Biomass bank with *Pennisetum purpureum* cv. CT-115. Its effects on the carbon storage in the soil

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In order to determine the effect of the technology used in the biomass bank with *Pennisetum purpureum* cv. CT-115 in the carbon storage in the soil, two dairy units of 60 ha each were studied for three years. These facilities are located in the Institute of Animal Science, Cuba. The carbon stored in the soil (CSS, t C ha^{-1}) was calculated using the percent of C in the soil (% CS), the apparent density (AD) and depth of the sampling (D). The evaluation was made in 30 % of the total area of each dairy unit, which is the surface occupying the biomass bank. The CSS oscillated between 38 and 60 t ha^{-1} in the depth from 0 to 30 cm. There was a significant raise in the CSS due to the increase of the exploitation time of each biomass bank, which was 9 and 5 years for A and B dairies, respectively. The dairy unit A had higher values: 60.55 t ha^{-1} from 0 a 15 cm and 28.8 t ha^{-1} from 15 to 30 cm. It can be concluded that the technology of the biomass bank with CT-115 in ferralitic and brown soils, properly used, can be a way to increase the carbon storage in the soil, at the same time that the exploitation time increases. Along with the use of this technology, the CSS values are higher than the ones informed as average for tropical grass. Further studies in order to determine the total amount of carbon stored in the system using this technology are recommended.

Key words: *carbon storage, soil, biomass bank, CT-115.*

In its land cycle, the organic carbon represents the highest reserve interacting with the atmosphere. It is estimated in 1 500 Pg[1] C within 1 m of depth (around 2 456 Pg[1] C within 2 m of depth). The inorganic carbon represents, approximately, 1700 Pg, but it is collected in more stable forms like calcium carbonate. Vegetation (650 Pg) and atmosphere (750 Pg) store lower amounts than soil (Anon 2011).

Organic carbon of the soil is contained in the organic matter. Vegetation, plant remains, plant composition, weather factors (temperature and humidity) and soil properties (texture, content, type of clay, acidity and others) are the main factor interacting with the organic matter. There are some other factors influencing on the content of the organic matter which are the use of land, crop systems, and management of soil and crops (Lal 2004). In a kind of soil that is constantly exposed to practices, it can reach a balance or stability of the organic matter after 30 or 50 years (McVay and Rice 2002). The technology used in the biomass bank with *Pennisetum purpureum* cv. CT-115 or grass Cuba CT-115 is based on the use of this variety of *Pennisetum purpureum*, created in the Institute of Animal Science through the *in vitro* tissue culture. The most outstanding feature of this kind of grass is the shortening of internodes in the highest part of the stem, which gives it less height than its progenitor. Besides, it has a higher content of soluble carbohydrates and a better proportion leaves/stems. Therefore, technology recommends its grazing, which has to occupy 30 % of the area from the productive system. A proper paddocking should be also considered to guarantee its proper management.

[1]Pg = 10 15 g = Gt =109 square t

This technology is very used and spread because it is a viable alternative to store food for the dry season. According to Martínez (2006), the CT-115, under grazing conditions, has yields between 12 and 25 t DM/ha/year, mainly according to the grassland age, management, climate and soil. Studies carried out by Lok *et al*. (2009) showed the tendency of these systems to achieve a positive balance in the recycling of the nutrients. However, no results to prove the potential of this technology for fixing carbon to the soil area occupied with this grass have been informed. Therefore, the objective of this study was to determine the carbon storage in the soil in the areas occupied by the biomass bank with CT-115 in two systems, with more than five years of constant exploitation.

Materials and Methods

The study was carried out during 2005, 2006 and 2007 in two dairy units, located in areas of the Institute of Animal Science, placed in San José de las Lajas municipality, Mayabeque province, at 22º 53 NL and 82º 02 WL, at 80 m a.s.l. (Anon 1989).

Dairy unit A is pioneer introducing this technology. It has a biomass bank established since 1999, with 9 years of continuous exploitation, according to the time it was evaluated. This dairy unit has 60 ha, organized into 100 paddocks for its exploitation. The area corresponding to the biomass bank with grass Cuba CT-115 represents around 30% of its surface and it is located on a brown soil with carbonates (Hernández *et al*. 1999). The remaining 70 % contains *Cynodon nlemfuensis* as basis pasture. The area contains 80 % of brown soil with carbonate and 20 % of reddish brown ferralitic soil. Its relief is lightly waved. The herd is composed of Siboney and Crossbred Siboney cows. The global stocking rate is of

2.46 LAU ha^{-1}.

The dairy unit B has 52 ha, organized in 50 paddocks for its exploitation, and also has the area for the biomass bank with Cuba CT-115 pasture, established since 2003 with five years of continuous exploitation, according to the last assessment year. This biomass bank is located on a hydrated red ferralitic soil, which is the predominant soil in this productive area (30 ha). In the evaluation moment, it corresponded to the 26 % of the dairy unit area. The new paddocks were sown to reach the 30 % established by this technology. The rest of the area had *Panicum maximun*, *Cynodon nlemfuensis* and natural grasslands as basis pastures. With a flat relief, three small lakes covering an area of two hectares are located. The herd was composed of Holstein, Commercial Holstein, Siboney, Crossbred Siboney, 5/8 H-3/8 C. Its average stocking rate corresponded to 1.8 LAU ha^{-1}.

The assessment to determine the CSS was performed only in the biomass bank area. The animal management in this area, occupying around 30 % of the total area in both dairy units, was stable during the evaluated years, according to the demands of the technology of biomass bank with CT-115. Besides, no crop activities like fertilization, irrigation, renewal or rehabilitation, pest control and crop rotation were conducted during this period. Supplementary feed were supplied to cover the animals' requirements, according to the feeding balance.

For the edaphic study, a reference profile soil of 1.30 m width x 2.0 m length x 1.0 m depth was opened in the biomass bank area. Three composed samples were obtained for the depths from 0 to 15 and from 15 to 30 cm, respectively. Besides, with the use of a helicoidal drill, three random composed samples were extracted for each hectare occupied with CT-115 and for each evaluated depth (0 to 15 cm and 15 to 30 cm). The samplings were conducted in June of each year, once the rainfall was stable.

In order to estimate the amount of carbon in the soil (CS), the organic matter was determined by the method of Walkley and Black (1934). Later, the OM percent resulting from this method was divided into 1.7 (McVay and Rice 2002 and Miranda *et al*. 2007). A cutting-based cylinder, with 106.76 cm^3 of volume (8.5 cm length and 4 cm diameter) was used for the apparent density (AD), according to the method of Martín and Cabrera (1987).

The CSS (t C ha^{-1}) was estimated from the C percentage in the soil (% CS), the AD and its sampling depth (D). It was determined, according to Amézquita *et al*. (2004):

CSS= % CS x AD x D

The CSS in 30 cm depth was obtained through the sum of each analyzed depth. The statistical software InfoStat (2001) was used to carry out the analysis of variance. A linear model was used in all cases to determine the CSS behavior in time.

Results and Discussion

The technology of biomass bank with CT-115 is widely applied in Cuba and Central America, for being a viable alternative to solve the defficit of food during the dry season. This technology states that this pasture occupies 30 % of the area, and the remaining area should be occupied by improved pastures and legumes and trees. The Cuba CT-115, as species of the Pennisetum genre, has a growth curve of higher duration than other tropical grasses (Martínez 2006) and kept its quality using CP values of more than 7 % in the leaves until 112 d (Valenciaga, 2006). At the same time, as C_4 plant, produces high annual yields, only surpassed by the Sacharum genre. According to Martínez (2006), it can reach values higher than 34 t DM ha^{-1}year^{-1} with fertilization.

The study carried out in the dairy units A and B (table 1) showed that, for both depths, (0 to 15 and from 15 to 30 cm), the CSS increased in consecutive exploitation years. Consequently, the same happened for the evaluated total (0 to 30 cm). Although the assessed systems were not compared, the dairy unit A, with nine years of constant exploitation on a brown soil, obtained higher CSS values compared to the dairy unit B, with only five years of exploitation and located on a ferralitic soil. The factors exploitation time and type of soil could be determinant for this behavior. During the course of time, the favorable behavior of one indicator of the system points to a proper management. In this case, it evidenced that respecting the basic principles of this technology like stocking rate, time of staying and of occupation and paddocking for the rational rotation, improved the carbon capture in the soil of the areas occupied by Cuba CT-115 of both dairy units. Likewise, the type of soil is determinant because every type of soil has the characteristic of having determined contents of OM, where mainly carbon is accumulated (Céspedes *et al*. 2011), although these values may be improved according to its plant cover and system management. Moreno and Lara (2003) stated that the type of soil, the record of the land use and the management of the evaluated area are among the main factors that determine the carbon capture.

The values reached in both systems during the three years of evaluation were between 38 and 60 t C ha^{-1}, superior to the ones informed as the average number for tropical region (FAO 2008), that ranges between 35 and 40 t C ha^{-1}, from 0 to 30 cm depth. This behavior should be related to the features of the technology of the biomass bank with CT-115 because carbon in the soil is stored as part of the OM (Post and Kwon 2000). The OM contents and its dynamics depend, among other factors, on the vegetation, its peculiarities and management.

In Nicaragua, Ibrahim *et al*. (2007) compared the behavior of the stored carbón in different uses of the land like degraded pasture, pastures of different density

Table 1. Carbon stored in the soil of the assessed systems

System	Depth (cm)	Carbon stored in the soil (t ha^{-1})			SE ± and Sign
		2005	2006	2007	
Dairy unit A	0 to 15	22.19[a]	25.92[b]	31.75[c]	0.05***
	15 to 30	21.15[a]	22.31[a]	28.8b	0.14*
	Total assessed (0 to 30 cm)	43.34[a]	48.23[b]	60.55[c]	0.02**
Dairy unit B	0 to 15	21.89[a]	24.42[b]	26.55[c]	0.08***
	15 to 30	16.57[a]	23.12[b]	24.20[b]	0.10**
	Total assessed (0 to 30 cm)	38.46[a]	47.54[b]	50.75[c]	0.11***

[abc]Values with different letters in a row differ at $P < 0.05$ (Duncan 1955)
*P < 0.05 **P < 0.01 *** P < 0.001

levels in trees, secondary vegetation, and secondary woods and biomass banks with Penisetum purpureum for forage, with four exploitation years. The quoted authors confirmed that this last use of the land was among the systems with higher amount of total carbon (biomass and soil), with 130.6 t C ha^{-1}. Out of these, 124.6 t ha^{-1} corresponded to the CSS in 1 m depth, only exceeded by the values obtained from the secondary wood. The 75 % of the organic C of the soil is located between 20 and 80 cm depth (Fisher and Trujillo 2000 and Amézquita *et al*. 2004), estimating that from 0 to 30 cm there was at about 40 t C ha^{-1}.

In this study, the CSS values obtained with CT-115 surpassed those informed by Ibrahim *et al*. (2007) for this genre from 0 to 30 cm depth, except the value referred in the dairy unit B in 2004. This system, at that moment, had the lowest exploitation time, which could be one of the causes of this low value, increasing later with the exploitation time.

Another element that could influence on the CSS value in the studied systems was that the biomass bank was used for grazing, main element of this technology. This includes the animal in the area and the possible contribution to the nutrients recycling and the OM in the system because of the depositions and accumulation of leaf litter between consecutive grazing. Crespo (2003) assure that the presence of cattle in the grasslands favors the nutrients recycling due to its re-incorporation through the feces and urine, which stimulates different decomposing feces organisms and activates the edaphic biota in general. It is responsible for the OM decomposition and, thus, for making the nutrients cycle viable.

Although it belongs to the Pennisetum genre, Cuba CT-115 pasture differs from its progenitor *Pennisetum purpureum* (king grass), not only fenotypically, but also because of its productive behavior and management. Its use for grazing makes it different when used as cutting forage. Besides, grazing conditions the presence of the animals in the area and makes them depposite and urinate. This may contribute to the nutrients recycling in the soil and to the OM contents as the main source of edaphic carbon.

Ibrahim *et al*. (2007) indicated that the CSS of the biomass bank with *P. purpureum* was only surpassed by the secondary wood. This shows the importance that the use of this species in the cattle systems may have as an alternative to improve the carbon capture.

The values informed in this study are higher than the ones found by Arias *et al*. (2001), who state that the amount of carbon stored in the tropical grasslands in the soil and herbaceous vegetation is estimated to be between 16 and 48 t/ha. These authors assure that, when comparing meadows with grasslands, on the basis of "improved" grasses, these lasts capture more carbon in deep parts of the soil profile, mainly under the plowable layer (10-15 cm, generally). This feature makes the carbon to be less exposed to the oxidation processes and, therefore, is lost as greenhouse gas.

These criteria of Arias *et al*. (2001) coincide with that previously referred by Fisher and Trujillo (2000), who stated that the accumulation of organic carbon in the soil in tropical grasslands are estimated to be around 48 t /ha. However, studies of McVay and Rice (2002) and Giraldo *et al*. (2006) refer higher values.

Besides the quoted factors, the in and out of OM in the system also influence on the CSS. Likewise, the physical and biological conditions of the soil may determine the change rates of organic carbon. By the time vegetation and management practices change, as when eliminating woods to establish grasslands, using fertilizers or removing the plant cover, the amount of carbon in the soil may increase or decrease depending on specific circumstances (Post and Kwon 2000).

If considering the results of this study and that the soils used for cattle exploitation has agroproductive limitations, which are mostly damaged and even degraded, it could infer that this technology may improve not only the carbon capture in the soil but also its fertility. The CSS raise due to the application of this technology, when properly used, should restore the dynamics balance needed for the edaphic component (Espinoza 2000).

It is concluded that when used correctly, the biomass bank with CT-115 in ferralitic and brown soils can be a way to increase the carbon storage in the soil, at the same time that the exploitation time increases. This technology achieves higher values of carbon storage in the soil than the average values informed for other tropical pastures. Further studies in order to determine the total amount of carbon stored in the system using this technology are recommended.

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