The use covers crop and no tillage as management that increases the potential sequestration carbon in the Venezuelan central plain soils.

Hernández-Hernández, R.M.[1]; Lozano, Z.[2]; Bravo, C.[1]; Moreno, B.[3]; Piñango, L.[3]

[1]IDECYT, Universidad Simon Rodriguez, Miranda, Venezuela, Fax: 00582124517226, e-mail: rhernandez@reacciun.ve [2]Facultad de Agronomía, Universidad Central de Venezuela, Maracay, Venezuela, Fax: 00582435507169, e-mail: lozanoz@agr.ucv.ve [3]INIA, Guarico, Venezuela, Fax: 02353415322 e-mail: lep@cantv.net

Abstract

A study about changes in carbon content and mineralization carbon was conducted in two savanna soils (sandy and clayey) of the Venezuelan Central Plains. For three years, these soils have been managed with perennial cover crops: *Brachiaria dyctioneura, Brachiaria decumben* (pastures) *and Centrosema macrocarpum* (leguminous) together with maize . The objective was to improve the quality of soil and the forage offer for sheep. The use of these crop covers in the sandy soil produced a fast increase of the total carbon content (0 - 30 cm), especially with the *Centrosema macrocarpum* and control (natural vegetation) treatments. The latter has a high proportion of leguminous. The soil under *Centrosema* also showed a lesser CO_2 emission to the atmosphere. For this reason, the *Centrosema* is a potentially useful cover crop in the savanna ecosystem in terms of productivity and environment protection.

Key word: Carbon, savanna, Brachiarias, CO_2, soil, Centrosema., Venezuela

Résumé

On a analysé les changements dans le contenu et la minéralisation du carbone dans deux sols de savane (sableux et argileux) des Llanos centraux du Vénézuéla. Ces sols sont utilisés depuis trois ans avec de couvertures permanentes de *Brachiaria dyctioneura* et *Brachiaria decumbens* (deux gramineés) et de *Centrosema macrocarpum* (une légumineuse) en association avec de maïs, pour améliorer la qualité du sol et la disponibilité de fourrage pour le bétail. L`utilisation de ces couvertures a produit une rapide augmentation du contenu en carbone total dans le sol sableux (0-30 cm), surtout dans les traitements avec *Centrosema macrocarpum* et dans celui de la végétation native de contrôle, qui contient une proportion importante de légumineuses. De même, le sol avec couverture de Centrosema a émis moins de CO_2 dans l'atmosphère, de sorte que cette couverture constitue une amélioration potentielle pour les systèmes de savane du point de vue de la production et de l`environnment.

Mots clés: Carbone, savane, Brachiarias, CO_2, sols, Centrosema, Venezuela

Introduction

The South American savannas count for approximately 260 million hectares, representing the largest land reserve for agrarian purposes in the world (PNUMA 1999). In less than 30 years, the contribution of the South American savannas to the agrarian production increased from almost zero to percentages between 20% and 90% depending on the country (Vera 2000). Most of what were savannas once are now huge extensions of monocultures, 55 million hectares sowed with introduced pastures (Lopes et al 2000), and a smaller extension of yearly crops such soy, maize , sorghum, and rice with high fertilizer and pesticide requirements and excessive mechanization.

On the other side, cattle raising is the agrarian activity that uses the biggest number of hectares in the American savannas (Gonzalez-Stagnaro et al., 1998). Generally, these production systems show low productivity (Torres, 1996), which oscillates between 20-40 kg ha^{-1} $year^{-1}$ in the seasonal *Trachypogon* savannas. These low production indexes are associated with the dominant loam sandy soils, acid pH, low organic matter, calcium, phosphorus, sulfur, and potassium contents in seasonal savannas (San José and García-Miragaya, 1979). They also show deficient micronutrients (copper and zinc) and iron, aluminum, and manganese toxicities. All these characteristics favor natural vegetation with poor potential for animal production. Two alternatives to solve this problem have been the introduction of cereal-cattle systems in savanna ecosystems and the use of better-quality pastures for forage purposes.

The use of cereal crops such as maize and sorghum helps support the bovine population for several months in the dry season. However, these production systems (sheep and cereals) have contributed to the deterioration of the physical, chemical, and biological characteristics of soils, due to both highly mechanized practices, which involve preparing the dry soil, using several harrow and plowing unprotected soils (over grazing), and the typical climate conditions of these ecosystems: highly intense and unpredictable rains that have caused severe soil loss problems (higher than 40 t ha^{-1} in the first 45 days of the sorghum and nutrient's growth, according to Pla et al., 1981) This has also caused irregularities in the soil's hydric regimen, leading to a reduction of its production potential. On the other hand, high potential genotypes with high nutrient requirements are now being promoted, which has resulted in an indiscriminate use of supplies (fertilizers, amendments, and pesticides) for the soil to meet the needs of crops with low adaptability to acid soils. All this has caused a considerable benefit decrease because of high production and environmental costs associated with soil deterioration, water pollution.

Soil degradation is maybe the severest problem that agriculture is facing worldwide. Around 40% of the arable land and 21% of the grazing land show certain degree of degradation (de Wit et al., 1995). The decrease of C in the soil, as a consequence of managements lacking the means to recover the organic amendments, leads to a decrease of the nutriment supply for crops, a reduction of the structural stability of soils, the loss of water storage capacity, and a restriction of the biological activity. Several studies have therefore suggested using fallows or covers periodically (Wood et al. 1991), increasing the organic matter in quantitative and qualitative terms to improve the physical, chemical, and biological properties (Tisdal and Oades, 1982; Anger, 1992; Golchin et al., 1994; Bravo et al., 2001; Hernandez-Hernández and López Hernández, 2002), and improving fallows by introducing leguminous to increase the forage offer throughout the year (Vera et al., 1986; Norman, 1989; Bravo et al., 2001).
The use of inappropriate managements has not only a local effect, but also detrimental effects worldwide. Burning savannas, for example, causes a significant percentage of carbon dioxide emissions to the atmosphere, which contribute to the global warming (White et al., 2001). However, savanna soils can become, with an adequate management, carbon sinks, counteracting, to a certain extend, CO_2 emissions to the environment. In ecosystems, soils play an important role in the carbon (C) cycle, by transforming the organic matter in its dynamic forms and becoming a source of or a sink for C and influencing the atmospheric CO_2 concentration. The direction of this balance is generally determined by the management

of soils. Non-tillage represents a conservationist way of managing agro ecosystems that may favor the potential C sequestration. In tropical soils, this is especially important because of their characteristic high mineralization rates and low organic matter content, which might lead to a decrease in productivity together with losses of C content (Theng et al. 1989)

This study is part of technological management proposal for a more conservationist management of maize. The proposal consists in combining non tillage and sowing cover crops (gramineous and leguminous) to improve the physical conditions, reduce the loss of soil due to erosion, and foster the chemical conditions which serve as organic inputs and nutrient sources for the future growing of maize. Finally, combining maize stubble and cover crops can improve the forage offer for cattle in the dry season.

One of the aspects of this work is the study of the environmental implications associated with this type of conservationist management in savannas. In this regard, the objective of this study is to prove that vegetable covers are more suitable for the potential sequestration of C, lower microbial respiration and a higher organic C content in two soils of the Venezuelan plains with contrasting textures. The soils have been managed in a conservationist way to sow cereals.

Materials and methods

Description of the study site

This study was conducted in two representative savannas of the Venezuelan Central Plains located southeast of Guarico state, Venezuela (Figure 1). The first site was La Iguana Experimental Station, located in the influence area of the Orinoco River watershed. The ecosystem is well drained savanna with typical vegetation dominated by gramineaes: *Trachypogon* sp, *Axonopus canescen, Axonopus capillacea, Diectomis fastigiata* and cyperaceaes in less proportion. There are dispersed trees called "chaparros"; *Curatella americana, Byrsonimia crassifolia, Bowdichia virgilioides* (Matheus, 1986). The climate has two contrasting seasons: A dry season, between November and May, and a rainy season, between June and October. The total annual precipitation is 1369 mm, and the average temperature is 27,3° C (Bravo et al., 1999). The soil is a sandy entisol. It has a low organic matter content (Table 1), which results in very low P, N values that decrease with the depth. The extremely acid pH could influence a greater control of ammonium over nitrate at both depths (Table 1). The amount of ammonium is higher in the surface. Nitrate does not show any change in the first 15 cm, though. Since nitrate is a very mobile ion and the soil is a sandy soil, nitrate could be easily lost by lixiviation from the superficial horizons to the deeper ones. This is a well-aired high-porosity soil in which the macroporosity-microporosity ratio is 2:1. The high content of thick particles could be one of the causes of the apparent density values shown. (Table 1). The soil has the typical characteristics of well-drained savanna soils, in which macronutrients resulting from the decomposition of organic residues are very low due to the deficient quality of the vegetal material of dominant species.

Table 1: Physical and chemical characteristics of La Iguana and San Pablo soils

	La Iguana		San Pablo	
Characteristics	0 - 5 cm	5 - 15 cm	0 - 10 cm	10 - 20 cm
B.D. (Mg/m^3)	1.75	1.73	1.62	1.63
Porosity (%)	35.60	36.82	44	41
Macro porosity (%)	20.73	22.53	8	8
Micro porosity (%)	14.87	14.49	36	33
Textural Classification	Sand	sand	Loam sandy	Clayey
pH 1:1)	5.17	5.04	5.50	5.80
CEC (cmol kg^{-1})	2.08	1.21	23.35	20.3
P (mg kg^{-1})	4.0	3.2	9.00	3.1
N-NH_4 (mg kg^{-1})	22.1	14.3	31.75	28.3
N-NO_3 (mg kg^{-1})	8.9	7.3	20.05	17.3
Total N (%)	0.0321	0.0255	0.1155	0.0891
Co (%)	0.71	0.46	1.44	1.07
O.M. (%)	1.24	0.80	2.51	1.86

The second site was a farm (San Pablo) located in Valle de la Pascua (Figure 1). The ecosystem consists in a transition zone between savanna and tropical dry forest. The climate is also seasonal with an average annual precipitation of 1074 mm, and an average temperature of 27.3 °C. The soil is Vertisol, clayey, at undulating relief with an approximate slope of 3 -6 %. The San Pablo soil represents the opposite extreme, with a better nutritional quality (Table 1), despite its lower organic matter percentage due mainly to the intensive mechanization it had experienced before. This soil shows an average-high CEC because of its clayey nature and higher organic matter content (Table 1). The N and P levels are higher than those of La Iguana, which evidences the fertilizations of previous cultivations. The moderately acid pH favors the domination of ammonium over nitrate. In this case, nitrate had less mobility because of a clayey soil with a high percentage of micropores. The density values are high for clay soils, which show a natural tendency to compacting and being little-aired soils because of their high micro porosity (Bravo et al., 1999).

Figure 1: Geographical location of the studied areas

Management Background Information

Four years ago, experimental plots for maize crops under no tillage, and cover crops were sowed (pastures and leguminous). These managements intend to offer conservationist alternatives for the typical maize-sheep production units of the region. Despite their high technology, these production units have caused serious problems in poor soils: soil degradation and production decrease as time goes by.

In this technological, conservationist propose, we used perennial crop covers that improve the physical, chemical, and biological characteristics of soils in order to cultivate maize in the rainy season, and serve, after the harvest, as good quality forage for sheep in the dry season. The crops were stabilized in 1999:

Brachiaria dyctioneura (pastures) (Bdy)
Brachiaria decumbens (pastures) (Bde)
Centrosema macrocarpum (Leguminosae) (Cm)
Natural vegetation (control) (VN)

The four covers were used at La Iguana. However, only *Brachyaria dyctioneura* and *Centrosema macrocarpun* could be introduced in San Pablo. In both cases, the control was the natural vegetation.

Phosphoric rocks (350 kg ha^{-1}) were used to sow the cover crops. A year later, they were mechanically mown. Then, SEFLOARCA 02 maize treated with semevin was sowed under non-tillage management. Contact herbicide was used at a rate of 4 l ha^{-1}. Urea with diammonium phosphate and KCl 120 - 90 -90 kg ha^{-1} (N-P-K) were used as fertilizers. After 30 days a second dose of urea (120 Kg/ha) was applied. After the harvest, sheep were let in: Six animals per treatment for an eight-week period to feed on the covers and the rest of the maize harvest. The same management was performed over and over again for 3 consecutive years.

The same procedure was performed at San Pablo, but the first and second doses of fertilizers were 60 - 60 - 30 kg ha^{-1} (N - P - K), and 60 kg ha^{-1} respectively.

Experimental design

The design corresponds to big plots without repetition (Machado, 2000). A space variability study was conducted in the sampling area to determine whether it was similarly heterogeneous and consequently determine the size and shape of plots (30 x 30 m^2 at La Iguana, and 30 x 40 m^2 at San Pablo). It was also determined that 12 should be the minimum number of samples to be taken per management in order to get representative samplings for both studied zones. The plots' size was determined in accordance with the statistical criterion that states that the size of each plot should not be smaller than 100 times the size of the effective experimental unit for maize crops (10 m^2) (Machado, 2000).

The samples were taken in three important moments for the development of the suggested system: i) Each year before mowing the covers (BC), on May; ii) at the flowering peak of maize (F), August; and iii) after taking the sheep out of the plots (after 8 or 10 weeks of grazing), (AG), on February. At San Pablo, we were not able to conduct the experimentation with sheep due to logistic problems. Therefore, there were only two sampling moments.

The depths at which the samples were taken were 0 - 5 cm, 5 - 15 cm, 15 - 30 cm, at La Iguana, and 0 - 5 cm, 5 - 10 cm, 10 - 20 cm at San Pablo. The biological and chemical parameters were measured only in first depth, and at the highest depth respectively. The soil samples were kept frozen at a temperature of 4° C until the analysis was made.

The statistical analysis involved ANOVAS, using parametric tests with Tukey mean difference, and no- parametric tests using the Kruskall-Wallis test. The package used was the SAS.

Chemical Analysis

The soil samples were homogenized and put through a 2-mm sieve. The total organic C was determined applying the complete humid oxidation method by Nelson Sommer (Anderson and Imgran, 1993). The Alef and Nannipieri (1995) method was used to determine the basal respiration (50 g free organic residue soil incubated in alkali traps - KOH 0.5 N – for 24 hours). The edaphic respiration was estimated directly in the field using alkali traps (NaOH 1 N), placed in areas closed by plastic cylinders and incubated for 24 hours (Machado, 1978).

Results and discussion

Total organic C

After two cycles of this maize-sheep conservationist system, La Iguana soil has shown some changes in the total Co content at the three depths (Table 2). Considering the Co average present in all managements and at all depths through this three-year period, there has been an increase of the Co content from 0 to 30 cm in this sandy soil.

Table 2: Total Co Content (%) in the first three years of this experimental system at La Iguana

Proof	Co 1999	Managements	Co BC-00	Co F-00	Co BC-01	Co F-01	Co AG-01	$\overline{Co}$
		VN	1.12 a	0.91 a	1.08 a	1.01 a	1.02 a	**1.03**
		Cm	0.83 b	0.79 ab	1.12 a	1.10 a	0.94 a	**0.96**
0-5 cm	0.71	**Bdy**	1.08 a	0.85 ab	0.85 a	0.82 a	0.81 a	**0.88**
		Bde	1.00 ab	0.69 b	1.01 a	0.90 a	0.76 a	**0.87**
		VN	0.45 ab	0.50 a	0.83 a	0.59 a	0.60 a	**0.59**
		Cm	0.39 b	0.50 a	0.68 a	0.72 a	0.64 a	**0.59**
5-15 cm	0.46	**Bdy**	0.52 a	0.53 a	0.76 a	0.55 a	0.65 a	**0.60**
		Bde	0.44 ab	0.37 a	0.80 a	0.58 a	0.64 a	**0.57**
		VN	0.48 a	0.31 a	0.48 a	0.45 ab	0.44 a	**0.43**
		Cm	0.29 a	0.34 a	0.68 a	0.52 a	0.42 a	**0.45**
15-30 cm	0.30	**Bdy**	0.42 a	0.28 a	0.63 a	0.40 b	0.40 a	**0.43**
		Bde	0.30 a	0.35 a	0.58 a	0.48 ab	0.44 a	**0.43**
			P	**P**	**P**	**P**	**P**	
		Method						
		Variation Analysis						
		Managements	**					
		Proof	**					
		Time	**					

Managementss:		Proof:		Time:
	VN a		0-5 a	BC-00 b
	Cm ab		5-15 b	F-00 c
	Bdy ab		15-30 c	BC-01 a
	Bde b			F-01 b
				AG-01 b

** Significant at 99% of probability
P= ANOVA using the parametric method / differences measured using Tukey.

The Co values were higher in the surface and decreased with the depth in all the managements. There were some fluctuations among the different samplings. There was more C before cutting the covers (at the and of the dry season) than in the flowering peak of maize (in the middle of the rainy season). The biggest increase took place a year after introducing the covers, particularly in the natural vegetation and *Brachiaria* managements. Regarding the *Centrosema macrocarpun*, the biggest changes were observed two years after sowing the covers.

There were little differences among the cover managements. The VN (natural vegetation) soil showed higher Co values in the surface before mowing the covers, during the first year's flowering and the second year's grazing. This behavior together with the similarly high Co contents previously observed favored the highest Co average at that depth in the soil under the VN management compared with the other managements. It is important to say that the diversity of species involved in the VN management is not the same as that of the native savanna. This change occurred because this plot was fertilized and mechanically managed, too. As a result, the presence of the dominating species, *Trachypogon* sp, decreased and that of other species such as the *Indigosfera espelezioides* and other gramineaes increased. Consequently, the quality of the native cover changed.

Of the pastures used, *Brachiaria dyctioneura* yielded the highest Co values in the first 15 cm of soil in the first year and after the grazing of the second year. Regarding the leguminous, the *Centrosema macrocarpun* started to yield high values at all depths in the second year. In average, this was the second cover favoring the potential increase of Co at depths between 0-30 cm. These results evidence that sandy soils rapidly respond to the introduction of covers under no tillage by increasing the Co content.

Table 3: Total Co Content (%) in the three years of this experimental system at San Pablo

Proof	Co 1999	Managements	Co BC-00	Co F-00	Co BC-01	Co F-01	$\overline{Co}$
		VN	1.47 b	1.54 b	1.43 b	1.31 a	**1.44**
0-5 cm		**Cm**	1.52 b	1.65 ab	1.59 ab	1.43 a	**1.55**
	1.54	**Bdy**	1.83 a	1.71 a	1.69 a	1.55 a	**1.70**
		VN	1.40 a	1.25 a	1.33 a	1.20 a	**1.30**
		Cm	1.12 b	1.20 a	1.23 a	0.91 b	**1.12**
5-10 cm	1.34	**Bdy**	1.39 a	1.37 a	1.39 a	1.17 ab	**1.33**
		VN	1.07 a	1.14 a	0.92 a	1.06 a	**1.05**
		Cm	1.06 a	0.96 a	0.75 a	0.68 b	**0.86**
10-20 cm	1.07	**Bdy**	1.00 a	0.94 a	0.73 a	0.78 ab	**0.86**
		Method	NP	NP	NP	NP	
		General Variation Analysis					
		Managements	**				
		Proof	**				
		Time	**				

Managementss:	VN ab	Proof: 0-5 a	Time: BC-00 a
	Cm b	5-10 b	F-00 ab
	Bdy a	10-20 c	BC-01 b
			F-01 c

** Significant at 99% of probability
NP= ANOVA using no parametric methods (Kruskal-Wallis)

The introduction of different covers in the clay soil (San Pablo) did not yield remarkable changes in the Co content at depths between 0-20 cm (Table 3). The soil managed with *Brachiaria dyctioneura* was the only one that showed a Co increase in the surface compared with the Co content before introducing the covers. At other depths and in the rest of cover managements, the Co values tended to decrease.

Likewise, the *Brachiaria* yielded the highest Co values compared with the other covers, in which the Co contents were similar or lower. The natural vegetation (VN) only kept the Co content at depths between 5-20 cm.

Regarding the clayey soil, any possible effect of covers on the Co content was not evident. Therefore, their introduction did not help improve the quality of the soil for maize sowing purposes.

CO_2 evolution

The use of perennial covers of different quality has caused significant differences in the CO_2 production by microorganisms in La Iguana soil (Table 4). The soil managed with *Centrosema macrocarpun* showed the lowest basal respiration values, except during flowering period of the first year (F-00) and before cutting the covers the second year (BC-01). The VN management always yielded the lowest basal respiration values, except in F-00 and after the grazing (AG-01). Soils under pastures tended to show a higher CO_2 production most of the time. The *Brachiaria dyctioneura* especially excels because it yielded the highest basal respiration values throughout the course of this conservationist maize-sheep system.

Three years after using pasture and leguminous covers the CO_2 production tended to decrease compared with the virgin savanna soil. There was only a slight basal respiration increase in the soils with *Briachiaria dyctioneura* covers.

Table 4. CO_2 evolution (mg/kg) with different management covers in sandy savanna soils

CO_2 1999	Managements	CO_2 BC-00	CO_2 F-00	CO_2 AG-00	CO_2 BC-01	CO_2 F-01	CO_2 AG-01	$\overline{CO_2}$
	VN	74.67 b	184.89 a	98.09 b	42.22 b	31.69 b	193.14 a	104.12
175.50	Cm	75.74 b	185.78 a	77.47 b	146.46 a	65.87 ab	52.70 b	100.67
	Bdy	119.36 ab	191.73 a	235.57 a	198.45 a	103.25 a	87.15 ab	181.91
	Bde	216.30 a	115.62 b	236.07 a	145.59 a	39.74 b	85.27 ab	163.03
Method		NP	P	NP	NP	NP	NP	

NP= ANOVA using no parametric methods (Kruskal-Wallis)
P= ANOVA using the parametric method / differences measured using Tukey means

The effect of covers on the CO_2 production by microorganisms in the clay San Pablo soil is not as remarkable as that in La Iguana soil (Table 5). There were only significant differences among managements before cutting of the first year (BC-00) and the flowering season of the second year (F-01). In both cases, soils under *Brachiaria* as well soils under *Centrosema* showed higher microbial activity values than soils under natural vegetation.

With the introduction of covers and the use of no tillage for maize cultivation purposes, there occurred a decrease of CO_2 production in the clayey soil; maybe because its texture and natural tendency to compact – this soil already had degradation signs (Bravo et al., 1999) – create unfavorable conditions for microbial growth and its decomposing activity.

Table 5. CO_2 evolution (mg/kg) in clayey savanna soils under different crop cover managements

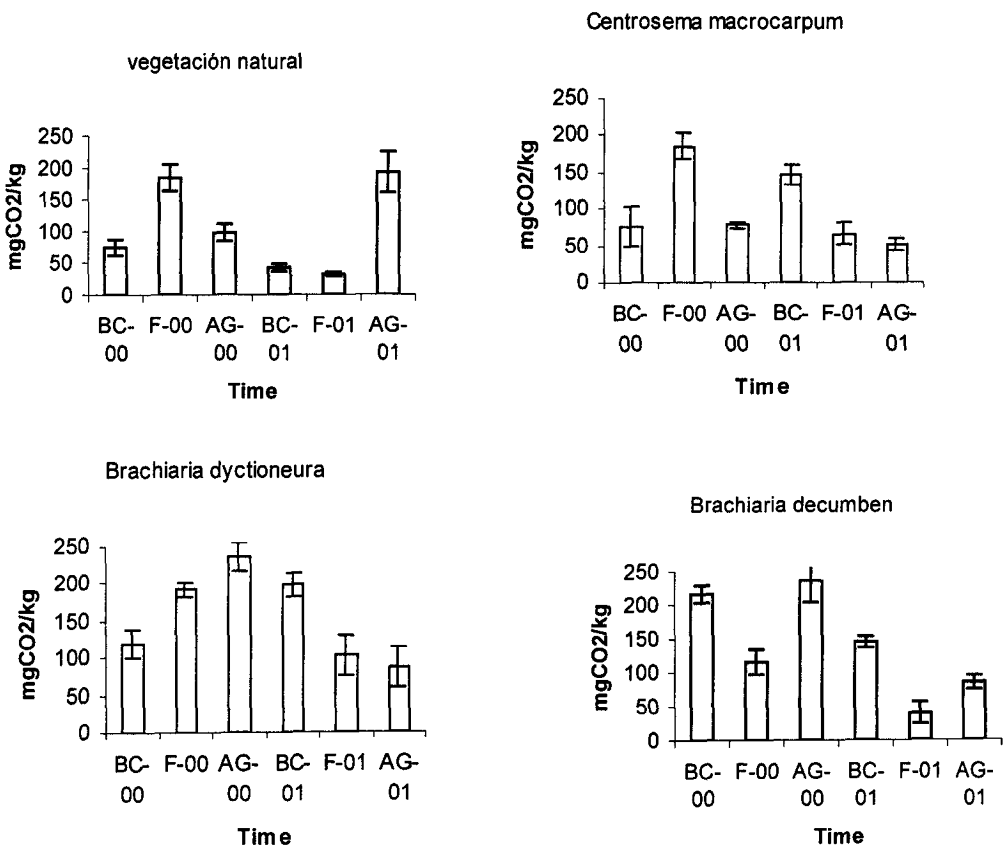
CO_2 1999	Managements	CO_2 BC-00	CO_2 F-00	CO_2 BC-01	CO_2 F-01	$\overline{CO_2}$
	VN	36.68 b	82.38 a	55.45 a	160.76 b	83.82
233.59	Cm	46.99 ab	82.75 a	75.04 a	215.74 a	105.13
	Bdy	60.48 a	63.51 a	59.59 a	192.43 ab	94.00
Method		P	P	P	NP	

NP= ANOVA using no parametric methods (Kruskal-Wallis)

P= ANOVA using the parametric method / differences measured using Tukey means

Figures 2 and 3 show the CO_2 evolution through time according to the different covers. In all cases, there were fluctuations at different moments of the system's development. These fluctuations could be associated with climatic variations characterized by an intense rainy season during the flowering of maize, and an extremely dry season during the cutting of covers and after grazing. These climatic changes would affect the dry biomass production of covers.

Figure 2. CO_2 evolution in savanna sandy soils (La Iguana) in the first two years of this conservationist management

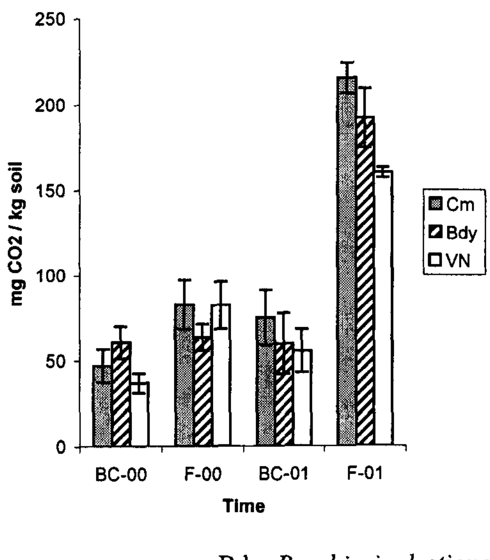


In these three years, the general tendency of soils treated with pastures and leguminosaes is to decrease the CO_2 production as time goes by. Soils under natural vegetation experienced an increase in the dry season after the grazing of the second year. The *Brachiarias* showed high CO_2 values after the grazing of the first year. Regarding the *Centrosema macrocarpum* and the natural vegetation, the peak was during the flowering period of the first year. In the second year, there was considerable precipitation, and some of the covers' biomass, such as the *Brachiaria dyctioneura* and the *Centrosema macrocarpum*, was high (Briceño, 2002). In these cases, the humidity levels could increase to such extend that they might have had an effect on the microbial respiration decrease. These CO_2 production levels could be also due to the fact that at those times there was more biomass in each of the above mentioned covers.

Unlike La Iguana soil, which showed significant variations of microorganisms' respiration with the different covers, at San Pablo the activity of microorganisms was homogenous and similar among covers, responding in the same way no matter what the time or type of cultivation (Figure 3). Only was there a peak in the flowering period of the second year and in all managements; it could be the result of a more suitable humidity level for micro organisms, their activity, and a better development of covers and maize (Briceño, 2002).

On the other hand, it is worth mentioning that the reached CO_2 levels in the San Pablo soil under *Brachiaria dyctioneura* and leguminous tended to be lower at different times of the year than that of La Iguana. This could be associated with the lower aeration of clayey soils, which create unfavorable conditions for developing and keeping the covers and for the decomposing activity of microorganisms.

Figure 3. CO_2 (mg / kg) evolution in savanna clayey soils (San Pablo) under different crops

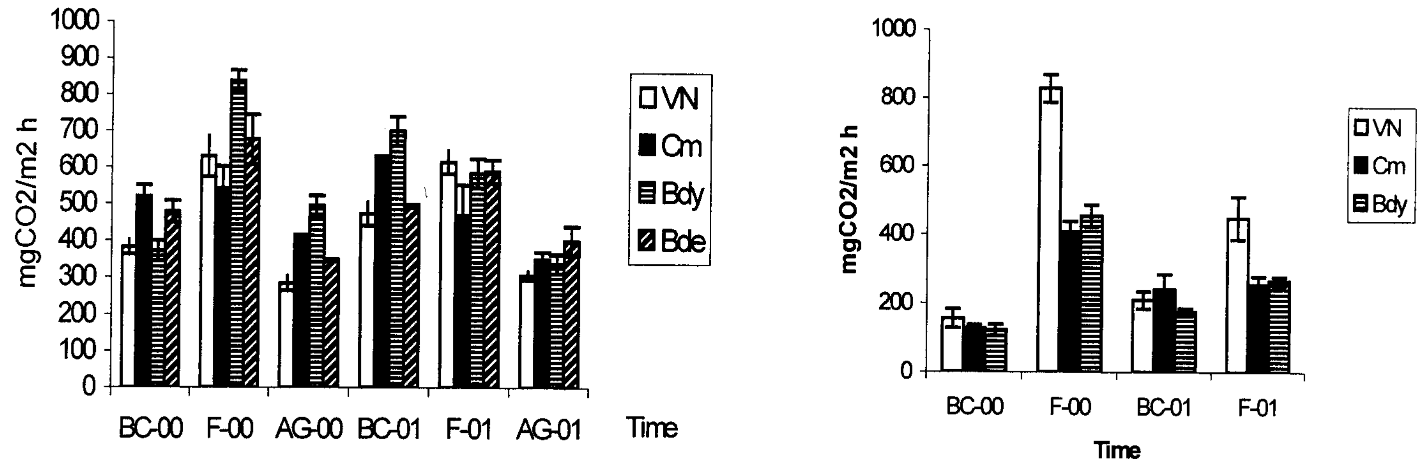


Cm: *Centrosema macrocarpum* Bdy: *Brachiaria dyctioneura* VN: Natural vegetation.

Edaphic Respiration

When we observe the edaphic respiration values, which include the microbial and radical respirations and that of other organisms living in the soil, during these three years (Figure 3), it becomes evident that there has been a change in CO_2 emissions due to the presence of different covers. In the case of La Iguana soil, of sandy texture, the effects of covers are more contrasting and significants than the ones they have on the clayey soil (San Pablo) During the flowering period, the respiration is higher in soils under the *Brachiarias*. In soil under *Centrosema macrocarpum* had the highest level before cutting the covers, and it is comparable with that of pastures. The control soil always had the lowest values at all times. After the grazing, in the middle of the dry season, the edaphic respiration values are lower in all of the managements, which is in accordance with the micro organisms' respiration observed in Figure 2, excepting the control management, which experienced a significant increase of basal respiration.

Figure 4. Edaphic Respiration (mg CO_2/ m^2 h) in two savanna soils under different cover crops



At San Pablo, the edaphic respiration values were lower, without differences among covers, excepting the soil under natural vegetation, which showed a significant higher CO_2 production during the flowering period compared with soils under pastures and leguminous (Figure 4). The microbial respiration (Figure 3) provided an important contribution to the edaphic respiration during the flowering period of the second year. This contribution is evident in the remarkable increase observed at that time, despite the lower CO_2 emission values (edaphic respiration). However, it should be taken into account that the basal respiration was only measured in the first five cm. Therefore, this value could vary if measures at deeper points are made.

Conclusion

Considering the C content, the microbial and edaphic respirations contributing to the CO_2 in the environment, the use of conservationist managements in savanna soils involving no tillage and perennial covers could help increase the potential sequestration of carbon in said soils. The effect is better on well-drained savannas with sandy soils because they respond fast to this type of management. In only three years, there has been a Co increase up to a depth of 30 cm in soils with both leguminous and *Brachiarias*. However, if we consider the biological activity promoted by the presence and development of covers in different important moments for the cereal-sheep unit – such as the development of the maize crop (rainy season) and the grazing (dry season), the *Centrosema macrocarpum* turns out to be the most promising for the potential sequestration of carbon. This is an important result because leguminous could meet other requirements that might favor for improving the quality of soils and other aspects related to this production unit. However, we also have to say that so far the use of natural vegetation, which promotes a series of better quality native leguminous and gramineaes if we compared them with the *Trachypogon sp.*, is the best cover management for keeping and increasing the potential sequestration of carbon, since this cover favored the highest Co increase in the profile soil and showed the lowest CO_2 emission values to the atmosphere. The suggested management was not favorable for savanna soils, which are very clayey and tend to compact. The covers and the use of no tillage reduced the Co content. The CO_2 emissions reacted mainly to humidity variations caused by the existing climatic season and not to the effect of covers.

Acknowledgments

We acknowledge the support of the laboratory technicians Lic. Hugo Cánchica and Lic. Isabel González from CEDAT, Universidad Simón Rodríguez. We acknowledge to FONACIT (S1-97001360).

References

Anderson J. , Ingram J., 1993. Tropical soil biology and fertility (TSBF). Handbook of methods. C.A.B. International. 293 p.

Anger D. ,1992. Changes In Soil Aggregation And Organic Carbon Under maize And Alfalfa. Soil Science Society American Journal. 56:1244 - 1249.

Alef K., Nannipieri P., 1995. Methods in applied soil microbiology and Biochemistry. Substrate incorporation. Fertilita del terreno e Biomasa Microbica. Att del VII Convengo Nazionale S.I.C.A. Nork. Shop XV Commisione potenza.

Bravo C., Hernández R.M., Lozano Z., Piñango L. Moreno B., 2001. Alternativas para el mejoramiento de la unidad de producción maíz-ganado en el Estado Guárico. Informe técnico. CONICIT. Proyecto S1-97001360. Venezuela. 213 p.

Bravo C., Hernández RM., Lozano Z., Moreno B., Piñango L., 1999. Alternativas para el mejoramiento de la productividad del sistema maíz-ganado en suelos del Estado Guárico. Informe FONACIT proyecto S1-97001360. Venezuela 120 p.

Briceño O., 2002. Evaluación de diferentes coberturas vivas como barbechos mejorados en un sistema de labranza conservacionista y su relaciòn con las propiedades químicas de dos suelos de textura contrastantes del Estado Guárico. Tesis de grado. Facultad de Agronomía. Universidad Central de Venezuela. Maracay. Venezuela. 71 p.

De Wit J., Oldenbroek J., van Keulen V., Zwart D., 1995. Criteria for sustainable livestock production: a proposal for implementation. Agriculture, Ecosystems and Environment 53: 219-229.

Golchin A., Oades J.M., Skjemstad J.O., Clarke P., 1994. Soil structure and carbon cycling. Australian Journal of Soil Research 32: 1043-1068.

González-Stagnaro C., Madrid-Bury N., Soto E., 1998. Mejora de la ganadería mestiza de doble propósito. Ediciones Astro Data S.A., Maracaibo, Venezuela. 89 p.

Hernández- Hernández R.M., López-Hernández D., 2002. Microbial biomass, mineral nitrogen and carbon content in savanna soil aggregates under conventional and no-tillage. Soil Biology & Biochemistry in press.

Machado W., 2000. Planificación y análisis de experimentos de campo en grandes parcelas sin repetición. Revista alcance de la Facultad de Agronomía 59: 1-73.

Machado B., 1978. Método Químico De Mediçao Da Respiraçao Edáfica: Algunos Aspectos Técnicos. Ciencia E Cultura. 30: 82 - 88.

Matheus R., 1986. Los suelos de la Estación Experimental La Iguana, Sur Oriente del Estado Guárico. Tesis de Maestría, Facultad de Agronomía U.C.V., Maracay, Venezuela, 306 p

Lopes A., Ayarya M., Thomas R., 2000. Sistemas agropastoriles en las sabanas de América latina tropical: lecciones del desarrollo agrícola de los Cerrados de Brasil. En: E. P. Gimarães, J. I. Sanz, I. M. Rao, M. C. Amézquita, E. Amézquita, eds. Sistemas Agropastoriles en Sabanas Tropicales de América Latina . Publicación CIAT No 313.

San José JJ., García-Miragaya J., 1979. Contenido de nutrientes en el suelo y en la fitomasa de comunidades en las sabanas de *Trachypogon sp.* Calabozo, Venezuela. Boletin Sociedad Venezolana Ciencias Naturales 136: 113-122.

Pla I., Florentino A., Lobo D., 1981. Regulación del régimen hídrico de suelos bajo agricultura de secano en Venezuela, mediante la aplicación superficial de emulsiones de asfalto. En: Revista de la FAGRO, UCV. Alcance N° 12 (1-2): 137-163

PNUMA, 1999. Perspectivas del Medio Ambiente 2000. Chapman Bounford & Associates. 215 p.

Theng B., Tate K., Sollins Ph., 1989. Constituents of organic matter in temperate and tropical soil. In: *Dynamics of soil organic matter in tropical ecosystems.* D Coleman, JM Oades and G Uehara (Edits). NifTAL Proyect Honolulu, Hawaii. pp 5-32.

Tisdal J., Oades J., 1982. Organic Matter And Water-Stable Aggregates In Soil. Journal Of Soil Science. 33:141 - 163.

Torres G., 1996. Manejo de las sabnas venezolanas: Problemática y perspectivas. San Fernando de Apure, Ven. FONAIAP. Estación Experimental Apure. 44 pp.

Vera R. R., 2000. Invenstigación en sistemas agropastoriales: antecedentes y estrategias. pp. 1 – 8. En: Sistemas agropastoriales en sabanas tropicales de america latina. Publicación CIAT. N° 313.

Vera R., Sere C., Tergas L., 1986. Development Of Improveved Grazing Systems In The Savannas Of Tropical America. A Resource Under Siege. Proceeding Of The Second International Rangerland Congree, Australian Academy Of Science, Canberre. Pp. 107 - 110.

White R. P., Murray S., Rohweder M., 2001. Grassland Ecosystems. Informe del PAGE (Pilot analysis global ecosystems).

Wood C., Westfall D., Peterson G., 1991. Soil Carbon And Nitrogen Changes On Initiation Of No-Till Cropping Systems. Soil Science Society American Journal 55(2):470-476.

RESEAU EROSION

Référence bibliographique Bulletin du RESEAU EROSION

Pour citer cet article / How to citate this article

Hernandez-Hernandez, R. M.; Lozano, Z.; Bravo, C.; Moreno, B.; Pinango, L. - The use covers crop and no tillage as management that increases the potential sequestration carbon in the venezuelan central plain soils, pp. 374-386, Bulletin du RESEAU EROSION n° 23, 2004.

Contact Bulletin du RESEAU EROSION : beep@ird.fr