the evaluation and shaft attestation or forestry ecosystems function. The evaluation temporal method envisaged in the context of a re-forestation of a massif should enable a low cost certification.

Sugar cane burning emissions have an impact on the respiratory system of children and the elderly (Jose *et al.*, 2004). According to these authors, the impact of biomass and fossil fuel burning is felt throughout the world; studies have documented the impact of fossil fuel air pollution on health (Braga *et al.*, 2001; Hoek and Brunekreef, 1994; Hoek *et al.*, 1997; Laden *et al.*, 2000; Lin *et al.*, 1999; Pope *et al.*, 1995; Saldiva *et al.*, 1994; Schwartz and Dockery, 1992; Schwartz *et al.*, 2001; Cancado *et al.*, 2006; Arbex *et al.*, 2007). Sugar cane fires also have significant effects on the composition and acidity of rainwater over large areas of South eastern Brazil because of the emissions of aerosol and trace gases (Oppenheimer *et al.*, 2004;

Lara *et al*., 2001). Works exist about aerosol particles emitted from sugar cane burning (Lara *et al*., 2005). The production of sugar cane in Brazil lead to emissions of greenhouse gases (Ana *et al*., 2004). A very conspicuous source of air pollution in many tropical regions is the burning of sugarcane (Nayamuth and Cheeroo-Nayamuth, 2005). The agricultural waste source appears to be one of the major contributions to atmospheric emissions from biomass burning.

According to Oliveira *et al*. (2005) and Jacobson (2004) the major contributor to global warming is considered to be the high levels of greenhouse gas emissions, especially carbon dioxide (CO_2) caused by the burning of fossil fuel. Thus, to mitigate CO_2 emissions, renewable energy sources such as ethanol have been seen as a promising alternative to fossil fuel consumption. Brazil was the world's first nation to run a large-scale program for using ethanol as fuel. Eventually, the United States also developed large-scale production of ethanol.

Now it is established that the sugarcane plantations soil sequestration exist; this sequestration is better than forests soil one (Rhoades *et al*., 2000; Marris, 2006; Goldemberg *et al*., 2008; Solomon, 2010).

In Congo, the evaluation of carbon sequestration concerns a chrono-sequence of eucalyptus populations. It focuses on a primary annual production amounting to 20 tons of carbon per hectare and a clear assessment of carbon averaging 3.7 tons (Saint-Andre *et al*., 2005).

The works of Saint-Andre *et al*. (2005) done on industrial plantation of eucalyptus within coastal areas in Congo; allowing to reach other vegetal formations such as annual cultures, heterogeneous and savannah's. The vegetal formations represent the carbon sequestration forms whose management methods also can influence the atmospheric level. These forms of carbon sequestration have not been evaluated yet and should reinforce achievements of the climate change project in Congo.

Currently, the industrial plantations of sugarcane which have a high economic value for the country are the object of high preoccupation in the context of sustainable development. However, these industrial plantations are subjected to a climate variability which acts on their productivity (Samba-Kimbata, 2002; Diamouangana, 2003). Climate variability is characterized by a rains irregularity, a reduced sunstroke and a very pronounced hydric deficit during the dry periods.

This study seeks to evaluate the carbon sequestration by the industrial plantations of sugarcane in the Niari valley.

MATERIALS AND METHODS

The vegetal material is constituted of sugarcane varieties which cover an area of 16,000 hectares. These sugarcane varieties are located in the Niari valley (4-4°15'S and 12-13°E). They possess a high production potentiality.

The sugarcane plantations heights of the Niari valley are between 160 and 187 m (Acquarium 169 m, Dakar 181 m, Bouala 162 m, Moutela 161-187 m). Sugarcane varieties are used in Saris (Congo) for more than twenty years (Table 1).

Table 1: Divers informations on the sugarcanes varieties

Varieties	Establishment of creation	Date of introduction	Number of acres
B 46364	Barbade	1953	2279
R 570	Reunion	1984	946
NCo 376	Natal coimbatore South Africa	1959	2693
Co 997	Coimbatore (India)	1984	1758
SP 70	Sao paolo Brazil	1981	631

The soils of the Niari valley in which industrial plantations of sugarcane are cultivated, essentially ferrallitic, highly non saturated, hydromorphous and less developed.

This study is based on data obtained from the sugarcane growing according to different agriculture campaigns (1999-2007) of SARIS (Agricultural and Industrial Sugar Refinery Society).

The agriculture campaigns of SARIS generally take place during the dry and cold seasons (between May and October). Most of data are climatic and agronomic following the agriculture campaigns. These are: rains, air temperatures, exhibitions exposures in the sun, the relative humidity, the planted and harvested areas, dendrometric measure, brix and efficiency of sugar cane.

The sampling of the sugarcane analysis maturity is made by the agronomic service of SARIS. On 100 lines of sugarcane, it carries out samplings over the 25th, 50th and 75th line.

Estimations of carbon sequestration by the sugarcane plantations in the Niari valley have been carried out on the basis of the dendrometric measures (biomass) varieties sugarcane (Nayamuth and Cheero-nayamuth, 2005).

The GENSTAT DISCOVERY 3rd edition software has enabled us to make calculations on the different selected variables. These operations concern the estimation of sequestrated carbon quantity per sugarcane from their biomass, the determination of the averages and their application to Bonferroni ($p<0.05$) test.

The comparison of averages has been done with the light of sugarcane varieties in spatial and temporal scales. It tackles the question of carbon sequestration in sugarcane plantations of Niari vally.

RESULTS

In Fig. 1 and 2, it may be noted that the average of carbon sequestration per sugarcane plantations reaches 50 tons per acre. Maximum values are mostly observed at Dakar (Dak). These maximum values depend on the stations but also on the year (60 t ha^{-1}) for Dakar (Dak) and Yokangassi (Yok) in 1999/2000 and 2004, respectively.

On Niari valley, the carbon sequestration depends on the varieties and also on the sugarcane plantations (Fig 3). It points out a dominance of the variety Co 997 compared to variety NCo 376. The maximum values of about 50 t ha^{-1} were observed in 1999, 2000 and 2002; the weakest of about 30 t ha^{-1} were observed in 2007 ($p<0.05$).

The carbon sequestration per varieties NCo 376 and Co 997 in the plantations of Niari valley is represented in the Fig. 4. Maximum values amounting to 70 tones per acre are observed during the first two years of fresh growth (R1 and R2).

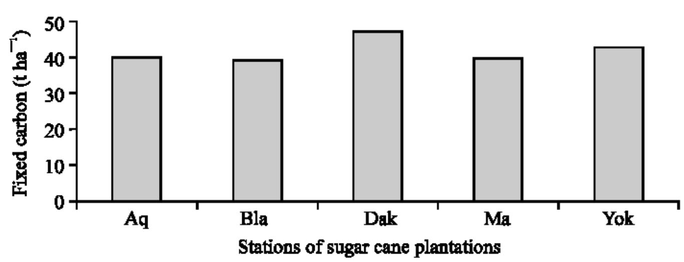

Fig. 1: Sequestration of carbon in the sugar cane plantations of 'Acquarium (Aq), Bouala (B), Dakar (Dak), Moutela (M) and Yokangassi (Yok) in the Niari Valley

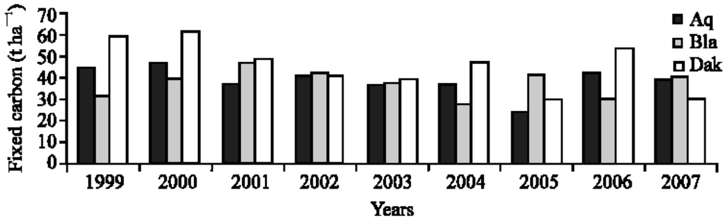

Fig. 2: Sequestration of annual carbon in the sugar cane plantations of Dakar (Dak), Moutela (Ma) and Yokangassi (Yok)

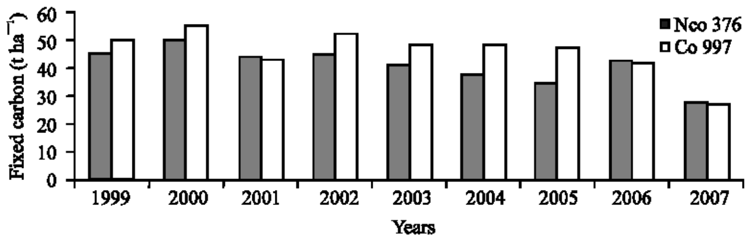

Fig. 3: Sequestration of carbon for NCo 376 and Co 997 sugar cane varieties in the Niari Valley

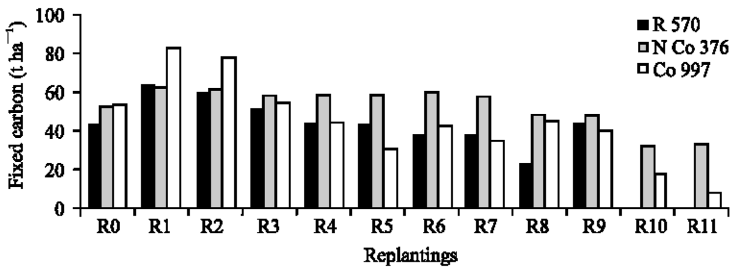

Fig. 4: Sequestration of carbon for R570, NCo 376 and Co 997 of the Niari Valley following replanting

The variety Co 997 dominates the other two ones: NCo 376 and R 570. The minimum values amount to 10 tons per acre concerning the variety Co 997 (R 10 and R 11) and amount to 20 tons per acre concerning the variety R 570 (R8).

Fresh growths: Figure 4 shows the Carbon sequestration by the fresh growth of the sugarcane plantations in the valley Niari for the varieties R 570, NCo 376 and Co 997. This figure relates to carbon sequestration according to the fresh growth of sugarcane varieties and also highlights a decline of about 30 tones per acre for Co 997 from (R3 to R7) and for R570 (R3 to R8).

The capacity of carbon sequestration of varieties Co 997 and R 57 by fresh growth decreases more rapidly than that of NCo 376.

The fresh growth of the variety NCo 376 presents a very stationary sequestration of the carbon up to 9th fresh growth. This capacity amounts from 50 to 60 tons per acre (R1 to R9) and to 30 tons per acre (R10 to R11).

DISCUSSION

The sugarcane industrial plantations of the Niari valley present a capacity of carbon sequestration amounting to about 50 tons per hectare. This value depends on the sites of SARIS, of the sugarcane varieties and also the climate. These results are not similar to those found by Nayamuth and Cheeroo-Nayamuth (2005) which amount to 7 tons per hectare in Mauritania.

Saint-Andre *et al.* (2005) affirm that the primary annual production of the coastal eucalyptus plantations approximates 20 tons of carbon per hectare and the net assessment of carbon is limited to 3.7 tons. The results of Saint-Andre *et al.* (2005) and our results agree with those of Goldemberg *et al.* (2008) and Rhoades *et al.* (2000). These authors showed that the sugarcane plantations soil sequestration is better than forest one.

These carbon sequestration differences of several varieties of sugarcane could probably derive from the agriculture practices used in these industrial plantations, from rain variability to which the Niari valley is submitted from the environment conditions (Moundzeo *et al.*, 2005) and from genetic values of the different varieties (Badaloo *et al.*, 2005). They can equally come from the photosynthetic capacity of the sugar cane which is a C_4 plant, capable to make cost-effective on best received energy.

The results of Badaloo *et al.* (2005) particularly those obtained through fresh growth (R1, R2 and R3) as opposed to others, can also be explained because of their extraction capacity and roots exploration of the sugarcane varieties. These authors demonstrate that sugarcane roots are extremely developed and explore soil very efficiently. They can settle down in the soil to 6 m depth and spread in an area of 2 to 5 m around the stump in favourable conditions.

The cited works above also recognize that more than 50% of the roots appear in the first centimetres and 90% at less than 60 cm.

In spite of these characteristics which make sugarcane a fixative plant capable to enrich soil with organic materials by a double restitution of air and underneath vegetal industrial waste, the industrial refinery of the sugar and the agriculture practices with burning sugarcane plantations before each harvest, reinforce with certain gases such as the CO_2, the increase of the greenhouse effect in the atmosphere.

The traditional method to burn the sugarcane certainly facilitates sugarcane cutters work, but favours the erosion risks of the soil. On other hand, sugar cane fires have significant effects on the composition and acidity of rainwater, on air pollution, on health, on climate change because of greenhouse emissions (Allen *et al.*, 2004; Bohm *et al.*, 2000; Laden *et al.*, 2000; Braga *et al.*, 2001; Schwartz *et al.*, 2001; Jose *et al.*, 2004). The studies carried out by Oliveira *et al.* (2005) show a production of residual biomass between 7 and 20 tons of dry matter per hectare.

It can be recognized that sugarcane plantation are of paramount importance in the struggle against climate change during the growth phase. The traditional method to burn the sugarcane is not good because of soil erosion risk, its implication for health, atmospheric pollution, climate change. On the other hand, the combustion of leaves leads to the emission of the CO_2 in the atmosphere instead of to sequester additional carbon of these leaves in the soil.

Sugarcane has good capacities of fixing the CO_2 for its functioning. Also, sugarcane is presently ranked among the most adapted plants in Sub-Saharan Africa because of their ethanol production in view of replacing petrol. Ethanol is a liquid alcohol resulting from sugar fermentation or from the conversion of starch into sugar. The production of this bio-fuel from sugarcane is technically possible.

In this respect, Castellan (2004) comparing the CO_2 related to the use of petrol and ethanol, shows that the difference is about 7.1 in favour of ethanol. In reality 1000 L of ethanol are capable to produce 2.7 kg of CO_2 whereas 1000 L of fuel can produce 19.2 kg. This bio-fuel is more interesting taking into account the setting of or the implementation of the Kyoto Agreement.

CONCLUSION

It is conculded from these results that the carbon sequestration in the sugarcane plantations, average of sequestration is 50 tons per hectare and the maximum values are more observed in Dakar (Dak), entirely planted in NCO 376. These maximum values depend on different stations but also on the year (60 ha^{-1} for Dakar (Dak) and Yokangassi (Yok), respectively in 1999, 2000 and 2004. On the annual scale, carbon sequestration in sugarcane plantations of the Niari valley show a preponderance of the variety 00 997 as opposed to the variety NCo 376 .The maximum values average 50 tons per hectare and have been observed in 1999, 2000 and 2002 against the weakest averaging 30 tons ha^{-1} in 2007.

This carbon sequestration in plantations of Niari valley presents maximum values averaging 70 tons ha^{-1} during the first two years of fresh growth (R1 and R2). The Co 997 variety dominates the other two sugarcane varieties (NCo 376 and R 570) and the minimum values average respectively 10 tons per hectare for the Co 997 variety (R10 and R11) and about 20 tons ha^{-1} for the R570 (R8) variety.

With regard to the carbon sequestration by the fresh growths of the varieties of sugarcane, a drop is observed. The average of this drop is 30 tons ha^{-1} for the varieties Co 997 (from R3 to R7) and R570 (R3 to R8).

This capacity of carbon sequestration by the fresh growth varieties Co 997 and R 570 decreases more rapidly than the fresh growth of the variety NCo 376.

The fresh growth of the variety NCo 376 presents a capacity of carbon sequestration very stationary up to the 9th fresh growth before the decrease. The averages vary from 50 to 60 tons ha^{-1} (R1 to R9), the most low value is 30 tons ha^{-1} (R10 to R 11).

It can be recognized that sugar cane plantations during the growing phase are of a paramount importance in the struggle against climate changes because of their capacity of carbon sequestration. Their use of making bio-fuel is very important regarding the implementation or the applicability of the Kyoto Agreement.

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