Agricultural Practices to Mitigate Soil Degradation and Increase Carbon Capture

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ABSTRACT

The implementation of new practices and their results to prevent or mitigate soil degradation and increase carbon capture were presented in this paper. The study was made on "Los Barzaga" farm, in the province of Guantanamo, where poor drainage conditions, low soil fertility and erosion affect 90% of the area, causing greater degradation and reduction of production. Several soil preservation and improvement procedures were established, considering the limiting factors identified. The physical and chemical indexes were evaluated, and the carbon reserves were monitored. The practices implemented (live and dead barriers, rill and reservoir correction), contributed to a 62 t. ha^{-1} reduction of soil loss, with positive changes in apparent density, infiltration and compacting velocity, and nutrient contents. Additionally, soil carbon increased to 20.67%.

KEY WORDS/: degradation, preservation, carbon reserves, erosion, live barriers

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INTRODUCTION

Land degradation is one of the major world problems nowadays. It can be defined as a temporary or permanent reduction in land production capacity, which may appear due to natural or human processes, or a combination of both (Semarnat, 2011).

The causes of land degradation are multiple, but most are derived from deficient management, inadequate exploitation, and non-sustainable agricultural practices, including overgrazing and deforestation. Land ownership also plays a key role, as incentives for sustainable land management investments are meager or non-existent. Actually, such resources are used to meet short-term demands.

In Cuba, as well as in other tropical countries, agriculture has been compromised by the effects of soil degradation and deficient attention, so it is important to reduce its causes (Ministry of Agriculture, 2001 and Vargas, 2008), and establish agricultural systems that can satisfy the growing demands of food for the people.

The best example of soil degradation in the province of Guantanamo is the erosion caused by water to different extents in broad areas (428 189.77 ha, from highly to slightly damaged). Accordingly, 70% of the soils are eroded (current erosion) (Ministry of Agriculture, 2008). Most soils are within fragile ecosystems, where agricultural development relies on high efficiency and extreme care to maintain the existing balance. Accordingly, it is important to implement agricultural practices that allow improved soil management to increase their productivity.

Based on the need to confer greater attention and due priority to protection and rational use of natural resources to tackle and adapt to the effects of climate change, the provincial authorities established the National Program for Preservation and Improvement of Soils. It focuses on processes with a major incidence on soil degradation, where anthropogenic action has played a key role (Ministry of Agriculture, 2008). Besides, proper implementation may help mitigate climate change, by reducing gas emissions from agricultural practices (carbon is stored in plant and soil biomass) (Michel, 2002).

The Mariana Grajales Cuello Cooperative of Credits and Services is already implementing the program in the municipality of Guantanamo, where nearly all of its areas are eroded to some extent. In addition to it, drainage deficiencies and low fertility are leading to yields below the expectations. As a result, considerable losses in production and land fertility reduction have been observed. Hence, this paper intends to disclose the findings achieved with the use of soil improvement and preservation practices, as tools to prevent or mitigate degradation and increase carbon capture.

MATERIALS AND METHODS

The study was made between 2013-2015, on "*Los Barzaga*" farm, at the Mariana Grajales Cuello Cooperative of Credits and Services in the province of Guantanamo, where poor drainage conditions, low soil fertility and erosion affect 90% of the area, causing greater degradation and low production.

Based on the characterization results of the area studied, according to the Proceedings Manual for Sustainable Land Management (Urquiza *et al*., 2011), a management plan consisting of soil preservation and improvement actions was implemented, following the Cuban Standard for Soil Quality (Ministry of Agriculture, 2010 and Fuentes *et al*., 2004).

Sampling lots (25 m^2) were set up, and their physical properties were determined (apparent density, moisture, penetration resistance), and chemical properties (MO, P, K, pH, CO3). Analyses were made at the laboratory of the Provincial Soil Station in Guantanamo, and they were time-monitored for comparison and definition of changes that took place in the soil, according to the management procedure applied.

The following procedures were put into practice for analysis of physical and chemical indicators:

Chemical: the samples were taken from the arable layer in the areas studied (0 – 20 cm)

- pH (H2O), by potentiometry, and a soil: solution ratio 1:2.5, (NC 32, 2008).
- Organic matter (% O.M.), by chemical determination of organic fertilizer samples. 1988.
- Carbon (C), by dividing the percentage of organic matter by 1.724.
- Absorbable phosphorus and potassium (mg.100g^{-1}), by ammonium carbonate extraction at 1%, with soil solution 1:20 (NC 52, 1999).

Physical:

- Gravimetric soil moisture, stove at 105º C, until the samples reached constant weight (NC 110 -2010) and (Hernández, 2007).
- Volume or apparent density (Da g.cm^{-3}), by field cylinders (100 cm3 volume), (NC ISO 10272 -2003) (Hernández, 2007), and classification, by Rivero *et al*. (1990).
- Infiltration speed Method USDA, (1999)
- Resistance to penetration: Eikelkamp Penetrometer

The carbon reserves were calculated by the formula below,

RC (t ha^{-1})= %C * da * h

Where: %C is the carbon percentage; (ad) is the apparent density, (h) is depth or thickness of the layer to be determined.

Soil loss is measured from the volume of soil trapped behind the barrier (t.ha^{-1}), estimated through measurement of the amount of soil sedimented and the area covered with it. (Urquiza *et al*., 2011).

RESULTS AND DISCUSSIONS

The *Barzaga* Farm, from the Mariana Grajales Cuello Cooperative of Credits and Services has 18.1 ha, on washed gley siallitic brown soil (Hernández *et al*., 1999), basically plain and with poor drainage. Vegetation is varied and precipitations are poor. Temperatures are predominantly high. The main crops are tomatoes, onions, bananas, papayas, guavas, maize and beans.

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The results of the initial diagnostics showed the need to set up soil improvement and preservation actions to stop or mitigate soil degradation and recover its productive capacity (figure 1).

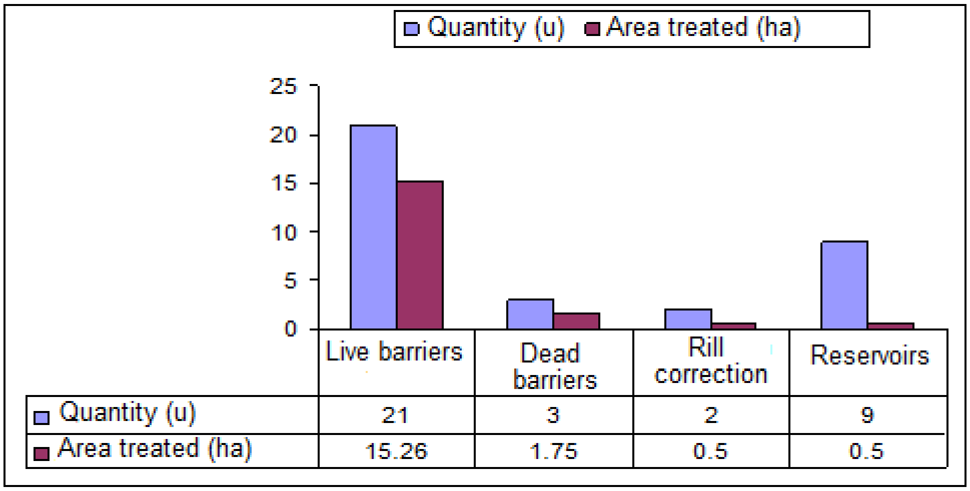

Figure 1. Simple soil preservation actions implemented on the *Barzaga* farm, from the Mariana Grajales Cuello Cooperative of Credits and Services, in Guantanamo, Cuba.

Live barriers made of pineapple (four barriers 190 meters long); sugar cane (ten barriers 589 meters long); kingrass (two barriers 100 meters long); maize (two barriers 160 meters long); banana (one barrier 95 meters long); and sorghum (two barriers 20 meters long), were the most widely used types. Dead barriers were made of rocks and stalks; whereas tree trunks were used for reservoirs.

The construction and rehabilitation of drainage canals, and establishment of field water autonomy, were the actions with the highest impact on the current conditions of the soil. They helped recover flooded areas back into production, and provided better conditions for crop development and gradual improvements in soil fertility.

An increased number of areas treated with organic sources was observed (figure 2), particularly cattle, equine and ovine manure (318t), and a larger number of hectares were treated (18ha). Likewise, 29t of compost and 7t of worm casting were applied, along with green fertilizers and bio products (*Azotobacter, Rhizobium*, liquid humus and FitoMas).

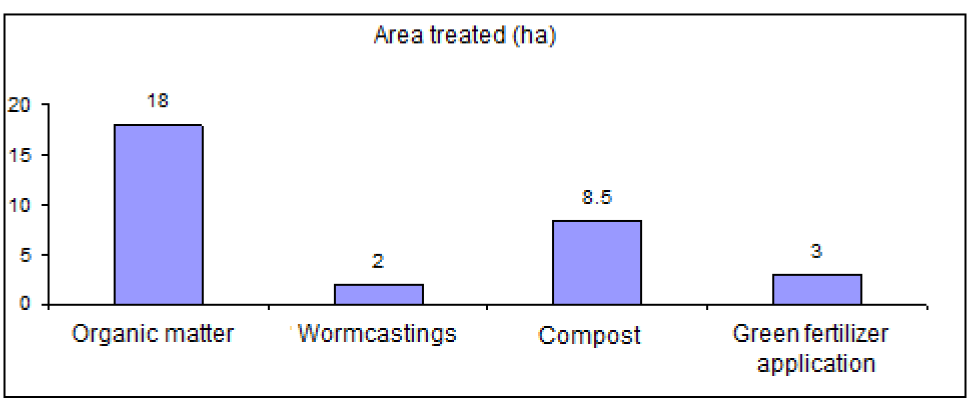

Figure 2. Area treated with organic fertilizers on the *Barzaga* farm, from Mariana Grajales Cuello Cooperative of Credits and Services, in Guantanamo, Cuba.

Organic materials stimulate the physical, chemical and biological properties of soils, because organic matter supplies nutrients and has effects on porosity (John *et al*., 2004). Additionally, according to Díaz and Cairo (2004), the higher the contents of organic matter, the grater structural stability and soil tilth range. Thus, soil fertility is critically altered, with positive structural effects and enhanced crop conditions.

Reforestation is one of the most efficient preventive actions in terms of soil degradation, caused by erosion (Fuentes, 2002 and Marrero, Riverol and Aguilar, 2006). These elements were essential to increase the forest area on the farm (1.75ha recovered with 1 575 fruit and wood trees. Another positive action in that direction was the construction of hedges (4 km). Proper implementation of soil improvement and preservation actions had positive effects on the soil, particularly, changes in the chemical and physical indicators assessed.

The chemical indicators studied (Table 1) showed increased contents of organic matter and phosphorous, thus indicating enhanced fertility, despite reduced potassium values.

Table 1. Behavior of different chemical soil indicators on the *Barzaga* farm, Mariana Grajales Cuello Cooperative of Credits and Services, in Guantanamo, Cuba.

Depth	O.M. (%)		P_2O_5 (mg.100g^{-1})		K_2O (mg.100g^{-1})		pH (KCl)	
	Before	After	Before	After	Before	After	Before	After
0-20	2.85	4.0	29.2	30.2	45.9	40.1	6.59	6.12

The results achieved are associated to the contribution made by the organic fertilizers used and the improvements observed after the soil preservation actions were implemented. In all, they encourage nutrient recycling, nitrogen contribution and stabilization or increase of organic matter in the soil. Similar criteria were reported by Benítez and Friedrich (2009), who said that organic fertilizers increase soil nutrient retention which plants can use longer.

The analysis of physical indicators (Table 2) resulted in improved physical conditions of the soil, by decreasing the apparent density and compaction values, and increasing the infiltration speed values. Apparent density, initially classified as very high (Rivero *et al*., 1990), moved to mid-high in either depth. Infiltration speed increased (USDA, 1999), whereas resistance to penetration dropped.

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Table 2. Behavior of different physical soil indicators on the *Barzaga* farm, Mariana Grajales Cuello Cooperative of Credits and Services, in Guantanamo, Cuba.

Depth	ad ($g.cm^{-3}$)		Moisture (%)		VI ($cm.hr^{-1}$)		Resistance to penetration ($Kg.cm^{-2}$)	
	Before	After	Before	After	Before	After	Before	After
0-20	1.42	1.25	29.68	29.0	3.81	38.10	41.5	19.2
20-40	1.50	1.30	19.72	33.1			60	19.5

Overall, the results evidenced improved soil conditions, with positive changes produced by the combined actions of management practices (higher soil porosity, aeration, decreased compaction) and enhanced fertility, which raised soil fertility.
Similar results were reported by Font (2008), who implemented soil preservation actions to improve soil quality with positive effects. Yields increased after two years, which made the system sustainable.

Bugarín *et al*. (2010), highlighted variations in apparent density values, through different management procedures. They also indicated that those changes may be attributed to the absence of mechanization and the high vegetal covering. Furthermore, Figueredo *et al*., (2004), observed improvements in the physical and chemical properties of the soil when the bio-intensive method for organic agriculture was applied.

The carbon reserves in the soil (Table 4) raised to 12 $t.ha^{-1}$, for an annual average of 4 $t.ha^{-1}$, as a result of implementing preservation actions in the period evaluated.

Table 3. Behavior of the carbon reserve on a washed glay, siallitic brown soil, after implementation of soil preservation actions.

Depth	**O.M. (%)**		**CO (%)**		**Ad (g.cm-3)**		**RCO ($t.ha^{-1}$)**	
	Before	After	Before	After	Before	After	Before	After
0-20	2.85	4.0	1.65	2.32	1.42	1.25	46.00	58.00

The results achieved owed to improvements provided by proper implementation of soil preservation actions. They had a direct impact on soil improvement. Accordingly, the contents of organic matter rose, erosion declined, and excessive soil tilling was reduced. These actions helped fight back key elements causing depleted soil carbon reserves worldwide (Leemans, 1999, cited by Ortega, Fernandez and Volpedo, 2009)

In that sense, Michel (2002), claimed that the application of manure had duplicated the contents of organic carbon, leading to soil improvements by means of organic matter accumulation.

Similarly, he said that every practice directed to achieve carbon accumulation in croplands, can also help restore degraded soils, or prevent erosion.

Generally, the implementation of soil preservation and improvement actions led to decreased particle movement throughout the field, with about 62t ha^{-1} trapped in the barriers. That way, continuous soil loss was cut down, and yields had increments of more than 20% in onions, maize, tomato and banana.

CONCLUSIONS

The actions taken to preserve and improve soil reduced soil loss in 62t ha^{-1}, producing positive changes in apparent density, infiltration speed and compaction, aside from increasing soil nutrients and carbon reserves in 20.67%.

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